Docket No:A-93-02
V-C-1

RESPONSE TO COMMENTS

Criteria for the Certification and Recertification of
the Waste Isolation Pilot Plant's
Compliance with 40 CFR Part 191
Disposal Regulations: Certification Decision

May, 1998

Office of Radiation and Indoor Air
U.S. Environmental Protection Agency
Washington, D.C.

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Introduction

EPA has made a final determination, pursuant to Section 8(d) of the Waste Isolation Pilot Plant Land Withdrawal Act (WIPP LWA),1 and in accordance with the Criteria for Certification of the Waste Isolation Pilot Plant, 40 CFR Part 194, that the Department of Energy's Waste Isolation Pilot Plant (WIPP) will comply with the radioactive waste disposal regulations set forth at 40 CFR Part 191, Subparts B and C (Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste). EPA's final determination is based on EPA's comprehensive evaluation of DOE's compliance certification application, supplemental information required by EPA, EPA's own independent analyses and studies of certain issues, and consideration of specific issues raised in public comments. The basis for EPA's final certification determination is set forth in the final rule signed by EPA Administrator Browner on May 13, 1998, and in Compliance Application Review Documents (CARDs) and Technical Support Documents (TSDs) accompanying the final rule. This document contains EPA's responses to all significant public comments received on or before February 27, 1998, on EPA's proposed decision to certify that the WIPP will comply with the radioactive waste disposal regulations. 62 Fed. Reg. 58791 (October 30, 1997).

EPA's certification of compliance allows the emplacement of transuranic (TRU) radioactive waste in the WIPP to begin, provided that all other applicable health and safety standards, and other legal requirements, have been met. The certification allows Los Alamos National Laboratory to ship transuranic waste from specific waste streams for disposal at the WIPP. However, the certification is subject to four specific conditions, most notably that EPA must approve site-specific waste characterization measures and quality assurance plans before other waste generator sites may ship waste for disposal at the WIPP. In the final certification decision, EPA is also amending the WIPP compliance criteria [40 CFR Part 194] by adding an appendix that describes EPA's certification, incorporating the approval processes for waste generator sites to ship waste for disposal at the WIPP, and adding a definition for "Administrator's authorized representative." Finally, EPA is finalizing its decision, also pursuant to the WIPP LWA, that DOE does not need to acquire existing oil and gas leases near the WIPP.

Background

The Waste Isolation Pilot Plant (WIPP) is a potential disposal system for TRU waste. Developed by the Department of Energy (DOE), the WIPP is located near Carlsbad in southeastern New Mexico. DOE intends to bury radioactive waste over 2,000 feet underground in an ancient layer of salt which will eventually "creep" and encapsulate waste containers. The WIPP has a total capacity of 6.2 million cubic feet of waste.

Congress authorized the development and construction of the WIPP in 1980 "for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States."[1] The

[1] Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Pub. L. 96-164, section 213.

waste which may be emplaced in the WIPP is limited to TRU radioactive waste generated as byproducts of defense activities associated with nuclear weapons production and disassembly; no high-level waste or spent nuclear fuel from commercial power plants may be disposed of at the WIPP. TRU waste is defined as materials containing alpha-emitting radio-isotopes, with half lives greater than twenty years and atomic numbers above 92, in concentrations greater than 100 nanocuries per gram of waste.[2]

Most TRU waste proposed for disposal at the WIPP consists of items that have become contaminated as a result of activities associated with the production of nuclear weapons or with the clean-up of weapons production facilities (e.g., rags, equipment, tools, protective gear, and organic or inorganic sludges). Some TRU waste is mixed with hazardous chemicals. The waste proposed for disposal at the WIPP is currently stored on Federal lands across the United States, including locations in Colorado, Idaho, New Mexico, Nevada, Ohio, South Carolina, Tennessee, and Washington. Much of the waste proposed for disposal at the WIPP will be generated in the future as weapons are disassembled and additional facilities are decontaminated and decommissioned.

EPA's certification decision process

EPA's certification decision was made by comparing relevant information to the WIPP compliance criteria [40 CFR Part 194]. The primary source of information examined by EPA was the compliance certification application (CCA) submitted by DOE on October 29, 1996. (Copies of the CCA were placed in Category II-G of the docket.) As required by EPA after preliminary review of the CCA, DOE submitted additional information after that time, and on May 22, 1997, EPA announced that DOE's application was deemed to be complete. [62 FR 27996-27998]

EPA's certification decision is based on the entire record available to the Agency, which is contained in Docket: A-93-02. The record consists of the complete CCA, supplementary information submitted by DOE in response to EPA requests for additional information, technical reports generated by EPA and EPA contractors, EPA audit reports, and public comments submitted on EPA's proposed certification decision. All materials which informed EPA's proposed and final decisions have been placed in the WIPP dockets or are otherwise publicly available. A full description of the supporting documentation for EPA's certification decision and a full list of DOE compliance documentation considered by the Agency are located at Docket: A-93-02, Item V-B-1.

Public comments on proposed rule

Approximately 85 sets of written comments were submitted to EPA's Air Docket regarding the proposed decision to certify WIPP. In addition, the Agency received oral testimony on the proposed rule from 275 speakers during public hearings and comments from various stakeholder

[2] WIPP LWA, § 2(18).

meetings. Comments received on the proposal were categorized according to topics, which correspond generally to sections of the compliance criteria. While a section of this document is assigned to each topic, the document should be read comprehensively. Because so many of the performance assessment issues have similarly overlapping requirements and are often complex, EPA has chosen to combine some of these sections and discussions. A list of the issues addressed in each section can be found at the beginning of each section. While in some instances EPA has cross-referenced related responses, it has not done so in every instance. The entire document should be considered as a whole, for it collectively reflects EPA's consideration of significant comments. In some cases, EPA has combined or paraphrased comments.

This document addresses comments received on the proposed decision to certify WIPP by summarizing the views expressed by commenters and presenting the Agency's response to the comments. All comments received during the public comment period (October 30, 1998 through February 27, 1998) and the public hearings have been fully considered. Some comments were received after the close of the public comment period on February 27, 1998. These comments were identified as late and placed in the dockets. EPA reviewed these comments and determined that no new issues were raised. The Agency has addressed all significant comments, both written and oral. Responding to comments was difficult in some cases because certain comments did not articulate specific concerns, did not suggest concrete alternatives, or did not substantiate the position advocated.

In publishing the proposed certification decision, EPA considered all comments that were received on the CCA November 15, 1996 through August 8, 1997. These comments and the EPA responses can be found in Docket: A-93-02, Item III-A-01. One commenter requested that EPA reconsider all of the comments that were received on the Advanced Notice of Proposed Rule Making (ANPR)[61 FR 58499-58500; November 15, 1996] when developing the final rule. EPA has chosen not to reconsider these comments based on the fact EPA has adequately addressed these issues in III-A-01 and because the issues raised in the ANPR comments pertain to the CCA and not specifically to EPA's proposed decision to certify WIPP. Where commenters requested reconsideration of specific comments previously submitted, to the extent such comments are relevant to the proposed certification decision, EPA has fully addressed the issues raised therein. Comments on the ANPR that were received after August 8, 1997, were not included in the proposed decision but are addressed in this document.

Each comment is identified by a unique number in parentheses that follows the comment. Appendix A of this document correlates these identification numbers to the docket numbers and name(s) of the commenter. Appendix B lists the names of the people who testified at the public hearings and the corresponding comment numbers. Copies of all comments submitted to EPA regarding the proposed certification decision can be found in Air Docket Number A-93-02 Categories IV-D, IV-F, and IV-G. A list of acronyms and the terms they represent are in Appendix C. To locate references used in response to comments or references that are cited in other EPA support documentation, see Docket: A-93-02, Item V-B-1. DOE's Compliance Certification Application (CCA), including references, can be found in Docket: A-93-02, Item II-G-1.

The hours and locations of EPA's public information dockets are as follows: Docket No. A-93-02, located in room 1500 (first floor in Waterside Mall near the Washington Information Center), U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, D.C., 20460 (open from 8:00 a.m. to 4:00 p.m. on weekdays); 2) EPA's docket in the Government Publications Department of the Zimmerman Library of the University of New Mexico located in Albuquerque, New Mexico, (open from 8:00 a.m. to 9:00 p.m. on Monday through Thursday, 8:00 a.m. to 5:00 p.m. on Friday, 9:00 a.m. to 5:00 p.m. on Saturday, and 1:00 p.m. to 9:00 p.m. on Sunday); 3) EPA's docket in the Fogelson Library of the College of Santa Fe in Santa Fe, New Mexico, located at 1600 St. Michaels Drive (open from 8:00 a.m. to 12:00 midnight on Monday through Thursday, 8:00 a.m. to 5:00 p.m. on Friday, 9:00 a.m. to 5:00 p.m. on Saturday, 1:00 p.m. to 9:00 p.m. on Sunday); and 4) EPA's docket in the Municipal Library of Carlsbad, New Mexico, located at 101 S. Halegueno (open from 10:00 a.m. to 9:00 p.m. on Monday through Thursday, 10:00 a.m. to 6:00 p.m. on Friday and Saturday, and 1:00 p.m. to 5:00 p.m. on Sunday). As provided in 40 CFR Part 2, a reasonable fee may be charged for photocopying docket materials.

Section 1 General Comments and Issues

<u>Issue A: The health effects of radiation on children should be considered.</u>

1. Only a Court of Justice, such as the State Supreme Court, the U.S. Supreme Court and the World Court, could take into consideration the debilitating health effects of radiation on tiny children, un-born children, all children, in decisions concerning WIPP. (134)

2. The WIPP project constitutes a form of child abuse. In the sense of a potential hazard and accident that may not occur this year but may occur well beyond our own lifetime, I am particularly disturbed in terms of looking at the accident potential, the lack of safety standards in terms of what this means for our children -- not just our present children but also for future generations of children. (254)

3. I think it's important to remember that the WIPP site and others like them in the future are going to expose millions of people to radioactive food and water, increased incidences of genetic diseases, deformed babies, epidemics of children dying from cancer and Leukemia, and is this the kind of environmental devastation that the Environmental Protection Agency, with its fine record of service to the American people, wants to leave the next seven generations of humanity? (277)

4. On perusal of the <u>Federal Register</u> notice dated October 30, 1997, we find no reference to the effects of radioactive release on children. Do the same rules apply to tiny children as to adults? Also, does the President's Executive Order to Protect Children from Environmental Health and Safety Risks apply to the EPA? (892)

5. EPA radiation standards and regulations refer to adult safety with no consideration of the disproportionate effects of radiation (ionizing and non-ionizing) on children's health, growth, and development. (133)

<u>Response to Comments 1.A.1 through 1.A.5:</u>

The Environmental Protection Agency (EPA, or the Agency) is required by law to determine, using the compliance criteria at 40 CFR Part 194, whether the WIPP complies with the disposal regulations of Subparts B and C at 40 CFR Part 191. The disposal regulations are binding for the disposal of transuranic waste at the WIPP. The disposal regulations clearly establish that the releases of regulatory concern at a disposal facility such as the WIPP are: 1) radionuclide releases to the accessible environment, 2) radiation doses to humans from all exposure pathways, and 3) radiation exposure and radionuclide concentrations in underground sources of drinking water. [Sections 191.13, 191.15, 191.24] The disposal regulations do not contemplate a separate standard for radiation doses to children; rather, all people must be protected from unnecessary exposure, and the standards require the Department of Energy (DOE) to estimate radiation doses to a hypothetical individual located at the point of highest potential radiation exposures.

Although the Executive Order (E.O.) pertaining to protection of children did not yet exist when EPA developed the disposal regulations, EPA considered the issue of how age might affect both radiation doses and cancer risks. [E.O. 13045, "Protection of Children From Environmental Health Risks and Safety Risks," April 21, 1997] The Agency specifically examined *in utero* effects as well as how radiation might affect children differently than adults. [High-Level and Transuranic Radioactive Wastes: Background Information Document for Final Rule, EPA Document Number 520/1-85-023, August 1985, pp. 5-14, 6-18, 6-30] In addition, the risk estimates used as the basis for EPA's disposal standards account for the potential longer exposures of children to radiation by modeling a population with ages distributed over a wide range. [EPA 520/1-85-023, p. A-9] The disposal regulations established specific standards for radiation releases and doses based on radiation dose-response effects consistent with widely held views of national and international scientists. Scientific methods are required to be used for calculating annual committed effective doses to the most exposed individuals. These methods are consistent with the International Commission on Radiation Protection (ICRP) Publication 60 guidelines available at the time the disposal regulations were developed.

It is beyond the scope of the certification rulemaking to establish a new level of protection or to fundamentally re-examine the basis of the disposal regulations, which are binding on the Agency and DOE pursuant to Section 8(a) of the WIPP Land Withdrawal Act (LWA), as amended. [Pub. L. 102-579, Pub. L. 104-201] E.O. 13045 does not apply to the disposal regulations, which already exist, nor to the certification decision, which does not meet the definition of a "covered action" under the order since it is not deemed to be economically significant. [E.O. 12045, Sections 2-202, 5-501] For further discussion of non-ionizing radiation, refer to the response to Issue BB.

Issue B: EPA made the correct decision in its proposed rule. The WIPP should be certified to be in compliance and should be opened. (135) (195) (175) (204) (217) (184) (216) (213) (206) (221) (224) (225) (247) (253) (350) (365) (388) (423) (547) (588) (589) (614) (623) (624) (625) (632) (638) (642) (669) (672) (810) (812) (813) (814) (1097)

1. I have looked at the DOE submittal, and I don't see how EPA could ever regulate in favor if not in this case. Some would have you block the possibility of WIPP, whatever the evidence. (136)

2. It's been my observation over the years that -- notwithstanding the credibility of our PA, there's a whole lot of intuitive reasons for believing the viability of the WIPP project. It's also

been my observation that a lot of rational and non-biased scientists, geologists, and related disciplines have the same opinion. (181)

3. The WIPP is a well-thought-out solution that has evolved over the past 22 years with a foundation of top scientific and engineering minds and national research organizations. Independent groups and the public have scrutinized the project from all angles. The WIPP is a carefully, deliberately designed, developed and implemented facility, closely audited by domestic and international experts in nuclear waste and mining technology. (162)

4. Our studies show the repository is so robust that it will comply even with the stringent regulations, even in the unlikely event of the human-intrusion scenarios. This clear assurance of compliance I think means we have successfully completed the investigatory phase and it's now time to move forward to certify the WIPP and to operate it for its intended purpose. (172)

5. We feel this project is a totally safe project. We feel it's been ready to be opened for years. New testing has been done that is probably overkill, and I think it's time for us to go ahead and get this facility open. (205) (548)

6. It's time we got what we paid for as taxpayers: A nuclear waste repository for the environmental good health of our nation's people and our environment. WIPP is a well-regulated solution to the national transuranic waste problem. (207) (223) (458) (894)

7. Does the WIPP comply with the Radiation Disposal Standards defined in 40 CFR 194? I believe the answer is a resounding yes. (209) (479)

8. Removing nuclear waste from above ground temporary storage scattered across the United States and disposing of it 2,000 feet below ground, in 250 million year old bedded salt is the right thing to do. The WIPP is the right thing to do. (218) (462)

9. Sandia Laboratory supports the EPA draft rule and believes that WIPP should be certified as a facility for transuranic waste disposal. (318)

10. Even worst case at the WIPP, you still don't have a radiation dose where people drink the water directly which results in detectable health consequences. Overall, I have not found a disaster that would cause the WIPP to be unsafe. (478)

11. Currently available information and data clearly demonstrate that the WIPP TRU waste repository readily complies with all applicable TRU waste disposal regulations. Indeed, the potential cancer death risk imposed by the proposed WIPP TRU waste repository is 36 times less than that permitted by the EPA in 40 CFR 191 and 766 times less than the average natural background radiation in the USA. I, therefore, again, urge the EPA to comply with its own regulations and the WIPP Land Withdrawal Act, as amended, and promptly certify the WIPP TRU waste repository. (483) (339)

12. I support EPA's certification decision that WIPP will comply with the radioactive waste disposal regulations found in 40 CFR Part 191. (568)

13. The vast majority of the citizens of Carlsbad and the people most affected by WIPP support WIPP. We feel comfortable with the pilot plant's opening in May of 1998, the safety thereof and to delay any longer in moving forward with the project would certainly be detrimental to those people with waste deteriorating in their own backyards. (579) (590)

14. WIPP is the first thing that has to happen, the first shipments, and oddly enough, it is the lowest level of radioactive waste. We have problems that are enormous compared to transuranic waste in the country, WIPP is the first domino in a series of dominoes that has to go ahead and fall in order for us to go ahead and proceed to begin to solve some of this nation's problem. (637)

15. I believe you are being distracted, delayed or detoured by an overwhelming expression of concern by people who haven't the foggiest notion of what they're talking about. Two contaminated gloves that touch each other during transport to WIPP are not going to cause a nuclear explosion. It is time to open WIPP and prove that the concept is either valid or not. (671)

16. It is time to move forward and approve the proposed certification and not prolong further the opening of the WIPP by raising unlikely, non-science-based, non-critical, time-consuming "red-herring" scenarios. (896) (677)

Issue C: EPA made the incorrect decision in its proposed rule. The WIPP is not safe and should not be opened. (237) (273) (266) (323) (346) (333) (338) (387) (418) (481) (519) (537) (591) (598) (644) (648)

1. Environment, health and safety issues related to waste handling, packaging, transport and storage have not been adequately addressed at this point. (255)

2. I am not a scientist, but I do not feel that WIPP is safe nor that EPA is in fact doing its job, that of protecting the health and well being of this nation's population. (281)

3. We'll stop it. We'll continue to stop it because we care. (319)

4. The WIPP project is a serious environmental threat and it's the duty of your agency to protect us New Mexicans from that threat. (343)

5. So what we are asking you to do here tonight to avoid a lawsuit is to preclude the opening of the WIPP. . . If you don't decide otherwise, we will end up in court, and it's going to cost thousands and thousands of dollars, temporary restraining orders, et cetera. (452)

6. I don't believe these people who say that this waste is safe. To put it in a pit and cover it up is not getting rid of the problem. All that's doing is camouflaging it so nobody will see it, nobody will notice it. It's still there, it's still dangerous, it's still waste. (469)

7. We are only guessing whether the facility is safe; there are lot of people who don't really know whether it is going to be safe. I don't think that's good enough. (473) (734)

8. I want to assure the EPA that the people of this community [Santa Fe] are overwhelmingly opposed to WIPP. (508)

9. The impossibility of isolating the WIPP site from human activity and natural breaching for a period of 240,000 years should be a concern of the government. The current studies show that even with known factors such as the existence of brine below the waste site, that long term isolation is impossible. (545)

10. I oppose WIPP because no amount of radiation is safe. (551)

11. If the WIPP is opened, our children will be cleaning up our mess for years to come. (640)

12. I am not in favor of WIPP. It should not be opened. Recently two earthquakes here in New Mexico are giving a warning. Do not open WIPP. (831)

13. I'll never be convinced that the proposed metal and salt containment will be safe for 10,000 years. (890)

Issue D: EPA should not bow to political pressure.

1. I am convinced that a vast number of people in this area want the waste removed to WIPP. I am convinced that the U. S. Department of Energy and the EPA are committed to reason, not politics. I am convinced that we should not spend time discussing the merits of deep burial of the waste, in as much as all available scientific studies have established deep burial as the current best method of handling waste of this type. (461)

2. Please, all I ask is that you do the job right the first time. At least 400 generations will be affected by what you do. Don't bow to expediency or be cowed by political pressure. In fact, if you must err, please err on the side of extreme caution. (634)

Issue E: The Department of Energy cannot be trusted.

1. Delay the opening until federal health agencies independent of the Department of Energy assure its safety. We think it is inappropriate to have an agency with an interest in moving waste to a facility be an agency that's involved with establishing the standards. (396)

2. We don't trust this project. (348)

3. DOE has been illegally moving nuclear waste to the WIPP site and lying about it. (240)

4. Up until two years ago, the WIPP site could not pass safety tests, but all along DOE's been saying they're ready to receive waste and begin operations. (732)

5. CARD has long maintained that DOE's need to meet its schedule to open WIPP has caused various tests necessary to reduce uncertainty in important areas of site hydrology, waste characterization and repository characteristics, to be done incompletely or not done at all. (904)

Response to Issues B through E and Comments 1.B.1 through 1.E.5:

The Agency is aware that radioactive waste issues in general, and the WIPP in particular, often provoke strong reactions on all sides. While such reactions may be understandable, they are difficult or impossible to incorporate constructively in a rulemaking conducted pursuant to the Administrative Procedure Act (APA). In 1992, Congress addressed public concerns about DOE self-regulation of the WIPP by enacting the WIPP LWA, [Pub. L.102-579, as amended by Pub. L.104-201], which, in pertinent part, gave EPA independent regulatory oversight of the facility. Congress delegated to EPA the task of conducting an *independent technical evaluation* to determine whether WIPP complies with EPA's disposal regulations. The WIPP LWA required EPA to develop, through rulemaking conducted pursuant to Section 4 of the Administrative Procedure Act [5 U.S.C. § 553], compliance criteria by which to evaluate documentation submitted by DOE in a compliance certification application. [WIPP LWA, § 8(c)] The WIPP LWA also requires EPA to utilize these criteria in determining, through rulemaking conducted pursuant to Section 4 of the APA, whether DOE demonstrated that WIPP will comply with the 40 CFR Part 191 radioactive waste disposal regulations. [WIPP LWA, § 8(d)] Thus, EPA is tasked with evaluating the scope and quality of objective information directly relevant to the disposal regulations, not perceived motives or broadly stated opinions. Unsubstantiated claims related to illegal activities or deception by DOE are similarly irrelevant and difficult to incorporate in a rulemaking.

During the rulemakings for the disposal regulations, the WIPP compliance criteria, and the certification decision, EPA provided substantial opportunities for public input to the Agency's decision making. For example, in promulgating the compliance criteria, EPA (1) published an advance notice of proposed rulemaking (ANPR) soliciting public comment on seven major issues identified by the Agency as central to their development, and requesting assistance on identification of additional issues that should be addressed [58 FR 8029 (February 11, 1993)]; (2) solicited public comment on a preliminary draft proposed rule in January 1994; (3) proposed the compliance criteria with a 90-day comment period [60 FR 5766 (January 30, 1995)]; (4) conducted three technical workshops to receive input from both the public and scientific experts on certain technical issues [60 FR 43470 (August 21, 1995)]; and (5) in response to requests by the public, reopened the comment period for an additional 45 days. [60 FR 39131 August 1, 1995] In making the certification determination, EPA (1) published an ANPR soliciting public comment for 120 days on "all aspects" of DOE's CCA upon its receipt [61 FR 58499, 58500 (November 15, 1996]; (2) held meetings with major public stakeholders and a series of public hearings throughout New Mexico [62 FR 2988 (January 21, 1997)]; (3) extended the 120-day ANPR comment period until August 8, 1997, resulting in a comment period of over 250 days [62 FR 27996 (May 22, 1997)]; (4) published a notice of proposed rulemaking (NPRM) announcing the proposed determination to certify that the WIPP will comply with the 40 CFR Part 191 disposal regulations and soliciting public comment for 120 days on this proposed certification [62 FR 58791 (October 30, 1997)]; (5) held meetings with major public stakeholders and a series of public hearings throughout New Mexico [62 FR 64334 (December 5, 1997)]; and (6) made available for public comment EPA's analysis of a specific human intrusion scenario that had been identified by public comment as a potential future problem for the repository. [63 FR 3863 January 27, 1998] The purpose of this process was to ensure that the public was fully involved in all aspects of this critical determination and that the public, EPA, and DOE would have a common understanding of the objective basis on which the certification decision was made. Congress mandated that EPA conduct its evaluation of the application, and its decision regarding certification, in a rulemaking process that allows public input and makes transparent the Agency's justifications for its decision. EPA believes that, by making its decision through rulemaking and by comparing relevant technical information received from DOE (or otherwise obtained by EPA) against the objective WIPP compliance criteria, the Agency is sufficiently insulated from political or other pressure and can therefore make an independent decision on a solely scientific and objective basis.

Issue F: The conclusions from the National Academy of Sciences WIPP Report and the International Atomic Energy Agency review should be considered carefully.

1. First, it points out EPA's evaluation does not attempt to determine that WIPP will be safe. Rather, EPA states only that WIPP will comply with certain regulations. It is not a safety assessment. Such a limited analysis would not be acceptable anywhere else in the world where disposal sites are planned. In addition, the international group said EPA's compliance determination is arbitrarily limited, that there has been no determination that the limited scenarios examined in assessing compliance are the most appropriate from a safety standpoint. (401)

2. I think the science is very clear, I think that the National Academy's endorsement of the project is very clear. I think that those people that I represent I believe support this project very, very strongly, and I think it's time to certify the project and certify WIPP, and I encourage you to do so at the earliest point. (164)

3. The National Academy of Sciences report in October of 1996, stated emphatically that opening WIPP for disposal of transuranic waste was the correct thing to do from an engineering scientific perspective, the rational thing to do from an environmental protection perspective, and that there was no likely scenario by which any of that material would be reintroduced to the biosphere unless there were some highly speculative, very unlikely human intrusion scenario that would occur. (482)

4. EPA regulations do not require the applicant to present a comprehensive argument related to safety. Thus, the CCA does not represent a complete, self-standing performance assessment as understood in other countries. (1057)

5. With respect to disturbed performance, the International Review Group cannot reach a definite judgment whether WIPP would meet radiological performance standards typical of those used in other countries. (1065)

Response to Comments 1.F.1 through 1.F.5:

In developing the proposed certification decision, EPA considered the views of the National Academy of Sciences (NAS) committee on the WIPP, as expressed in the NAS report "The Waste Isolation Pilot Plant: A Potential Solution for the Disposal of Radioactive Waste" (National Academy Press, 1996). The Agency responded to both general and specific comments put forth by the NAS; these responses were contained in the Compliance Application Review Documents supporting the proposed rule and found in Docket: A-93-02, Item III-A-1. See proposed CARDs 14, 22, 23, 24, 25, 31, 33, 42, 44, and 51/52.

The NAS report reiterates NAS's belief that salt is an attractive medium for geologic isolation of radioactive waste. Based on its review of the 1992 Performance Assessment (PA) by DOE, the committee found no credible or probable scenario for release of radionuclides from the WIPP if it is undisturbed by human intrusion. The report concluded that disturbed scenarios -- i.e., those involving deliberate or unintentional human intrusion -- could compromise the integrity of the disposal system. Finally, the committee recommended several changes to produce a more technically defensible and more easily understood PA.

EPA did not give substantial consideration to the committee's general conclusions on the WIPP for a number of reasons. First, the NAS noted that the report was "a review of ongoing activities and should be viewed as a progress report rather than a final evaluation." [p. 12] EPA required significant changes to the PA subsequent to the NAS evaluation. Second, as noted by one commenter, the NAS review focused primarily on safety of the WIPP rather than evaluating the WIPP's regulatory compliance.[3]

For similar reasons, conclusions from the International Atomic Energy Agency (IAEA) review were not relied upon by EPA in developing the proposed certification decision. [International Peer Review of the 1996 Performance Assessment of the US Waste Isolation Pilot Plant: Report of the (OECD Nuclear Energy Agency) NEA/IAEA International Review Group, April 1997] That is, the IAEA panel stated that the purpose of its report was not to "undertake a formal comparison with the EPA regulations since this is the responsibility of EPA." [Docket: A-93-02, Item IV-G-40, Enclosure (IAEA Report), p. 2] The IAEA Report's only conclusions related to compliance were that the CCA was tightly focused on compliance with EPA's regulations and

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3 The NAS committee concurred with the commenter that EPA's compliance assessment is "not a safety assessment," stating that "[i]t is conceivable that a repository could comply with the standard, yet be significantly more or less safe than the measure of safety implicitly understood when the standard was formulated." [p. 12] However, the committee "found no probable situation for which the WIPP repository could be found in compliance with 40 CFR 191 and yet not be safe." [p. 12] EPA believes that a determination of compliance with 40 CFR Part 191 and 40 CFR Part 194 adequately addresses the safety of the WIPP facility and will provide protection of human health and the environment.

that the panel, during its review, did not find "any indication that the information presented [in the CCA] is not appropriate in the context of the EPA requirement." [IAEA Report, p. 30] The IAEA focused primarily on the technical soundness of the PA and on conformity with international practices.

As noted by a commenter, the panel did observe that there are some differences in approach between DOE's CCA and safety analyses as understood in other countries. However, the panel also explicitly stated that such observations "are statements of fact, not criticisms." [IAEA Report, pp. 7, 30] And while the panel found some differences between DOE's PA and similar international efforts, it also concluded that, in the main, the technical analyses in the CCA PA are based on appropriate studies and are technically sound. The panel also found that the methods used to assess the WIPP's performance are "generally in conformity with practices used in other countries" and that procedures for code configuration in PA "are consistent with best practice for computer simulation internationally." [IAEA Report, p. 31] Finally, the international review group concluded that for undisturbed performance, the WIPP "can easily meet typical [international] performance criteria based on dose to the individual." The review group could not reach a definitive judgment for undisturbed performance because of the difference between EPA's standards and those of other countries; however, the group did find that for the scenario of drilling into the disposal system, "the WIPP facility would meet an individual risk-based standard typical of those used in other countries." [IAEA Report, pp. 32-33]

While EPA has examined and responded to comments from the NAS and the IAEA in this rulemaking, the WIPP's compliance with international standards or any other safety reviews are not relevant to the Agency's current action. For the certification rulemaking, EPA -- and solely EPA -- is responsible for evaluating the WIPP's regulatory compliance with the disposal regulations. [WIPP Land Withdrawal Act (WIPP LWA), Pub. L. 102, 579, as amended, Section 8] Reviews by organizations other than EPA may be used to inform the Agency's decision making, but cannot and do not relieve the Agency of its legal obligation to conduct an independent scientific evaluation and determine, through rulemaking conducted pursuant to Section 4 of the APA, whether the WIPP complies with EPA's disposal regulations. That is, regardless of what conclusions are reached by outside review groups, the ultimate decision regarding the WIPP's regulatory compliance must be made by EPA. For further discussion of the NAS's statements regarding human intrusion scenarios, see the response to Comment 1.F.6.

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6. Heed the words of the National Academy of Sciences who stated, and I quote: We consider that it is not possible to assess the probability of human intrusion into a repository over the long term, and we do not believe that it is scientifically justified to incorporate alternative scenarios of human intrusion into a risk-based compliance assessment. (165)

<u>Response to Comment 1.F.6:</u>

In its report on the WIPP, the NAS committee stated that "[s]peculative scenarios of human intrusion should not be used as the sole or primary basis on which to judge the acceptability of the WIPP." [Docket: A-93-02, Item II-A-38, p. 3] The committee recommended that human intrusion scenarios could be made less speculative by refining probability estimates for the occurrence of future human activities, but suggested neither a methodology for doing so, nor an alternative approach to human intrusion that could be implemented within the framework of the WIPP compliance criteria. The rulemaking process used to develop the WIPP compliance criteria provided a forum for EPA to gather and weigh scientific evidence, public concerns, and other policy issues regarding the treatment of human intrusion in performance assessments. (The NAS never submitted official comments on the proposed 40 CFR Part 194.) The Agency believes that the human intrusion provisions of 40 CFR Part 194 represent a reasonable approach for considering the potential effects of future human intrusion, taking into account that the WIPP facility is located in an area with natural resources. In any case, it is beyond the scope of the current rulemaking to modify the 40 CFR Part 194 human intrusion criteria which were established previously through rulemaking.

Issue G: EPA should disclose the names and qualifications of its contractors, and should ensure that the contractors have no conflict of interest. (270) (311) (327) (334) (371) (402) (415) (518) (526) (560) (602)

1. A further very troubling aspect of EPA's proposed rule is the agency's refusal to disclose the names and qualifications of its contractor personnel. EPA should be accountable for the millions of taxpayer dollars it's spending for the qualifications of its technical contractors, so that it can be determined whether they in fact do have the world class science backgrounds that are needed and whether they have conflict of interest. (234)

2. For something as serious as the disposal of nuclear waste the EPA should present the credentials of its scientific sources. (280) (332)

3. EPA staff and their contractors were highly competent in understanding the technical complexity of the PA. They spent many weeks and months looking into the codes, the files, even files Sandia used in their PA calculations, and they had many, many meetings and discussion with the Sandia staff in order to ascertain the technical adequacy, traceability and reproducibility of the PA results. The questions they raised in the review the CCA were technically relevant to the safety of the WIPP performance. (287)

4. Apparently, EPA refuses to divulge the names of those who evaluate the DOE Certification Application. It's my understanding that such information is required by law to be available to the public. (468) (528) (647)

5. Why does EPA refuse to disclose the names and qualifications of those who worked on the technical analyses of the CCA? We have a right as citizens to hold them accountable if their data turns out to be unreliable or fraudulent. (511)

6. I've heard a lot of people here talk about disclosure of contractor names and so forth. I think it would be nice to know the names of those people, but I don't think it is necessary. I don't judge the quality of an idea by the letters behind someone's name; I don't judge the quality of an

idea by who is presenting that idea; I don't judge the quality of an idea by whether they belong to a certain professional organization or not, or whether they have the right degree from a college or whatever. The technical decisions, the technical findings that EPA has found and documented need to stand independent of who wrote them, and I think they will and I think they do and I think you've done a good job of documenting them. (576)

7. EPA only recently and reluctantly disclosed the names and qualifications of its contractor personnel (IV-C-13) after repeated requests. The fundamental concern about lack of agency expertise remains. Who are EPA's worldclass experts in rock mechanics, geochemistry, materials science, actinide solubility, mining engineering, fracture flow and other modeling techniques, and other fields? Moreover, it is relevant to determine whether EPA and its contractors have the required world class scientific expertise and whether they have conflicts of interest. Based on the record now available, the conclusion is that EPA does not have sufficient scientific expertise to carry out a credible certification process. (1119)

Response to Issue G and Comments 1.G.1 through 1.G.7:

Many comments requested that EPA release the names and qualification of contractors who provided technical support for EPA's certification rulemaking. EPA initially declined to disclose the names and qualifications of individual contractor employees because such information is typically claimed as confidential business information (CBI) by Federal government contractors. EPA determined that information concerning the "identities or qualifications of specific employees, consultants, subcontractors, and subcontractor's employees" that perform work under government contract is entitled to treatment as CBI under Exemption 4 of the Freedom of Information Act. [5 U.S.C. §522(b)(4)] Contrary to the assertions of commenters that such information is "required by law to be available to the public," the Trade Secrets Act prohibits EPA from releasing CBI, and imposes criminal liability on Federal employees for the unauthorized disclosure of CBI. [18 U.S.C. § 1905] Thus, EPA employees could be subject to prosecution for the unauthorized disclosure of contractor CBI.

In response to the public interest regarding this issue, EPA inquired whether the contractors that provided technical support on the WIPP certification proposed rule would waive their confidentiality rights with respect to this information. These contractors, in the interest of facilitating this rulemaking, agreed to a strictly limited waiver of their statutory confidentiality rights, solely in the context of the WIPP proposed rule and solely limited to the identities and qualifications of individuals providing technical support on the WIPP certification proposed rule. In January 1998, copies of contractor identities, qualifications, and waivers of confidentiality were provided to a number of interested stakeholders and were also placed in EPA's rulemaking docket. [Docket: A-93-02, Items IV-C-13 and IV-C-14]

Although EPA agreed to release specific information on contractors in the interest of allaying public concerns, such information is not relevant to EPA's certification decision, which must be conducted by informal rulemaking pursuant to Section 4 of the APA. [5 U.S.C. §553] EPA directed all analyses conducted by its contractors, analyzed the results of that work, and takes full responsibility for the proposed and final certification decisions. As required by the APA, the air docket contains all of the relevant information on which EPA's decision is based. Also pursuant to the APA, the public has the opportunity to hold rulemaking agencies accountable for the decisions that they make, and for the bases on which decisions are made. Therefore, any questions or concerns regarding scope or adequacy of EPA's supporting documentation must be directed to EPA, not its contractors.

Public comments also addressed potential conflicts of interest by contractors providing technical support on EPA's certification rule. The Agency agrees that it is important to ensure that contractors can provide objective analyses and are free from conflicts of interest. To that end, EPA independently identified and addressed such concerns prior to awarding the WIPP technical support contracts. During the initial stages of contracting for the necessary technical support for the WIPP certification rulemaking, EPA determined that the acquisition could involve potential conflicts of interest. Therefore, EPA's procurement process incorporated reasonable steps to avoid any such conflicts. During pre-award evaluations, EPA required and reviewed conflict of interest disclosures by potential contractors. The contracting officer (CO), under the authority of the Federal Acquisition Regulation, subpart 9.5, evaluated contractor's proposals to determine if there were actual or potential conflicts of interest. The CO found no conflicts of interest among the contractors selected to provide technical support for the WIPP rulemaking. EPA also concluded that the conflict of interest plan submitted by each offerer was acceptable and sufficient to identify any potential conflict of interest upon receipt of a work assignment.

Additionally, each contract contains a specific clause which requires continual disclosure of potential conflicts of interest during performance. These requirements also apply to any subcontractor or consultants used by the prime contractor. All work plans submitted by the contractor under the WIPP-related contracts must provide a list of personnel to be assigned to the project and a description, if any, of any potential conflicts of interest and/or a certification that no conflict of interest exists. EPA reviews any disclosure made by the contractor to ensure that no conflict of interest exists. The Agency believes that these measures are appropriate and adequate to ensure that its contractors do not have any conflict of interest in providing technical support on the certification rulemaking.

Issue H: EPA and DOE need to consider more carefully the potential effects of the WIPP on animals.

1. Now there are many aspects of WIPP, but the one I am dealing with specifically is the one dealing with the wildlife surveys which were done on the WIPP site or rather the lack of follow-up of the surveys after about 1985 to 1989. Up to that time, I see some integrity in the surveys. After that I do not. (244)

Response to Comment 1.H.1:

EPA's responsibility in this rulemaking is to determine whether the WIPP complies with the 40 CFR Part 191 disposal regulations. The regulations are binding for the disposal of transuranic waste at the WIPP. The disposal regulations clearly establish that the releases of regulatory concern at a disposal facility such as the WIPP are 1) radionuclide releases to the accessible environment, 2) radiation doses to humans from all exposure pathways, and 3) radiation doses and radionuclide concentrations in underground sources of drinking water. [Sections 191.13, 191.15, 191.24] Ecological protection is afforded through the release limits of the disposal regulations, which limit releases to the accessible environment (defined to include all areas outside the controlled area of the WIPP). In addition, Section 9(a)(1)(G) of the WIPP Land Withdrawal Act, as amended, obligates DOE to comply with all applicable Federal laws pertaining to public health and safety or the environment. [Pub. L. 102-579, Pub. L. 104-201] EPA believes that this requirement, in addition to WIPP's compliance with the disposal regulations, will provide the full range of protection for animal life that is available under Federal law.

Issue I: EPA's regulations are reasonable and protective of public health.

1. By concentrating on the system requirements that you have set forth for the repository, EPA promulgated in the public arena a regulation that effectively limits the potential exposure of our society to releases from the repository. The releases allowed are quite low. . . And specific factors related to the WIPP site such as the fact that it's saline water in the water-bearing zones versus potable water, things like that lead to very, very low releases and associated consequences. (248)

Issue J: EPA's regulations are unreasonable.

1. Consider the scientific discovery and the global environmental changes that have occurred in the past 100 years. What fool would presume to predict reliably what will happen in 10,000 years, which is 100 times 100 years? (260)

2. Another problem is that the facility has been designed to be safe for 10,000 years. Why 10,000 years? It's an arbitrary decision. (419) (823)

3. It is just an impossible problem to predict all the things that might occur that far in the future. (420)

4. Performance assessment calculations should be extended to calculate releases beyond the 10,000-year regulatory time frame. (996) (1051) (1280)

5. I have always been bothered by the notion of "acceptable levels" of substances known to be injurious to living things. Any level higher than zero cannot make for optimum health, and could cause cancer or birth defects or death. I have seen the figure for "acceptable level" fluctuate with whatever low or high concentrations happened to be found in the environment. (820)

Response to Comments 1.I.1 through 1.J.5:

The 10,000-year regulatory time frame, the acceptable risks associated with release limits, and the individual and ground water protection requirements were all established in EPA's disposal standards, 40 CFR Part 191, Subparts B and C. The disposal standards were the product of extensive technical analyses and were promulgated by rulemaking, which afforded the public multiple opportunities for input into EPA's decisions. The disposal regulations established specific standards for radiation releases and doses based on radiation dose-response relationships consistent with widely held views of national and international scientists. It is impossible to limit radiation doses to zero, since there are naturally-occurring sources of radiation, including energy from the sun and the materials comprising the earth itself. However, EPA's standards limit the risks to future generations to levels that the Agency believes are acceptably small because they are comparable to the risks that future generations would have been exposed to if the uranium ore used to create radioactive wastes had never been mined. [50 FR 38071] EPA believes that its disposal regulations are technically sound, reasonable and appropriate to protect public health and the environment. It is beyond the scope of the current rulemaking to establish a new level of protection or to fundamentally re-examine the basis of the disposal regulations, which are binding on the Agency and DOE according to the WIPP LWA. See also the response to Issue A.

Issue K: EPA's regulations were designed to help justify the opening of the WIPP.

1. We feel that the way that you adequately assure safety in a facility is you set standards and then you build the facility to those standards. What happened in this case actually is that the facility predated and the standards were, we believe, arranged to fit how the facility was going to operate, that it was done backwards. (398)

2. Rules can be changed with the stroke of a pen. A case in point: The WIPP could not comply with the criteria, so they change that criteria to fit the site. The DOE and the EPA have conspired to give the appearance of compliance with waste disposal rules when it is obvious to many that WIPP fails -- The WIPP fails. (185)

Response to Comments 1.K.1 and 1.K.2:

The Agency disagrees that its regulations were framed to ensure that DOE would obtain a compliance certification for the WIPP. In 1980, Congress authorized DOE to proceed with the construction of the WIPP. [Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Pub. L. 96-164, section 213(a)] In 1992, in response to public concerns about DOE self-regulation, Congress established EPA as the independent regulator of the WIPP. [WIPP LWA, sections 8 and 9] In the WIPP LWA, Congress tasked EPA with finalizing its disposal regulations [Subparts B and C of 40 CFR Part 191], developing site-specific WIPP compliance criteria [40 CFR Part 194], and determining whether the WIPP will comply with the disposal regulations (i.e., the certification decision). EPA completed the above tasks using notice-and-comment rulemaking procedures. [WIPP LWA, sections 8(b)(1), 8(c), and 8(d)(2)]

The compliance criteria did not "change" the disposal regulations to fit the WIPP; in fact, EPA emphasized numerous times that the compliance criteria rulemaking was not intended to change the underlying disposal regulations or their technical underpinnings. [Response to Comments for 40 CFR Part 194, pp. viii, 1-6, 1-7, 1-17, 19-4, 19-9, and others] Rather, the purpose of the WIPP compliance criteria was to implement the general disposal regulations at the WIPP, taking into account the particular characteristics of the WIPP site. EPA did this by, for example, providing specific requirements about how performance assessments must account for natural resources which are found in the vicinity of the WIPP. The compliance criteria also include the general requirements [Sections 194.21-26] to ensure that compliance applications are based on sound information and that EPA has the right to confirm the accuracy of such information. [Response to Comments for 40 CFR Part 194, p. 3-5] All of the requirements in the compliance criteria are fully consistent with the disposal regulations and in some instances are more stringent than the Appendix C guidance which accompanies the disposal regulations. [Response to Comments for 40 CFR Part 194, Section 12]

EPA takes its responsibilities under the WIPP LWA very seriously, and this is reflected by the fact that EPA's efforts to solicit public involvement far exceed its legal requirements under the APA to do so. [40 CFR Part 194, Subpart D; 62 FR 58794-58795] During the rulemakings for the disposal regulations, the WIPP compliance criteria, and the certification decision, EPA provided substantial opportunities for public input to the Agency's decision making. (EPA's efforts to ensure extraordinary public participation opportunities are discussed in greater detail in the response to Issues 1.T - 1.V.) All of the many comments received were carefully considered by EPA during these rulemakings. The purpose of this process was to ensure that the public, EPA, and DOE would have a common understanding of the objective basis on which the certification decision was made. EPA conducted its evaluation of the application, and its decision regarding certification, in a notice-and-comment rulemaking process that allows public input and makes transparent the Agency's justification for its decision. EPA believes that, by making its decision through rulemaking and by comparing relevant technical information received from DOE (or otherwise obtained by EPA) against the objective WIPP compliance criteria, the Agency is sufficiently insulated from political or other pressure and can therefore make an independent decision on a solely scientific and objective basis. EPA believes that its disposal regulations and compliance criteria are both reasonable and sufficiently rigorous so that compliance ensures the protection of public health and the environment. These issues are discussed in greater detail in the responses to Issues 1.B - 1.E and to Issue 1.F.

Issue L: It is environmental racism to locate a nuclear waste disposal facility in New Mexico. (251) (536) (621) (627) (652)

1. It is very interesting that in this era of environmental justice that we would put a nuclear repository right close to the border with Mexico, right in one of the poorest states in the nations, one of the states in the nation populated with Hispanic people, people of color. (284)

2. I don't trust the government, and I have no faith it will act on my concerns or any minority concern related to WIPP; therefore, it would behoove this EPA panel to reconsider the idea of

prohibiting the opening of WIPP and transporting these dangerous radioactive materials in our low-income and minority populations until our input is heard. (471)

3. I deeply resent the fact that the government would choose a politically not powerful state to dump all their junk in. (581)

4. Your studies haven't addressed the social and cultural concerns of people that live in the communities in which these wastes are produced, stored, and transported. (586)

5. Siting WIPP here is the same old practice again of putting waste dumps in minority and low income neighborhoods. Even if the repository doesn't violate the containment criteria you have created, we know that it will be drilled into and that some radioactive material will come to the surface. Since minorities and low income people are living and working around WIPP, they are the most likely ones to be subjected to this contamination. They will also be irradiated in the present by the thousands of shipments coming to the WIPP site and are the most likely population to be working in the repository emplacing the waste and therefore being irradiated by that waste. (900)

6. The original date to begin shipping to WIPP was the year 2011. We do not understand the sudden rush to begin shipments before the Santa Fe bypass is built, endangering minority and low-income neighborhoods, contrary to President Clinton's 1994 Executive Order No. 12898. (1090)

Response to Issue L and Comments 1.L.1 through 1.L.6:

EPA's responsibility in this rulemaking is to determine whether the WIPP complies with EPA's disposal regulations and compliance criteria. [40 CFR Parts 191 and 194] The WIPP site was selected in the early 1980's. EPA's role at the WIPP was not defined until 1992. In the WIPP LWA which prescribes EPA's role at the WIPP, Congress did not delegate to EPA the authority to consider alternative locations for the WIPP. Similarly, Congress did not provide authority for EPA to examine the impacts in the communities in which wastes are produced, stored, and transported. Other agencies may address some of these concerns. For example, the National Environmental Policy Act, which requires DOE to develop an environmental impact statement, discusses the need to preserve cultural and historical artifacts. [National Environmental Policy Act of 1969, as amended, Pub. L. 91-190, as amended by Pub. L. 94-52, Pub. L. 94-83, and Pub. L. 97-258, § 4(b)]

Pursuant to Executive Order 12898 entitled "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," EPA has made concerted efforts to address environmental justice concerns to the extent possible in its WIPP certification activities. [E.O. 12898 published February 16, 1994, 59 FR 7629] EPA involved minority and low-income populations early in the rulemaking process. In 1993 EPA representatives met with New Mexico residents and government officials to identify the key issues that concern them, the types of information they wanted from EPA, and the best ways to communicate with different sectors of the New Mexico public. The feedback provided by this group of citizens formed the basis for EPA's WIPP communications and consultation plan. [62 FR 58836]

To help citizens, including a significant Hispanic population in Carlsbad and the nearby Mescalero Indian Reservation, stay abreast of EPA's WIPP-related activities, the Agency developed many informational products and services. EPA translated into Spanish many documents regarding WIPP, including educational materials and fact sheets describing EPA's WIPP oversight role and the radioactive waste disposal standards. Spanish translators are available at many of EPA's public meetings and at all the Agency's WIPP hearings in New Mexico, and newspaper announcements for public meetings and hearings are published in Spanish-language newspapers as well as papers that serve Indian constituencies. EPA also developed a vast mailing list, which includes many low-income and minority groups, to systematically provide interested parties with copies of EPA's public information documents and other materials.

EPA provides a toll-free WIPP information line to facilitate access to information by people of any economic status. The hotline offers a recorded message -- in both English and Spanish -- about current EPA WIPP activities, upcoming meetings, and publications; information cards advertising the telephone line are printed in Spanish and English.

The Agency will continue to pursue opportunities to work with community organizations to pass information on to their constituencies, and to address the specific concerns of minority and low-income populations.

Issue M: The WIPP should not be opened because it will enable the United States to continue making atomic weapons.

1. I strongly oppose opening WIPP. WIPP is about making it possible for Los Alamos and other U.S. death factories to continue to build weapons, to maintain, enforce and expend the U.S. empire to keep hogging the wealth of the world. (258)

2. I am writing to express the obvious point that WIPP is a crime against nature and an environmental disaster. Opening WIPP shows a blatant disregard for the land and its people, encouraging yet more nuclear production, both for energy and weapons. (650)

3. Let's 1) leave the waste where it is generated, while 2) stopping further weapons of mass destruction production, and 3) spend what it takes to truly detoxify the nuclear waste we have now. (1101)

Issue N: EPA should consider alternatives to WIPP for the disposal of nuclear waste. (316) (386)

1. We should store this waste where it was produced and wait until we can find a better and more permanent way to take care of the waste. (272) (507) (546) (556) (631) (639) (1096)

2. Instead of opening the WIPP, the money should be used to find safer solutions for dealing with this waste. (544) (641)

3. Focus massive attention on the subject of transmutation so we can learn how to neutralize nuclear waste instead of burying it. (453) (550) (599) (817)

4. It is illogical to create and contaminate a brand new site for storing nuclear waste. (450)

5. EPA needs to respond to our suggestion to leave the waste on site. (477)

6. More testing needs to be done and perhaps we need to look at alternative above ground safe storage methods until WIPP can be proven 100% safe without any doubt. (643)

7. [Russia] is experimenting with incorporating radioactive substances into solid materials. These can be ceramic or glass, not containers but solid blocks mixed with the wastes during the manufacture of the blocks. Thus wastes would be prevented from migrating into air or soil or water, would be rendered useless to terrorists, and would be more easily transported to new sites. (818)

8. While I understand it is a conundrum as to where to put such waste and it must be disposed of, I ask you: 1. please find a safer site than WIPP, [since] the evidence convinces me it is not safe. 2. Vote to discontinue making ALL items requiring this type of waste. (1105)

9. There are alternatives to radioactive dumping, including (1) transmutation, (2) vitrification, and (3) improved waste containers. DOE claims to have considered them, but DOE is not utilizing them. (1192)

10. Accelerator transmutation of waste is a brilliant and technologically elegant future means of dealing with the menace of accumulated plutonium and various accumulated radioactive wastes. It is far better in the long run both economically and environmentally than WIPP, which is unsound and dangerous. (1327)

Issue O: WIPP does not address the real (or entire) problem of nuclear waste in this country; therefore, it is not the best solution. (310) (1109) (1219)

1. Only a small amount of the waste in this country would go to the WIPP, and the rest of it – including some of the most dangerous waste – is going to stay at the sites where it is and continue to cause problems. (322) (376) (463) (490) (500) (561)

2. We should be spending money on stopping leaking drums at sites instead of on getting drums ready to go to WIPP. (330)

3. Only a small percentage of the waste at Los Alamos National Laboratory would go the WIPP, and the rest of it -- including some of the most dangerous waste -- is going to sit at Los Alamos and continue to leak and cause problems. (432) (433) (437) (480) (516) (901)

Issue P: WIPP is the best solution because it is much safer than the current temporary storage at waste generator sites. (160) (168) (183) (356) (393) (414) (421) (424) (425) (426) (430) (459) (475) (593) (610) (633) (635) (636) (668) (726) (811) (895) (1089)

1. Waste is much more protected from human intrusion, terrorists and natural disasters in the WIPP than in above-ground storage. (187) (329) (611) (674)

2. Waste that is stored above ground needs to be repackaged at periodical intervals to prevent the escape of materials due to loss of container integrity. Every time such waste must be handled, the potential for worker exposure is increased. We cannot afford to wait. We have the problem now and we need a solution now. That solution is WIPP. (276)

3. Today transuranic waste is in temporary storage at 23 sites throughout the country, potentially exposing millions of people within a 50-mile radius of these sites to adverse radiation impact. This alternative to the opening of WIPP is not acceptable. (349) (836)

4. This waste will not go away. Storing waste above ground creates a higher risks of an accidental release to the environment than does storing the waste underground in WIPP. (361) (412) (413) (440) (612) (626)

5. And I ask you to please study this, that we can move it away from Los Alamos. I ask you thank you very much. (427) (460)

6. The cost of maintaining, repackaging as required and verifying that the waste is stored according to federal, state environmental regulations is substantial and will continue to increase until a permanent repository for disposal is licensed. (595) (886)

7. [T]he present method of dealing with low-level radioactive waste (that is accumulating waste in temporary storage facilities near the multitudinous generation points) presents a much higher hazard to both the environment and public than any reasonable hazard that could occur by transportation to, and storage of such materials at WIPP. (645)

8. I am writing to ask that the EPA approve the Waste Isolation Pilot Plant Project (WIPP) opened [sic]. I am writing this letter to you to ask that the EPA approve the WIPP project so that the wastes from the Savannah River Site can be sent to New Mexico. (1100)

9. The timely opening of the WIPP is not only in the best interest of Idaho Falls, but it is the Idaho Falls Chamber's view the opening of WIPP is also in the best interests of the nation. Sufficient studies have been conducted and aspects evaluated. It is time for this nation to begin permanent disposal of transuranic, mixed and other forms of waste, and WIPP is a very appropriate place to do that. (1111)

Response to Issues M through P and Comments 1.M.1 through 1.P.9:

In 1980, Congress authorized DOE to proceed with construction of the WIPP:

> The Secretary of Energy shall proceed with the Waste Isolation Pilot Plant construction project authorized to be carried out in the Delaware Basin of southeast New Mexico (project 77-13-f) in accordance with the authorization for such project as modified by this section. Notwithstanding any other provision of law, the Waste Isolation Pilot Plant is authorized as a defense activity of the Department of Energy, administered by the Assistant Secretary of Energy for Defense Programs, for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission.
>
> [Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Pub. L. No. 96-164, section 213(a)]

In 1992, Congress withdrew the WIPP site from the public domain and reserved the lands for DOE's use for the following WIPP activities:

> Such lands are reserved for the use of the Secretary [of DOE] for the construction, experimentation, operation, repair and maintenance, disposal, shutdown, monitoring, decommissioning, and other authorized activities associated with the purposes of WIPP as set forth in section 213 of the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 and [the WIPP LWA].
>
> [WIPP LWA, Pub. L. No. 102-579, section 3 (citation omitted)]

At the same time that Congress withdrew the WIPP site from the public domain, Congress delegated to EPA certain regulatory responsibilities at the WIPP. [WIPP LWA, sections 8 and 9] As noted, EPA's responsibility in the present rulemaking is to determine whether the WIPP facility will comply with EPA's radioactive waste disposal regulations. This decision is based upon the WIPP compliance criteria issued previously, and a compliance certification application submitted by DOE. Thus, Congress delegated to EPA the responsibility to determine whether WIPP will comply with disposal standards intended to protect the public from radioactive releases for 10,000 years. Congress also mandated that EPA fulfill its regulatory responsibilities within specific time frames. [WIPP LWA, Sections 8(c) and (d)]

Congress did not delegate to EPA the authority to abandon or delay the WIPP because future technologies might evolve and eliminate the need for the WIPP. Congress did not delegate to EPA the authority to weigh the competing risks of leaving radioactive wastes stored above-ground at disperse sites or disposing of wastes in an underground repository. Finally, Congress did not delegate to EPA the authority to abandon the WIPP because it might affect other defense activities related to radioactive waste or atomic weapons. These considerations are outside the scope of this rulemaking.

Issue Q: There should be a baseline health assessment in Carlsbad so that it will be clear if there are any effects of radiation there. (321)

1. Carry out the independent baseline health studies which were promised in the agreement signed between the state of New Mexico and the Department of Energy. (397)

2. [R]ecently a new organization affiliated with New Mexico State University and the Carlsbad Environmental Monitoring Research Center has initiated a baseline health study of both the humans and the environment around WIPP. (577)

Response to Issue Q and Comments 1.Q.1 and 1.Q.2:

EPA's responsibility in this rulemaking is to determine whether the WIPP complies with the 40 CFR Part 191 disposal regulations. The regulations are binding for the disposal of transuranic waste at the WIPP. The disposal regulations clearly establish that the releases of regulatory concern at a disposal facility such as the WIPP are 1) radionuclide releases to the accessible environment, 2) radiation doses to humans from all exposure pathways, and 3) radiation dose and radionuclide concentrations in underground sources of drinking water. [Sections 191.13, 191.15, 191.24]

The requirements of 40 CFR Part 191 that apply to exposure of individuals are framed in terms of radiation doses, which correspond to specific levels of risk (i.e., specific probabilities that cancer may develop). The standards require DOE to estimate radiation doses to a hypothetical individual located at the point of highest potential radiation exposures. Thus, by confirming that radiation doses predicted by performance assessments are not expected to exceed the limits in the disposal regulations, EPA is also confirming that risks from radiation do not exceed acceptable levels. The risk levels used as the basis for EPA's disposal regulations were developed using internationally accepted scientific methods, and with significant public input through the rulemaking process. It is beyond the scope of the certification rulemaking to establish a new level of protection or to fundamentally re-examine the basis of the disposal regulations, which are binding on the Agency and DOE according to the WIPP Land Withdrawal Act, as amended. [Pub. L. 102-579, Pub. L. 104-201] See also the response to Issue A.

EPA does not have the authority to enforce the terms of the Consultation and Cooperation Agreement made between the State of New Mexico and DOE.

Issue R: EPA must have some authority to shut down and clean up the WIPP site if it is not operating as planned.

1. I noticed every five years you're supposed to recertify WIPP. I don't know what to do if you don't get recertification and what sort of remediation efforts you'll take if you suddenly discover there's a lot more water under the site. (359)

2. Based on certain amendments to the LWA removing language calling for the removal of waste, if WIPP has not complied with EPA standards within 10 years of its opening, the EPA may not require DOE to remove the waste! If EPA allows WIPP to open, and then it is shown to be not safe, a tremendous mistake will have been made which will be impossible to rectify. So the EPA must be absolutely sure of WIPP's safety before the first shipment. (1094)

Response to Comments 1.R.1 and 1.R.2:

EPA may stop operations at the WIPP site at any time if it becomes clear that the facility will not comply with the disposal regulations. Specifically, Section 194.4 of the WIPP compliance criteria clarifies EPA's authority to modify, suspend, or revoke a certification of compliance for the WIPP, all actions that may be taken apart from the recertification process. Recertification is a periodic review intended to confirm (and document) that the information and activities upon which a certification is based continue to exist. If review of information submitted for recertification, or provided or obtained at any other time, indicates that conditions or activities at the WIPP depart significantly from those upon which a certification has been based, it may be necessary to modify or revoke the terms or conditions of certification or, in the interim, to temporarily suspend the certification. The Administrator of EPA has the discretion to suspend the certification in order to promptly reverse or mitigate a potential threat to public health as stated in Section 194.4(b)(1). [Response to Comments for 40 CFR Part 194, p. 2-3] If the certification is revoked, DOE must retrieve (to the extent practicable) any waste emplaced in the disposal system. (This legally binding requirement is embodied in the WIPP compliance criteria at § 194.4(b)(1) and was not affected by the LWA amendments cited, which relate to a no longer applicable "test phase" for the WIPP.)

The WIPP compliance criteria require DOE to report to EPA any planned or unplanned changes from the most recent compliance application. [40 CFR 194.4(b)(3)] Furthermore, the criteria impose specific requirements for any releases that may lead to a violation of EPA's release limits, individual doses, or groundwater protection limits. If DOE discovers that a release has occurred which is (or is expected to be) in excess of EPA's standards, then DOE must immediately cease emplacement of waste in the WIPP, and must notify EPA within 24 hours so that the Agency can determine what action should be taken regarding the certification. [Id.] If such an event occurs, DOE cannot resume emplacement of waste until EPA issues a written notification that the suspension has been lifted. [Id., Section 194.4(b)(3)(iv)] The Agency believes that these measures are appropriate to ensure that the WIPP is performing as expected, and are adequate to ensure that the public's health and safety is protected.

Issue S: EPA should establish a field office in the State of New Mexico.

1. A resident WIPP site presence will serve the agency well both in terms of more effective EPA oversight and enhancing public confidence in its regulatory enforcement. The state urges EPA to pursue funding for the opening of a field office here in New Mexico. (410)

Response to Comment 1.S.1:

EPA does not believe that it is necessary to establish an office in New Mexico in order to ensure that the WIPP is operating as expected. The Agency will, however, exercise a robust inspection and audit program to guarantee that information, data, processes, and procedures documented by DOE in any compliance application are complete and correct. The WIPP compliance criteria provide EPA the authority to conduct unannounced inspections of any area of the WIPP and any locations performing activities that provide information relevant to compliance applications. The criteria also allow EPA to monitor and measure aspects of the waste proposed for disposal in the disposal system. [Section 194.21] EPA expects that it will conduct numerous inspections at multiple facilities; in particular, the Agency will audit or inspect quality assurance programs and waste characterization controls at waste generator sites. [Conditions 2 and 3, Section 194.8] If it becomes necessary for EPA to establish a more visible or permanent presence at the WIPP facility, DOE is required to provide to EPA permanent, private office space that is accessible to the disposal system. [Section 194.21(c)] The Agency believes that these measures are sufficient to allow effective regulatory enforcement.

Issue T: EPA has provided extraordinary opportunity for public involvement in its decision making on the WIPP. (166)

1. EPA has provided for and accommodated extensive public involvement. Your action in this regard is beyond what is required, and the positive aspects of it are without precedent. Most hearings are held only in the affected community, which in this case would be only Carlsbad. You have tripled your efforts in this regard. I commend you for that and offer this note to those who want more public involvement. (198)

2. This level of public involvement is unprecedented. Not only did EPA allow two extra-long public comment periods instead of a single shorter period, it kept going that extra mile by actively seeking out the public's view by meeting with various stakeholders during the first public comment period on DOE's application. EPA staff traveled to New Mexico and set up meetings to inform themselves of all stakeholder issues without any DOE presence. I understand the EPA has recently held a second round of private stakeholder meetings to elicit the public's concerns over the proposed rule to certify the WIPP. This kind of aggressive seek-out-and-poll regulatory approach is exemplary. (158)

Issue U: Additional opportunities should be provided for public involvement in the decision whether or not to open the WIPP.

1. New Mexico should have the opportunity to vote on whether the WIPP should open. (448) (467)

2. It is insane that we are talking about potential major toxic hazards so calmly, as if we were simply discussing some federal rules and regulations that were promulgated with a little deadline to submit comments. (447)

Issue V: EPA did not adequately respond to comments submitted on the Advanced Notice of Proposed Rulemaking (ANPR) for the certification decision.

1. EPA has now stated (see SRIC's February 25, 1998 letter to Administrator Browner) that the public must identify specific comments previously submitted that were not responded to. Such a task is not a public responsibility, as the agency is required to fully respond to all public comments. Furthermore, it is impossible for the public to determine what public comments were

recorded and whether EPA responded to them because there is no clear tracking system for comments nor do the CARDs clearly identify who the commenter was and where the comments have been responded to. (1125)

2. EPA has not fully considered and responded to comments submitted prior to issuance of the proposed rule. (1122)

Response to Issue T through V and Comments 1.T.1 through 1.V.2:

The WIPP LWA [Section 8(d)(2)] requires EPA to conduct its certification rulemaking by notice-and-comment rulemaking pursuant to Section 4 of the APA. Notice-and-comment rulemaking under the APA requires that an Agency provide notice of a proposed rulemaking, an opportunity for the public to comment on the proposed rule, and a general statement of the basis and purpose of the final rule adopted. [5 U.S.C. §553] Because of the great interest in this project expressed by New Mexico citizens and others, EPA has undertaken public participation measures which far exceed the requirements of the APA.

In Subpart D of the WIPP compliance criteria, EPA chose to bind itself to public participation requirements that allow the public to participate in the regulatory process at the earliest opportunity. The WIPP compliance criteria contain provisions that require EPA to: publish an ANPR in the Federal Register; allow public comment on DOE's compliance certification application (for at least 120 days) prior to proposing a certification decision; hold public hearings in New Mexico, if requested, on the application; provide a minimum of 120 days for public comment on EPA's proposed certification decision; hold public hearings in New Mexico on EPA's proposal; produce a document summarizing the Agency's consideration of public comments on the proposal; and maintain informational dockets in the State of New Mexico to facilitate public access to the voluminous technical record, including DOE's certification application.

EPA has complied with and has even gone beyond the requirements to provide for public input into the WIPP certification decision. In accordance with the WIPP compliance criteria, an ANPR was published in the Federal Register on November 15, 1996, after EPA received DOE's compliance certification application. [61 FR 58499] EPA announced and conducted public hearings on the application in three cities in New Mexico during February 1997. [62 FR 2988] The hours of the hearings were extended in two of those cities to accommodate all individuals who requested that they be allowed to address the EPA panel. A public comment period on DOE's application was opened for a minimum of 120 days. The proposed certification decision was announced in the Federal Register, and EPA provided a comment period of 120 days. [62 FR 58792-58838] Again, five days of hearings were provided in three cities in New Mexico, and the Agency extended the hours in two cities to allow the testimony of everyone present who wished to address the panel. [62 FR 64334-64335] The final certification decision is being published in the Federal Register, and this document itself – accompanying the final certification decision – responds in detail to all significant public comments received on the proposed rule. Finally, EPA has maintained informational dockets in Washington, DC and three cities in New

Mexico which contain copies of all information relevant to EPA's certification decision making and all documents supporting today's action.

Beyond the actions described in the WIPP compliance criteria, EPA has undertaken a number of additional steps to solicit and accommodate public input. First, although not required by either the APA or 40 CFR Part 194, EPA responded to all comments submitted on the ANPR, and on a number of other issues raised in the pre-proposal phase of the rulemaking. [62 FR 58795] The Agency considered these comments in developing its proposed rule, and provided responses to these comments both in the preamble to the proposal and in the compliance application review documents which supported the proposed rule. (ANPR comment responses were organized by topic rather than according to the commenter who submitted them; however, comments submitted in writing were listed in the proposed rule documentation with corresponding docket numbers, allowing the public to locate EPA's responses to specific commenters or documents.) EPA's intent was to respond to all comments submitted on the ANPR. In fact, EPA accepted ANPR comments submitted well after the end of the 120-day comment period initially announced; in the proposed rule, the Agency responded to comments submitted as last as August 8, 1997, leading to a comment period of nearly 9 months in duration. To the extent that any commenter believes that EPA has not adequately responded to particular submitted comments, EPA believes it is reasonable to request that commenter to identify such comments. Had any such comment(s) been identified, EPA would have been willing to: (1) determine whether the Agency had somehow inadvertently failed to respond to such comment(s) or (2) reassessed its earlier response(s) to determine if it (they) were somehow deficient or non-responsive. As no such comments have been identified, EPA is unable to undertake this exercise.

Second, EPA allowed the New Mexico Environment Department, the New Mexico Environmental Evaluation Group, and the New Mexico Attorney General's Office to observe meetings between EPA and DOE staff to discuss technical issues during the pre-proposal period. EPA also summarized all meetings between EPA and DOE and placed such summaries in the public docket. Third, the Agency held two series of meetings -- one in the pre-proposal period, and one after publication of the proposal -- in New Mexico with the principle New Mexico stakeholders to obtain comments on DOE's application and on EPA's proposed rule.

The Agency believes that it has not only met, but has far exceeded, the legal requirements for incorporating public input into its decision making process. The Agency believes that its efforts in this arena are important, given the public interest in this rulemaking. EPA will continue to inform and involve the public in its future actions regarding WIPP's compliance with the disposal regulations. See also the response to Issues W and Y.

Issue W: Private meetings between EPA and DOE exclude public notice and violate rulemaking requirements.

1. DOE has met with EPA in private numerous times since the CCA was filed. DOE provided EPA with data and information not available to the public, and EPA relied upon and made decisions based on such private information, frustrating the rulemaking process. (951)

2. EPA has established the numerical value to be assigned to numerous important PA parameters on the basis of information obtained privately from DOE and by a process that excluded public notice and comment. (952)

3. EPA engaged in secret meetings with DOE and its contractors in March and April 1997, at which point EPA apparently made the decision to deem the CCA complete and to certify WIPP. Such a non-public process is contrary to the requirements of the WIPP Land Withdrawal Act, the Administrative Procedures Act, and EPA's own commitments. (1110)

4. EPA did not provide any public notice nor were any representatives of the public present in the critical meetings with DOE and its contractors on March 5 (II-I-13), March 6 (II-I-14), March 13 (II-I-18), March 26 (II-I-20), April 3 (II-I-21), and April 14, 1997 (II-I-23). In those meetings EPA made two of the most fundamental decisions -- parameter values and completeness -- related to the certification determination. EPA and DOE held a nonpublic meeting with House Commerce Committee staff on March 14, 1997, II-I-22). EPA refused to supplement the meager details in those summaries, covering up the discussion and commitments that occurred. (1118)

Response to Comments 1.W.1 through 1.W.4:

After the receipt of DOE's CCA in October 1996, EPA engaged in necessary communication (including both telephone conversations and meetings) with DOE to discuss and clarify various aspects of the CCA. Such discussions comport fully with the requirements of the APA, which does not place limitations on the Agency's interactions with any interested parties in the pre-proposal phase of a rulemaking. EPA did not hide the fact of these meetings, many of which were attended by the New Mexico Environmental Evaluation Group (EEG), a Congressionally chartered State technical oversight organization. EPA's policy was to place summaries of meetings with DOE in its docket to ensure that the public was aware of such interactions. In response to concerns expressed by members of the public in letters to the Agency, EPA took additional measures (not required of the Agency) to ensure that its communications with DOE would be open to public scrutiny. To that end, the Agency agreed to provide more detailed meeting and conversation summaries for review in the public docket, and to invite interested members of the public -- including EEG, the New Mexico Office of the Attorney General, and the New Mexico Environment Department -- to observe all technical meetings or teleconferences scheduled between EPA staff (or contractors) and DOE staff (or contractors). [Docket: A-93-02, Items II-C-43, II-C-44, II-C-45, and IV-C-2.]

EPA's decision whether to certify the WIPP is being made through rulemaking, as required by the WIPP LWA. In conducting this rulemaking, EPA provided the public the opportunity to comment on completeness and other matters even before the proposed rule was published, by providing a 120-day comment period on the November 15, 1996, ANPR. [61 FR 58499] (EPA also accepted and responded to comments submitted after the close of the ANPR comment period.) Public comments submitted on the ANPR were considered by EPA when assigning values to certain parameters for a performance assessment verification test, and in EPA's requests to DOE for further information. Furthermore, although the completeness determination is only a preliminary administrative step in the certification determination process and not part of the rulemaking, EPA published its completeness determination in the Federal Register and also accepted public comment on that decision. [62 FR 27996-27998; May 22, 1997] The bases for all decisions leading to a proposed certification decision, including the parameters values, were fully documented in the public dockets when the proposed rule was published. Through a second 120-day comment period as well as public hearings and stakeholder meetings, the public had an opportunity to comment on EPA's proposed certification, as well as on whether the information submitted or otherwise communicated by DOE supports its conclusions on compliance.

EPA's actions regarding pre-proposal communications with DOE comply fully with both the APA and with EPA's more stringent public participation requirements in the WIPP compliance criteria. Beyond the legal requirements of the APA and 40 CFR Part 194, the Agency took further measures to ensure that the public was aware of the occurrence and subjects of such meetings and, in some instances, could participate in them. Finally, all information obtained in these meetings and relied on by EPA in its proposed certification was placed in the dockets for public review. The Agency believes its efforts fulfill, and in some instances go beyond, not only the letter but also the intent of the notice-and-comment rulemaking requirements.

Issue X: The public comment period was inadequate and should have been extended.

1. EPA has further compounded the lack of public comment by providing only a 30-day comment period on its air drilling report as part of the 120-day comment period on the proposed rule (1126)

2. SRIC also strongly objects to EPA not providing an adequate timeframe for public comment on the proposed decision and has formally requested an extension of the comment period, which EPA has denied. Because of the inadequate comment period, SRIC has not had time to fully comment on all aspects of the proposed decision. (1112)

Response to Comments 1.X.1 and 1.X.2:

EPA received only one written request to extend its 120-day comment period on the proposed certification. This request was received by the Agency two days prior to the close of the 120-day comment period. As noted by the commenter, EPA responded to this request by declining to extend the comment period. [Docket: A-93-02, Item IV-C-19] EPA believes that the 120-day period was sufficient, particularly in view of the numerous public participation measures undertaken by EPA for its WIPP certification decision. For the certification rulemaking, EPA bound itself to two comment periods of at least 120-days -- longer than typical for EPA rulemakings -- on the Department of Energy's certification application and on EPA's proposed certification decision. [Sections 194.61(c), 194.62(b); See 61 FR 58499-58500, November 15, 1996; and 62 FR 58792-58838, October 30, 1997] Since EPA agreed to respond (in its proposed rule) to comments submitted both during and after the comment period on the ANPR, the public had over a year to review and comment on most of the information on which EPA's certification is based.

Regarding the air drilling report, EPA conducted its analysis on air drilling near the WIPP in response to public comments submitted after the end of the comment period on EPA's ANPR. In fact, the first comments regarding this issue were submitted to EPA less than two weeks before the proposed certification decision was signed. Upon receipt of these comments, EPA immediately undertook to evaluate and address this newly raised issue, and to place its evaluation in the public rulemaking docket, to enable the public at large to comment on the issue and EPA's analysis. Far from truncating the public's review, the release of EPA's supplemental analysis a full thirty days before the end of the public comment period on the proposal allowed even greater insight for the public into EPA's decision making for the final rule. [63 FR 3863, January 27, 1998]

Issue Y: EPA's hearings were poorly scheduled.

1. These hearings were scheduled poorly. Citizens groups, those with the networks in place to alert the public, were not given any information on the definitive time and place of these hearings until it was published in newspapers. The first publication of this information took place on December 10, with a deadline for registration of December 30. The holidays were conveniently sandwiched between the announcement and the hearings, making it most difficult to organize citizen participation. Many of those who would have participated were disappointed to find that upon returning from their winter holiday the deadline for registration had already passed. While I'm aware that the time frame is legally correct, this does not appear to be an open process when its scheduling does not take into consideration the availability of the majority of citizens. (509)

Response to Comment 1.Y.1:

EPA believes that the public was provided adequate notice of public hearings on the proposed certification decision. The Agency conducted hearings in three cities in New Mexico -- Carlsbad, Albuquerque, and Santa Fe -- on January 5 through 9, 1998. EPA took a number of steps to ensure that citizens were aware of the hearings and to accommodate requests to testify before the EPA panel. A notice announcing the dates, times, and locations of the hearings was published in the Federal Register on December 5, 1997, fully a month before the hearings took place. EPA provided a toll-free hotline, staffed during mountain standard time (New Mexico time) hours and with a voice mail system at all other times, for people to register to testify. Over three weeks were provided for citizens to pre-register for the hearings. During the time when pre-registration was available, EPA took a number of other steps to make information available about the hearings: a press advisory was issued to over 1,500 media outlets in the southwest, an announcement was posted both on the toll-free WIPP information line and on EPA's WIPP home page on the internet. Forty-six notices were published twice a week in seven newspapers across the State of New Mexico -- including publications specifically addressed to native American populations -- beginning more than a month before the hearings (December 3, 1997) and continuing through the hearings in Albuquerque (January 7, 1998). In addition, EPA reiterated the specific details about the hearings to a number of significant New Mexico stakeholders (with constituencies known to be interested in the hearings) during meetings in New Mexico on December 10-11, 1997.

Despite the efforts to make information about the hearings available, EPA was aware that some individuals were unable to pre-register by telephone for the hearings. To accommodate these individuals, EPA conducted on-site registration at the hearings. When all time slots were filled in Albuquerque and Santa Fe, EPA extended the hours of the hearings in order to allow additional testimony. EPA remained at these locations each day until everyone present who wished to testify was given the opportunity to do so.

For people who were not able to testify -- either because of scheduling conflicts or because they do not live convenient to the hearing locations -- the 120-day public comment period provided ample opportunity to submit written comments to the Agency on its proposal. All comments received by EPA, whether written or oral, were given equal consideration in developing the final rule.

EPA believes that the hearings were well publicized, that the registration procedures were designed to make registration as convenient as possible, and that the Agency exhibited diligence in extending the hearing hours to accommodate additional testimony. Furthermore, citizens had ample opportunity to submit written comments. Thus, the Agency believes that the public was provided a reasonable opportunity to provide input to the certification decision.

Issue Z: EPA should be more concerned with transportation of radioactive waste, which is very hazardous. (186) (245) (246) (267) (271) (275) (369) (383) (385) (436) (446) (449) (454) (457) (472) (553) (587) (616) (628) (630) (825)

1. Communities do not have the training or emergency response and medical facilities necessary to handle potential accidents involving radioactive materials. (243) (252) (274) (342) (382) (395) (429) (470) (517) (520) (532) (622) (651)

2. DOE’s testing of transportation has not been adequate because it doesn’t reflect actual accident scenarios or the behavior of nuclear waste. (239) (320) (377) (434)

3. I’m concerned about nuclear waste being transported into New Mexico and through New Mexico, because no amount of radiation is safe. (241)

4. There is no law enforcement agency in New Mexico that has the authority to stop and check these loads. So what action are we able to take if the federal carrier is leaking on our interstates? People must stay away from these trucks. (242)

5. It is especially dangerous to transport waste through Santa Fe -- if the bypass is not built, waste will come down a busy highway in the middle of the city. (250) (399) (439) (441) (476) (499) (512) (570) (582) (646) (676)

6. I realize this hearing has nothing to do with transportation issues, but the reality is that there will be accidents, and sooner or later there will be releases of lethal radiation. (282)

7. Economically, the transportation of radioactive and other toxic waste through Santa Fe is a devastating proposition. An accident would cripple the entire real estate market. (445)

8. DOE's analysis of transportation is very poor. We would hope that EPA would have done a better job. (505)

9. Most of the canisters that will be transported to WIPP will contain what they call contact handled transuranic waste. These canisters emit two-tenths of a rem per hour of radiation, and a few of these canisters will also contain what is known as remote handled transuranic waste. These canisters can give off as much as 100 rem per hour at the container surface, and five percent of these canisters will emit up to one thousand rems per hour. . . This is dangerous stuff that will be transported through our community, through our state and through our nation. People all along these routes need to know what the long-term effect will be on their health. (538)

10. DOE now states there will be no releases, in past environment impact statements their statistics predicted that there could be at least 78 accidents with several releases of radiation at various locations around the country, and five accidents with one release in New Mexico. The containers used to transport the waste are supposed to be our primary protection against contamination during regular operations or accidents. But unfortunately the DOE has not finished the container to transport the RH TRU waste, to my knowledge. The TRUPACT container is used for larger amounts of radioactivity and has passed free drops, punctures, thermal and water immersion tests. However, it has not been subjected to a crush test even though DOE has said this would be a dominant accident scenario. Also, the thermal tests only subject the TRU pack to 1450 degrees Fahrenheit, even though there are now over 20 chemicals routinely transported on our roads, which includes propane and butane, that have plain temperatures more than twice as hot as 1450 degrees Fahrenheit. . . (540) (494)

11. DOE’s containers have not been qualified for what they are meant to be used for. DOE is saying that they are going to put these 55 gallon drums in these containers and taking them to WIPP. That's misleading. They are going to put these 55-gallon cans in these containers, but they are going to reuse these containers. (552)

12. Roads on transportation routes need to be resurfaced, redesigned or safeguarded with realistic speed limits to prevent accidents. (341) (431) (580) (617) (618)

13. I reviewed the draft Comment Resolution for the Safety Analysis Report for Packaging of the shipping cask which will be transporting high-level radioactive waste to the WIPP site.

Assurance of the quality of the material to be used for bolting material on this cask was not resolved despite my documented efforts to make the picture very complete. (736)

14. We as citizens of New Mexico do not want trucks carrying toxic radioactive wastes through, into, and about our state. (889)

15. There has also been a great amount of testimony showing that the transportation of the waste to WIPP cannot be made totally safe, especially in New Mexico which has the highest DWI accident rate of the nation. Does it concern the EPA that the EPA has no authority over the transportation, which should be a part of environmental protection oversight? (1095)

16. I have no doubt that these shipments are statistically safer than other hazardous materials being shipped along the route (propane, gasoline, etc.). However the contents that could potentially be released in an accident are more long lasting. Northern New Mexico is a beautiful place, but it is has some amazingly poor drivers, and very high DUI rates, possibly the highest in the nation. (1195)

17. Moving the TRU waste from LANL to WIPP will only remove the tip of the iceberg and will add to the dangers from radioactive materials transportation to the communities near LANL. (902)

Issue AA: It has been shown that transportation of WIPP waste will be safe. Transportation issues have been adequately examined. (210) (261)

1. This past September Idaho National Engineering and Environmental Laboratory shipped three TRUPACT containers with 42 drums filled with sand as simulated waste to the WIPP. Every DOE-specific procedure from inspection of mock waste shipment as it left the site in Idaho to final unloading and emplacement in the underground at the WIPP was tested during the in-depth exercise. (196)

2. As compared to the billions of pounds of hazardous materials driven in trucks through our communities in which each of us live, and flown overhead in planes everyday again and again, the TRU waste is minuscule and insignificant to our daily lives. (199) (422) (613)

3. I support the transporting of transuranic waste by truck. It has been well tested and proven to be safe. The TRUPACT II containers are proven strong and safe during extensive testing programs. The trip plans required are more stringent than any required by any other trucking operation. The State has worked together to design the shipping routes of the WIPP. The trucks are monitored and in constant communication along the route. (169)

4. The containers used to transport these wastes have been carefully designed and thoroughly tested. It has been demonstrated repeatedly there will be no leakage of radioactivity even under the most severe accident scenario. (325)

5. No TRUPACT tubes will be opened outside the building. Furthermore there are no plans to ever open the container of waste at the WIPP facility. (373)

6. After many years of preparation we are thoroughly convinced that the transportation safety program developed jointly by DOE, New Mexico and other western states is arguably the best in this country, and will greatly minimize those opposed by WIPP shipments. . . The cooperative safety programs address both accident prevention and emergency response. It is noteworthy to mention that many of its components are extraregulatory in nature. In other words, they go well beyond the minimum transport requirements established under existing law. . . In addition, DOE and the state have provided extensive WIPP emergency response training throughout New Mexico in the last ten years. In conjunction with this training, emergency response drills and exercises have been conducted with the affected communities and Indian tribes along the entire WIPP transportation corridor. These activities have involved all responder levels, including emergency personnel in the field and at hospitals. (411)

7. The experiments conducted at LANL have established the gas generation rate of different waste matrices and the TRU element concentration to verify the department of transportation regulations can be fully managed. (596) (887)

8. Some untruths and distortions entered into the record by WIPP opponents need to be corrected. First, TRUPACT testing does include testing in an engulfing fire. Second, in the case of traffic accident, radioactive materials will not be released immediately and dispersed through the environment; this scenario ignores the integrity of the packaging and the nature of the waste. (679)

9. I am in favor of the method of transfer of radioactive material to the WIPP site via specially built containers and transport vehicles. (815)

<u>Response to Issues Z and AA and Comments 1.Z.1 through 1.AA.9:</u>

In this rulemaking, EPA is establishing whether the WIPP will comply with EPA's radioactive waste disposal regulations at 40 CFR Part 191, Subparts B and C, and with EPA's WIPP compliance criteria at 40 CFR Part 194. Transportation is entirely outside EPA's general authority for regulating radioactive waste. Moreover, in the WIPP LWA, Congress did not authorize any role for EPA with respect to transportation. Congress addressed transportation issues by requiring DOE to: (1) use only shipping containers approved by the Nuclear Regulatory Commission; (2) notify in advance States and Indian Tribes of the transport of transuranic (TRU) waste through their jurisdictions; (3) provide technical assistance and funding to ensure that jurisdictions along WIPP transportation routes receive appropriate training for accident prevention and emergency preparedness; (4) provide transportation safety assistance to States or Indian Tribes through whose jurisdictions waste will be transported; and (5) study transportation alternatives. [WIPP LWA, Section 16] Transportation of radioactive waste is regulated by the Nuclear Regulatory Commission, the U.S. Department of Transportation, and the State of New Mexico. All transportation requirements for the WIPP are established and enforced by regulators other than EPA, and the Agency has no regulatory authority to affect transportation routes or requirements.

Issue BB: EPA should be concerned about electric and magnetic fields at the WIPP.

1. Electric and magnetic fields can cause momentary disorientation in the adult workforce which could result in the mishandling of radioactive material. Is the WIPP installation in conformance with the National Electrical Code and has it been surveyed for electric and magnetic fields? (893)

Response to Comment 1.BB.1:

EPA's disposal standards apply only to ionizing radiation -- specifically, to alpha particles, beta particles, gamma rays, and other atomic particles. 40 CFR Part 191 does not apply to non-ionizing radiations such as sound waves, radio waves (including electric and magnetic fields), nor to visible, infrared, or ultraviolet light. [Section 191.02 and Section 190.02(e)] Therefore, electric and magnetic fields are not regulated under the disposal standards or compliance criteria and are thus outside the scope of the certification decision. Moreover, in the WIPP LWA, Congress did not authorize any role for EPA with respect to either electromagnetic fields or operational safety of the WIPP. It is beyond the scope of his rulemaking to expand EPA's fundamental regulatory role at the WIPP.

Regulations related to operational and occupational safety of the WIPP and handling of waste are addressed by a number of regulatory agencies, including the U.S. Occupational Safety and Health Administration and the New Mexico Environment Department. Some further information on DOE's compliance with some other environmental and safety requirements (beyond EPA's disposal regulations) can be found in DOE's biennial compliance report. [Docket: A-93-02, Item II-D-52] Various regulatory agencies are responsible for overseeing the enforcement of these Federal and State regulations. It is the responsibility of the Secretary of Energy to report the WIPP's compliance with all Federal laws pertaining to public health and the environment. [WIPP LWA, sections 7(b)(3) and 9] EPA evaluates DOE's compliance with such Federal regulations every two years, but that evaluation is entirely separate from EPA's certification determination and thus outside the scope of the present rulemaking. [WIPP LWA, section 9(a)(2); see, e.g., 62 FR 44276-44277] The WIPP's "Compliance with Other Environmental Laws and Regulations" is also addressed in the preamble to the final rule.

Issue CC: By certifying WIPP to receive only certain waste streams, EPA is in effect granting a piecemeal certification. Such an action is illegal under the WIPP Land Withdrawal Act.

1. In certifying WIPP for operation only as to certain Los Alamos National Laboratories debris wastes, EPA has in effect made such a piecemeal certification. Thus, there is a clear legal

question whether the certification, in the form proposed, would conform with the WIPP Act. (1066)

2. Indeed, if Congress intended that DOE could submit a partial certification application, the stringent sanctions of §8(d)(2) would make no sense. Under §8(d) (2) if EPA does not certify that the facility will comply with the disposal regulations by a specific date, the land withdrawal terminates, and hazardous waste permits terminate -- ending any possible use of the site as a waste repository. But if the EPA certification proceeding could involve only a small subset of the planned waste inventory, it would not make sense to end the entire repository project on a determination that small part of the inventory was not acceptable. Plainly, the "application for certification of compliance with such regulations" (§6 (d) (1) is intended to encompass DOE's plans to use the entire capacity of the site. (1075)

3. EPA should determine in this rulemaking, after public notice and comment, whether the necessary characterization facilities can, in fact, be certified to operate and should certify those that meet the applicable requirements. Then, based on the assumption of receipt of waste streams for which characterization facilities and methods can be so approved, the inventory and release limit assumptions and other assumptions of the performance assessment should be established, and compliance should be tested on those bases and against those limits. Whether such a certification can thereafter be modified to include entire types and categories of waste not previously certified, such as RH waste, is to be decided at such later time, but the attached letter would suggest that such piecemeal certification cannot be done under the WIPP Act. (1068)

4. [LWA Section 7b] Subsection (1) calls for EPA's certification "that the WIPP facility will comply with the disposal regulations" -- language that calls for a ruling as to the entire facility, not as to a subcategory of the waste intended to be emplaced. (1069)

5. [LWA Section 7b] Subsection (2) requires that DOE submit plans for "decommissioning" WIPP and managing the withdrawn land. The "decommissioning" phase is defined as the period from the completion of emplacement of waste until the backfilling and sealing of shafts (WIPP Act §2(4), (6)). . . In order words, DOE must obtain EPA's certification of compliance as to the entire repository capacity before it can prepare a decommissioning plan, which is a prerequisite to begin disposal. (1070)

6. [LWA Section 7b] Subsection (3) requires that DOE notify Congress and initiate a 180 day waiting period. The legislative history indicates that this waiting period was introduced as a substitute for a previous provision that required that Congress take a "second look" and enact new legislation authorizing disposal of waste, after EPA has determined that WIPP would comply with the disposal regulations. . . It would make no sense for this provision to apply unless EPA has certified use of the entire capacity of WIPP. (1071)

7. [LWA Section 7b] Subsection (4), in conjunction with §4(b) (5), requires EPA to determine whether acquisition of certain nearby oil and gas leases is required to comply with the radioactive waste disposal regulations or the Solid Waste Disposal Act. EPA could not make that determination without reviewing a performance assessment based on stated assumptions as

to the nature and amount of the waste to be emplaced (in other words, a full compliance application). . . in other words, a certification of compliance by the entire repository based on use of its full capacity. (1072)

8. [LWA Section 7b] Subsection (5) requires that DOE present comprehensive recommendations for the disposal of all transuranic waste under its control, including a timetable. Such requirement means that before disposing of any waste at WIPP, DOE must have a plan for disposal of all its transuranic waste, including a plan and timetable to send to WIPP all the waste that DOE may want to send there. In that situation, to allow DOE to postpone obtaining EPA certification for some of the shipments make very little sense. (1073)

9. [LWA Section 7b] Subsection (6) requires that DOE complete a "survey identifying all transuranic waste types at all sites from which wastes are to be shipped to WIPP." Thus, DOE must know all the locations which will send waste to WIPP. By implication, DOE must know what wastes "are to be shipped to WIPP" before disposal can begin. DOE can only have that information if EPA has certified WIPP to receive such waste. Thus, EPA must certify use of the full capacity of WIPP before any disposal may begin. (1074)

10. The WIPP Land Withdrawal Act provides for EPA to make one certification decision (Section 8(d)(2)) which is subject to judicial review (Section 8(d)(3)). This one-time decision is a key requirement for whether WIPP can open (Section 7(b)). (See attached opinion of the NM Attorney General of December 29, 1994, Docket: A-92-56, IV-D-49.) In its proposed decision, EPA has fundamentally violated that requirement by allowing for piecemeal, continuing certifications that are not subject to judicial review. (1114)

11. The certification in its present form is based on assumptions that certain types and quantities of waste will be brought for disposal, including waste that is not allowed to be brought because characterization methods have not been approved. Thus, waste from ten major sites, it is assumed, will be introduced, even though EPA has found that only one such site has acceptable characterization facilities, and those are limited as to waste type. (1067)

Response to Comments 1.CC.1 through 1.CC.11:

EPA's certification is not a "phased certification" as described by the commenter. In fact, EPA's certification that the WIPP will comply with the 40 CFR Part 191 radioactive waste disposal regulations is based on the Agency's determination that the WIPP will comply with the release limits and other requirements of 40 CFR Parts 191 and 194 for the waste inventory described for purposes of the performance assessment. Those inventory estimates include both remote-handled and to-be-generated waste. Thus, the WIPP is certified to accept such wastes so long as they fall within the waste envelop limits determined by the performance assessment to be compliant with the 40 CFR Part 191 standards.

It is not necessary to certify waste characterization facilities and methods in order to determine whether the WIPP facility will comply with the disposal regulations (and thus to determine whether a certification should be issued). (The commenter acknowledges this when he states that "an application clearly may include such to-be-generated waste, even though such waste does not exist yet," and therefore cannot have characterization methods validated. [IV-G-41, Attachment, p. 1] To determine compliance with the release limits, it is necessary (as stated in Comment CC.3) that "the inventory and release limit assumptions and other assumptions of the performance assessment should be established, and compliance should be tested on those bases and against those limits." This is what EPA did in making its certification decision, as described in the preceding paragraph. Conditions 2 and 3 of the certification (related to waste generator sites, including the Los Alamos National Laboratory) change neither the performance assessment assumptions nor the terms on which the WIPP is authorized for disposal, but rather ensure that the assumptions on which compliance is based are adhered to in actuality. To that end, the conditions state that the WIPP may accept waste only after EPA has determined -- through a site-specific inspection and approval process -- that DOE has implemented necessary procedures to ensure that the results of waste characterization activities at waste generator sites are valid and accurate. [Section 194.8]

EPA disagrees with the assertion that the WIPP LWA prohibits a modification to the certification in order to include new types of waste. The WIPP LWA provisions which ostensibly support such an assertion have been removed from the Act or significantly revised in subsequent amendments. [WIPP LWA Amendments, Pub. L. 104-201] For example, the cited subsections 7(b)(2), (5), and (6) were removed from the WIPP LWA, so that section 7 no longer requires the preparation of a decommissioning plan, a timetable for disposal of waste, or a survey identifying all the wastes which are to be shipped to the WIPP. Section 8(d)(2) imposes a statutory deadline for EPA to complete its certification rulemaking, but no longer imposes "stringent sanctions" and does not contemplate termination of the land withdrawal for the WIPP; and former subsection 7(b)(3) was revised to shorten the waiting period from 180 to 30 days. The other subsections noted in the comments (formerly subsections 7(b)(1) and (4), now subsections 7(b)(1) and (2)) are addressed in the current rulemaking, supported by "a performance assessment based on stated assumptions as to the nature and amount of the waste to be emplaced," as suggested by the commenter.

If necessary, a change in the proposed waste inventory for the WIPP could be accomplished in accordance with the provisions of the WIPP Compliance criteria. [Section 194.4(b), Sections 194.65-66] In issuing the WIPP Compliance criteria, EPA considered changes to the waste inventory to be a primary example of a situation that might necessitate a modification: "If an initial certification is granted, and information subsequently becomes available which differs significantly from the basis upon which the certification was issued -- including changes relevant to long-term performance, or proposed disposal of waste not described in the application -- then EPA would undertake a modification, suspension, or revocation to the certification." [Response to Comments for 40 CFR Part 194, p. 2-11] Any modification to address new or different types of waste would require DOE to demonstrate, through performance assessment, that the WIPP will meet the disposal regulations if the proposed waste were to be emplaced. Any such modification would be done by rulemaking in accordance with section 8(d)(1) because EPA would be re-opening the initial certification. EPA believes that its approach is consistent with Congressional intent, as reflected by the WIPP LWA, as amended, and with the disposal regulations and WIPP compliance criteria.

Issue DD: DOE's compliance certification application was or is incomplete.

1. The Compliance Certification Application (CCA) was incomplete when filed and remains incomplete at this time. The public has had no opportunity to comment on the complete application before EPA announced its proposed certification decision, as the Compliance criteria require. EPA erred when it found the CCA complete; the error of that decision has been amply shown by the massive amounts of material submitted by DOE since that decision. (950)

2. EPA should have required DOE to fully examine potential release scenarios and should have not deemed the compliance certification application (CCA) to be complete until such analysis was included. (1113)

Response to Comments 1.DD.1 through 1.DD.2:

The completeness determination was an interim preliminary administrative step in the certification determination process that is required by the WIPP compliance criteria. [62 FR 27996] The purpose of the completeness determination is "to screen a final compliance application received from DOE that because of incompleteness does not even warrant further EPA and public scrutiny." [Response to Comments for 40 CFR Part 194, p. 20-7] The Administrator did not make the completeness determination until well after the end of the initial comment period, after all relevant timely comments had been analyzed. EPA received numerous public comments on the October 29, 1996, CCA that identified areas of concern; many of the issues raised by the public had been identified by EPA and were addressed in a December 19, 1996, letter to DOE identifying completeness concerns. [Docket: A-93-02, Item II-I-1, Attachment 1] To address completeness concerns, EPA requested additional information on (among other topics): site conditions, rock fractures in the Salado formation, documentation for computer codes, documentation on parameter development for computer models, organic compounds in waste, brine reservoirs as related to deep drilling, and the effects of explosions -- issues all identified in public comments. Other issues raised by commenters, such as fluid injection and other human intrusion scenarios, were addressed by EPA in its technical comments to DOE. [Docket: A-93-02, Item II-I-1, Attachment 2, and Items II-I-9, II-I-17, II-I-25, II-I-27, II-I-32, and II-I-37]

The publication of the ANPR and the duration of the public comment period are entirely consistent with both the intent and explicit regulatory language of the WIPP compliance criteria. During the ANPR comment period, EPA provided, in the public docket, significant information relevant to a complete application, including: the initial October 1996 submission by DOE, written EPA comments to DOE addressing both completeness and technical adequacy, and supplementary information submitted by DOE. Based on this information, the public was able to comment during the initial 120-day comment period not only on the CCA submitted in October 1996, but on most of the supplementary material submitted by DOE in response to EPA's written requests.

These pre-proposal opportunities for public comment fulfill the intent of the compliance criteria, that the initial 120-day comment period "will allow interested parties to comment on all aspects of the application, including any aspects that commenters believe are incomplete or inadequate." [Response to Comments for 40 CFR Part 194, p. 20-7] EPA considered comments submitted during the ANPR comment period when making its completeness determination, and also accepted and incorporated public input even after the end of the comment period. Moreover, EPA offered an additional public comment period subsequent to the Administrator's completeness determination. The additional comment period enabled the public to comment on all materials relevant to the completeness determination.

The 120-day comment period on the proposed rule provided an opportunity for the public to comment again on the complete application as well as on all other information considered by EPA in making its certification decision. To clarify what constitutes the "complete" application, EPA made available a list of the specific items that comprise the complete application. [Docket: A-93-02, Item II-G-29] In its proposed rule, the Agency clarified that its certification decision is based on the entire record available to the Agency, and is not limited to a review of the complete CCA. [62 FR 58797] The record on which EPA relied includes the complete DOE CCA, supplementary information submitted by DOE in response to EPA requests for additional information for technical sufficiency, technical reports generated by EPA and EPA contractors, EPA audit and inspection reports, and public comments submitted on EPA's ANPR and proposed decision. Technical support documents (the Compliance Application Review Documents) for the proposed and final rule reference the specific relevant portion(s) of the October 29, 1996, CCA and any supplementary information that was relied on in reaching a particular proposed and final certification decision. A full list of the supporting documentation for EPA's proposed and final decisions and a full list of DOE compliance documentation considered by the Agency were placed in Docket: A-93-02, Items III-B-1 and V-B-1, respectively. Finally, all materials that informed EPA's proposed decision were placed in the dockets or were otherwise publicly available. Through these means, the Agency believes that the public has been provided a clear indication of, and an opportunity to comment on, what materials constitute the complete CCA and what materials constitute the record basis for EPA's certification decision.

Issue EE: EPA has failed to comply with the requirement of the National Environmental Policy Act, to prepare an environmental impact statement.

1. EPA has not complied with the National Environmental Policy Act, 42 USC §4221 et seq. (NEPA) in that EPA has not prepared a detailed statement of the environmental impact of the proposed action, adverse environmental effects, alternatives to the proposed action, and other matters required to be included pursuant to 42 USC §4223 and applicable regulations. The Proposed Decision fails to satisfy the NEPA requirement since it does not show the environmental consequences of the proposed action, does not fully disclose the adverse effects, and fails to examine alternatives. (1048)

2. The National Environmental Policy Act (NEPA) requires that "major federal actions significantly affecting the quality of the human environment" be based on an environmental

impact statement (EIS) 42 U.S.C. 4332. EPA has not complied with the law as it has not done an EIS for WIPP and has not adopted nor been a cooperating agency with DOE's WIPP EISs. (1127)

3. EPA should have required that DOE include in its application an EIS that supports its proposal contained in the CCA. Since it did not do so, there are numerous aspects of the CCA that are in conflict with the WIPP SEIS-II and much information is substantially different between the two documents. (1128)

4. EPA has not done its own NEPA review of alternatives to WIPP disposal and EPA has not tiered its decision on any DOE NEPA review. . . EPA cannot eliminate its obligation to do a NEPA review by calling its certification a permitting process. Licensing and permitting are legally similar terms. . . EPA's review both in substance and process resembles a Nuclear Regulatory Commission licensing procedure for nuclear power plants. (1218)

Response to Comments 1.EE.1 through 1.EE.4:

EPA's WIPP certification rulemaking does not violate the requirements of NEPA. [National Environmental Policy Act of 1969, as amended, Pub. L. 91-190, as amended by Pub. L. 94-52, Pub. L. 94-83, and Pub. L. 97-258, § 4(b)] First, it goes beyond Congressional intent in the WIPP LWA and beyond the scope of this rulemaking for EPA to require the submission or review of DOE's environmental impact statement. Second, EPA already examined and addressed the potential risks to human health and the environment in the disposal regulations by limiting releases to the accessible environment and also restricting individual radiation doses and groundwater concentrations in the vicinity of the WIPP. It is not necessary for EPA to develop an environmental impact statement under NEPA for its WIPP certification decision.

Issue FF: EPA should require DOE to acquire oil and gas leases in the vicinity of the WIPP.

1. SRIC strongly disagrees with EPA's proposed decision to not require the Secretary of Energy to acquire the oil and gas leases (at 58836). Drilling on those leases poses a threat to the integrity of the repository and compliance with the disposal regulations because of activities that could be undertaken related to those leases. (1170)

Response to Comment 1.FF.1:

The commenter questions EPA's decision on the Federal and Oil Gas Leases (Nos. NMNM 02953, 02953C) based on drilling activities. In its analyses for the PA, DOE concluded that the drilling of a deep well would adversely affect the disposal system if the borehole intersected a waste panel in the underground portion of the WIPP. [Docket: A-93-02, II-G-1, CCA, Section 6.3.2.2] Drilling is of concern if the borehole penetrates the waste, and forces it to the surface, or allows a pathway for long-term transport of radionuclides. EPA finds that the effects of drilling a borehole -- and similarly, the effects of resource recovery (oil or gas production) -- would be highly localized, for several reasons.

Current oil and gas production drilling in the area near the WIPP site include well casing procedures and borehole plugging practices that would mitigate the potential impact of future drilling activities. Wells drilled in the Delaware Basin (which encompasses the entire Land Withdrawal Area) include at least two sets of steel casing lining the borehole (deeper wells use three sets of steel casing). Also, production and injection wells contain an additional set of tubing used to produce the oil or gas, or to inject fluid into the well. Present day practice would require multiple failures in these steel casings and tubings to cause any flow from the oil- or gas-producing zone towards the disposal system.

Borehole plugging practices near the WIPP site also employ multiple levels of protection that mitigate the potential impact of oil and gas operations in the immediate area. The State of New Mexico regulates borehole plugging practices with a robust series of requirements that control the flow of fluid in the subsurface. [New Mexico Oil Conservation Division, Order R-III-P] The use of these measures reduces the chance of any fluid flow toward or into the repository using current methods and technology.

The fluid injection scenario (i.e., causing the movement of fluid under pressure) was modeled by DOE using conservative geologic assumptions about the ability of the Salado geologic formation to transmit fluid. This conservative modeling demonstrated that fluid injection would have little impact on the results of PA. Based on this modeling and other information submitted by DOE on the frequency of fluid injection well failures, EPA found that DOE's screening was sufficient and realistic. As part of its analysis for its proposed decision, the Agency performed additional modeling of the injection well scenario. [EPA Technical Support Document for 194.32: Fluid Injection Analysis, Docket: A-93-02, Item V-B-22] EPA concluded that, although scenarios can be constructed that move fluid to the repository via injection, the probability of such an occurrence is less than one in 10,000. Therefore, fluid injection could be excluded from PA on the basis of low probability, as well as low consequence.

EPA's review of DOE's modeling studies and analyses of well construction and operating practices found that DOE's modeling is consistent with the characteristics identified independently by EPA for the region in the southwest part of the Land Withdrawal Area (the location of the 4(b)5(B) leases). [Docket: A-93-02, Item V-B-27] EPA concludes that potential activities at the section 4(b)(5)(B) leases have been considered and do not cause the WIPP to violate the disposal regulations. [Docket: A-93-02, Item V-B-27] Therefore, EPA finds that it is not necessary for the Secretary of Energy to acquire the Federal Oil and Gas Leases No. NMNM 02953 and No. NMNM 02953C.

Section 2 Conditions -- Appendix A, § 194.8

Comment Issue Page #

Issue A: EPA should accept DOE's Compliance Certification Application with whatever conditions are warranted by technical and regulatory issues.

1. The best way to meet her challenge is to move ahead to be the first nation to dispose of this legacy of the Cold War in the way recommended by the international scientific community: To accept, with whatever conditions are warranted by the technical and regulatory issues you identify, the Application of the DOE for Certification of the Waste Isolation Pilot Plant, and to set aside the political assertions of those whose purpose is simply to continue to delay the "doing" that is truly an American signature. (444)

Response to Comment 2.A.1:

Congress mandated the development of the WIPP as a disposal facility for transuranic radioactive waste. In 1980, Congress authorized DOE to proceed with construction of the WIPP:

> The Secretary of Energy shall proceed with the Waste Isolation Pilot Plant construction project authorized to be carried out in the Delaware Basin of southeast New Mexico (project 77-13-f) in accordance with the authorization for such project as modified by this section. Notwithstanding any other provision of law, the Waste Isolation Pilot Plant is authorized as a defense activity of the Department of Energy, administered by the Assistant Secretary of Energy for Defense Programs, for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes

> resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission.
>
> [Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Pub. L. No. 96-164, section 213(a)]

In 1992, Congress legislatively withdrew a tract of land surrounding the WIPP site from the public domain and reserved such lands for DOE's use specifically for WIPP activities:

> Such lands are reserved for the use of the Secretary [of DOE] for the construction, experimentation, operation, repair and maintenance, disposal, shutdown, monitoring, decommissioning, and other authorized activities associated with the purposes of WIPP as set forth in section 213 of the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 and [the WIPP LWA].
>
> [WIPP Land Withdrawal Act, Pub. L. No. 102-579, as amended by Pub. L. No. 104-201, § 3 (citation omitted)]

Congress determined, however, that, rather than designate the WIPP as the repository for transuranic waste by legislative fiat, it was appropriate to delegate to EPA the regulatory authority for determining whether the WIPP can be expected to safely contain such wastes. [WIPP LWA, Sections 8 and 9] EPA's responsibility in the present rulemaking is to determine whether the WIPP facility will comply with EPA's radioactive waste disposal regulations at 40 CFR Part 191. This determination is based upon EPA's evaluation of DOE's compliance certification application in accordance with the WIPP compliance criteria, promulgated at 40 CFR Part 194. The compliance criteria expressly provide that any certification of compliance issued pursuant to Section 8(d) of the WIPP LWA "may include such conditions as [EPA] finds necessary to support such certification." [40 CFR 194.4(a)]

Issue B: EPA should revise Condition 1 to allow DOE to take advantage of future improvements in materials or construction techniques.

1. Condition 1 of EPA's proposed rule for WIPP requires that DOE implement the panel seal design designated as Option D. The proposed rule also requires that DOE use Salado mass concrete (SMC) rather than fresh water concrete to construct panel seals. The Department agrees that the Option D design is appropriate for the first panel closures that will be installed at WIPP. However, there may be improvements in materials or construction techniques in the future that DOE should be allowed to take advantage of. DOE asks that EPA revise this condition so that DOE may, if the Department determines it is appropriate, reassess the engineering of panel closures when panels are to be closed in the future. This would allow the Department to explore opportunities to improve the panel closure system if and when such opportunities appear, and to request modification of the system in subsequent re-certification rulemakings. (945)

Response to Comment 2.B.1:

Condition One requires DOE to implement the panel seal design that it designated as Option D in the CCA. [Docket No. A-93-02, Item II-G-1, and 62 FR 58837] The Option D design must be implemented as described in Appendix PCS of Docket item II-G-1, except that DOE is required to use Salado mass concrete rather than fresh water concrete. [*Ibid.*] Nothing in this condition precludes DOE from reassessing the engineering of the panel seals at any time. Should DOE determine at any time that improvements in materials or construction techniques warrant modification of the panel seal design, DOE may so inform EPA. In accordance with 40 CFR 194.65, if the Administrator determines that modification of the panel seal design represents a "significant" departure from the CCA on which the certification was based, then EPA may initiate a rulemaking to appropriately modify the certification.

Issue C: The WIPP Land Withdrawal Act does not give EPA regulatory authority over waste generator sites.

1. I cannot find a passage in the Land Withdrawal Act that gives the EPA authority over the 21 sites to generate transuranic radioactive waste. Perhaps EPA cannot find it, either, otherwise you would have credited Congress rather than an obscure provision in your own regulation as a source of your authority over waste streams and waste sites.

The DOE has adequately regulated itself in this area, and Congress has never indicated that EPA could do a better job. I, therefore, recommend that you not create any more certification hurdles that would protract the disposal of transuranic radioactive waste. (167)

2. I'm concerned that EPA in its October 30, 1997 proposed rule has suddenly added a new role for itself as an adjunct to 40 CFR 194. This addition is a new process for the active involvement in waste generator site certification. (222)

3. Waste generator site certification by the Department of Energy -- with EPA as an observer, but not a certifying authority -- has been a basic tenet of DOE's operational plan for WIPP. In the proposed rule, EPA has defined a new process for its active involvement in waste generator site certification. This proposed extension of EPA's regulatory reach to transuranic waste generator sites is totally outside the scope of Congress' intent in the WIPP Land Withdrawal Act Amendments and exceeds the authorities defined for EPA with respect to the WIPP. The waste generator site certification requirements have no place in EPA's rule when it is published in its final form and should be excluded from any rulemaking. (1317)

Response to Comments 2.C.1 through 2.C.3:

The WIPP Land Withdrawal Act, Pub. L. No. 102-579, as amended by Pub. L. No. 104-201, (WIPP LWA) imposes a number of obligations upon EPA including, *inter alia*, developing, through informal rulemaking pursuant to Section 4 of the Administrative Procedure Act (APA), criteria by which to certify whether the WIPP will comply with EPA's radioactive waste disposal regulations at 40 CFR Part 191 [Section 8(c)], and utilizing such criteria to certify, through informal rulemaking pursuant to Section 4 of the APA, whether the WIPP will comply with such regulations. [Section 8(d)(2)] These provisions of the WIPP LWA constitute a broad Congressional mandate to EPA to develop the methodology by which to determine whether the WIPP will comply with the radioactive waste disposal regulations, and then to make that determination.

EPA included provisions for waste characterization in the compliance criteria because, in order to demonstrate compliance with the containment requirements of 40 CFR Part 191, it is essential to evaluate how actual waste characteristics will impact the containment of radionuclides for the long-term performance of the repository. In addition, the WIPP LWA establishes specific limits on waste which may be emplaced in the WIPP, and waste characterization activities must be undertaken to demonstrate that the wastes emplaced in the WIPP will conform to these limits. Therefore, the compliance criteria require that DOE demonstrate the application of appropriate quality assurance procedures to all aspects of waste characterization. 40 CFRs 194.22(a)(2)(i), 194.24(c)(3), and 194.24(c)(5) (addressing, respectively, all waste characterization activities and assumptions; use of process knowledge; and the system of controls developed to confirm that the total amount of waste emplaced in the repository will not exceed the requisite limiting values). As EPA explained in responding to comments on the proposed compliance criteria, EPA requires application of the requisite quality assurance program to waste characterization activities "to assure an appropriate level of rigor," and to substantiate that the quality of the waste characterization data "meets or exceeds that required by the intended use of the data to confirm the waste conditions assumed in the demonstration of compliance." [Response to Comments Document for 40 CFR Part 194, at pp. 6-5, 6-6, Docket: A-92-56, Item V-C-1]

The implication that EPA does not have authority to verify the establishment and execution of quality assurance programs related to waste characterization activities and assumptions at the various DOE waste generator sites is incorrect. As required by the WIPP LWA, EPA promulgated the compliance criteria pursuant to Section 4 of the APA after substantial public participation.[4] As a matter of administrative law, EPA is under the same obligations to follow and implement the provisions of its own regulations as it is to follow and implement the provisions of governing statutes, unless those regulations are contrary to, or inconsistent with, such statutes. There is nothing in the comments that indicate that the compliance criteria are contrary to, or inconsistent with, the WIPP LWA. Accordingly, EPA would be without its legal authority were it to attempt to certify that DOE had demonstrated complete compliance with 40 CFR 194.22(a)(2)(i), 194.24(c)(3), 194.24(c)(4), and 194.24(c)(5).

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5 In promulgating the compliance criteria, EPA (1) published an advance notice of proposed rulemaking (ANPR) soliciting public comment on 7 major issues identified by the Agency as central to their development, and requesting assistance on identification of additional issues that should be addressed [58 FR 8029 (February 11, 1993)]; (2) solicited public comment on a preliminary draft proposed rule in January 1994; (3) proposed the compliance criteria with a 90-day comment period [60 FR 5766 (January 30, 1995)]; (4) conducted three technical workshops to receive input from both the public and scientific experts on certain technical issues [60 FR 43470 (August 21, 1995)]; and (5) in response to requests by the public, reopened the comment period for an additional 45 days. [60 FR 39131 (August 1, 1995)]

Issue D: Condition 2 and 3 should be stricken or revised. The conditions are duplicative, redundant, will delay the certification process, increase costs, and add nothing to public health and safety, or the protection of the environment.

1. Concerning the proposed rule, I would like to request the EPA reconsider Conditions Nos. 2 and 3 of its proposed certification decision for the WIPP. These conditions address certifying the waste characterization process for waste generator sites. (197)

2. None of the four conditions add anything to public health and safety or protection of the environment. All for increase costs to the American taxpayer with no value added. DOE has five years to provide additional analysis for conditions one and four. Therefore, DOE believes inclusion of these two conditions in the final rule is acceptable. (219)

3. At DOE Carlsbad Area Office waste and site certification requirements and processes are very thorough. . . EPA conducting a separate and lengthy process to achieve the same end adds no real value. It will be very expensive. The language in the proposed rule addressing the separate EPA process for certification of waste streams, Condition 3, should be stricken. (215)

4. I'm concerned about the impact on the program of condition two of the proposed rule. I do not see convincing evidence of the need for EPA to inject itself in the middle of the generator site certification process. Condition two places EPA on a critical path at every generator site. The program, with the process defined by condition two, will slow down the certification process and lengthen the time required to achieve relocation of transuranic waste to the repository where safety is enhanced. (340)

5. Condition 3, is one of those things that's going to add to the cost of the project without adding any value to the project; and that is, the condition that requires a 30-day public comment period after the audits of the site, and when we're getting ready to certify the assignment to ship waste or added waste streams. (171)

6. EPA should allow the DOE to certify sites for the characterization of waste for shipment to the WIPP. . . EPA should stick to its oversight and monitoring role, and not become involved in TRU waste operations by certifying individual sites. It is a needless duplication of effort and will slow down the process. (649)

7. I strongly urge the EPA to remove unnecessary, redundant requirements and issue final compliance certification for the WIPP. One possible example of redundancy in requirements might be Conditions Number 2 and Number 3 of the EPA's proposed decision to certify the WIPP. The DOE's processes and requirements for certifying each waste generating site are quite stringent. Adding additional oversight, rule making and public comment periods to this ultra-conservative process will do nothing to improve the protection of human health and the environment. (163) (727)

8. It is strongly urged that any unnecessary redundant requirements are removed and EPA issue the final certification for the WIPP as soon as possible. (161)

9. We are concerned, however, with several of the conditions established in the proposed rulemaking concerning EPA's certification of DOE site quality and waste characterization programs. This proposed certification is redundant to establish processes and does not appear to add additional safety for environmental protection value but potentially delays the ability of the site to initiate waste shipments to WIPP and will increase costs. (362)

10. I would like to request that the EPA reconsider conditions No. 2 and No. 3 in this proposed certification decision for the WIPP. These conditions address certifying the waste characterization process for generator/storage sites. The conditions are redundant, time consuming and costly and add no additional assurance in protecting human health and the environment. (594)

11. There are sound reasons why these two conditions are unnecessary. First, they are duplicative. The EPA has reviewed the site certification audit program as it was fully described in the CCA. You've also observed the CAO implementation of this program and had the authority to do so at any time in the future. This level of involvement by the EPA at the generator facilities is both adequate and appropriate. You go to the next level as proposed in the rule, is clearly a duplication of effort that will result in substantial increased cost to the taxpayer with no added environmental safety or health benefit. Second, the EPA proposal to engage in additional formal public involvement processes for future waste certification decisions goes beyond prudent public involvement. There is no substantial new information that could come to life in public hearings that would allow EPA to make better informed technical decisions. This will merely lengthen processes and delay meaningful risk reduction for many Americans. (506)

12. As a concerned citizen and nuclear QA professional, I really don't see any value to the DOE certification process or any additional protection to the public by delaying the shipments from the TRU waste sites over and over again as EPA reapproves our Quality Assurance program over and over again. (278)

13. Of greater concern to us, however, is the value of EPA's role in quality assurance at the generator sites. DOE already has QA programs in place. We fear that the QA proposal by EPA is redundant, bureaucratic, and costly, yet without reducing risks. A possible compromise is a joint audit. . . Joint audits would make the process more efficient and less time consuming. Otherwise, we recommend that this part of the proposed rule be eliminated. (935)

14. DOE suggests that Conditions 2 and 3 be replaced with the following new Condition 2:

> Each waste generator site must be approved according to the requirements established in DOE's compliance certification application before it may ship waste to WIPP; these requirements include, but are not limited to, those set forth in the Quality Assurance Program Document (QAPD), the TRU Waste Characterization Quality Assurance Program Plan (QAPP), and the Waste Acceptance Criteria (WAC). In the context of EPA's certification of WIPP, the purpose of these requirements is to ensure that the inventory emplaced in the repository complies with the limits on waste components established in the compliance certification application pursuant to § 194.24(c). These

limits are set forth in Appendix WCL (Waste Component Limits) of DOE's compliance certification application. Pursuant to the authority granted to the Agency in sections 194.4(b), 194.21, and 194.22(e), EPA shall have the right to request information about and to participate in all aspects of the approval of waste generator sites to ship waste to WIPP that are relevant to EPA's certification of the repository; to inspect all activities at waste generator sites, WIPP, or elsewhere that are relevant to EPA's certification of the repository, including those relevant to the approval of waste generator sites; to verify appropriate execution of quality assurance programs relevant to EPA's certification of the repository, including those relevant to the approval of waste generator sites; and to suspend, modify or revoke the certification of WIPP if DOE fails to comply with the requirements established in the compliance certification application for approval of waste generator sites. (948)

Response to Comments 2.D.1 through 2.D.14:

The WIPP LWA requires EPA to, *inter alia*, develop, through informal rulemaking pursuant to Section 4 of the APA, criteria by which to certify whether the WIPP will comply with EPA's radioactive waste disposal regulations at 40 CFR Part 191 [Section 8(c)], and utilize such criteria to certify, through APA Section 4 informal rulemaking, whether the WIPP will comply with such regulations. [Section 8(d)(2)] Thus, EPA has a legal obligation to utilize the compliance criteria in its determination of whether the WIPP will comply with the 40 CFR Part 191 disposal regulations. EPA has no legal authority to ignore or disregard the explicit requirements of the compliance criteria in making its certification determination. The quality assurance and waste characterization conditions imposed upon EPA's certification that the WIPP will comply with the Part 191 regulations reflect the fact that DOE did not fully demonstrate compliance with Sections 194.22(a)(2)(i), 194.24(c)(3), 194.24(c)(4), and 194.24(c)(5) of the compliance criteria.

In making its certification decision, EPA cannot address such issues as: impact on DOE's schedule for placing transuranic wastes in the WIPP; whether EPA's evaluation of compliance is perceived as a redundant duplication of efforts; and increases in costs of compliance. EPA is legally required to determine whether DOE has met the requirements of the compliance criteria. As set forth in the rule, EPA has determined that DOE has only met the specific quality assurance requirements at issue and has met the waste characterization requirements for the process used to characterize legacy debris waste at Los Alamos National Laboratory (LANL). Further, the Agency believes that an approval process separate from DOE's internal procedures is neither redundant, nor should it be considered as a duplicative effort because DOE's process is not geared solely at confirming that programs adhere to EPA's compliance criteria, and because DOE's process does not provide for public participation.

Issue E: Provisions related to site certification in Sections 194.22(a)(2)(i) and 194.24(c)(3)-(4) do not require EPA to create a redundant separate process for authorizing sites to ship waste to WIPP.

1. The provisions relating to site certification are sections 194.22(a)(2) and 194.24(c)(3)-(4). Properly interpreted, these provisions do not require EPA to create a separate and redundant

process for authorizing sites to ship waste to WIPP. Rather, these provisions (along with other sections of Part 194) indicate that EPA's proper role is to audit and inspect DOE's site certification process to ensure that the Department properly implements it and that each site complies with the terms and requirements of its certification. (946)

Response to Comment 2.E.1:

Under 40 CFR 194.22 (a)(2)(i), DOE is required to demonstrate that a quality assurance program in accordance with NQA standards, has been "established and executed" for waste characterization activities and assumptions. Also, under Section 194.24 (c)(3-5), DOE is required to provide information that demonstrate the following: (1) that use of process knowledge to quantify waste components meets the requirements of Section 194.22(a)(2)(i); (2) that a system of controls has been and will continue to be implemented to confirm that the total amounts of waste components to be emplaced at WIPP will not exceed the established limits under Section 194.24(c); and (3) that such system of controls meets the quality assurance requirements of Section 194.22(a)(2)(i).

EPA finds that it is both necessary and within the Agency's authority to evaluate and approve site-specific QA and waste characterization programs. The compliance criteria expressly provide that any certification of compliance "may include such conditions as [EPA] finds necessary to support such certification." [Section 194.4(a)] Before waste is shipped for disposal at the WIPP, EPA must be confident that the waste will conform to the waste limits and other waste-related assumptions incorporated in the performance assessment -- that is, that the information and assumptions on which a certification of compliance is based will be adhered to in practice. Such confidence can be assured only by confirmation that the required QA and waste characterization programs are in place (i.e., established and implemented/executed) at waste generator sites. EPA believes that an approval process separate from DOE's internal procedures is beneficial because DOE's process is not geared solely at confirming that programs adhere to EPA's compliance criteria, and because DOE's process does not provide for public participation. EPA disagrees with the commenter and believes that EPA's site approval process is not redundant and has different regulatory objectives from DOE's certification process. EPA's main objective is to assess compliance with the applicable certification criteria. Waste generator sites produce relevant information on waste components that is critical to the performance of the WIPP disposal facility. The predictions made by the performance assessments, which are the basis for compliance with the radioactive disposal standards, set up limits on waste components that are fixed throughout the duration of this certification decision. Waste characterization activities will generate critical information on the amount of waste components comprising the various waste streams to be emplaced at WIPP. Evaluation of waste characterization quality assurance activities, waste analysis procedures, waste characterization instrumentation and techniques, etc., are of paramount importance in determining whether DOE has the ability to adhere to the identified waste component limits. Consequently, prior to approving shipment of TRU wastes from a waste generator site for emplacement at WIPP, EPA will assess whether DOE has demonstrated compliance with the requirements of Sections 194.22(a)(2)(i) and 194.24(c)(3)-(5). DOE's certification process, on the other hand, is part of DOE's internal activities, offers no access to the public in regard to information gathered during such activities, and includes a number of evaluations which are not relevant to EPA regulatory objectives (e.g., transportation requirements, etc). Therefore, the focus of DOE's certification process may not be appropriate to meet EPA's regulatory objectives.

Issue F: The public participation requirements of Conditions 2 and 3 are unnecessary and counterproductive or clearly insufficient.

1. The proposed rule's call for more public involvement is counterproductive. We are convinced that EPA must help by expediting the placement of TRU wastes in a repository, not by delaying the reduction of the risks that we face. We recommend that this part of the public interactions in this proposed rule are unnecessary and should be removed. However, we welcome public updates of subsequent results that indicate the value of certification (i.e., whether DOE's and EPA's QA programs actually reduced risks, or whether they simply escalate costs, etc.). (934)

2. We are concerned that the proposed new rules do not allow sufficient time for the approval of characterization procedures at other sites to receive adequate public scrutiny. . . If complex issues such as use of process knowledge and effectiveness of characterization of waste components are to be resolved in a public process, 30 days is clearly insufficient to do so, . . . Concerning the audit or inspection, such processes should be open to public participation and conducted on notice well before the comment period. Alternatively, and second best, records of the audit (or inspection) should be available in the docket before the public comment period begins. A full 120 days for comment should be allowed. It should also be made clear in the rule that certification only remains effective so long as the site and waste stream procedures on which certification is predicated continue in effect. EPA should note also that each waste stream certification is subject to judicial review. (1047)

3. Regarding proposed condition 2, SRIC supports requiring a site to comply with the quality assurance requirements of 194.22(a)(2)(i) and 194.24(c)(3) and (5) and for public comment prior to such an EPA determination. However, SRIC does not agree that 30 days is the appropriate public comment period. SRIC supports a comment period of at least 120 days, as a 30-day period is not sufficient, especially since the 30-day comment periods specified in conditions 2 and 3 are likely to be concurrent rather than at different times. Also, EPA's decision should be subject to judicial review, as the approval of LANL debris waste would be. (1167)

4. Regarding proposed condition 3, SRIC agrees that each site and each waste stream must be separately approved by EPA, following public notice and comment. SRIC does not agree that 30 days is an adequate time for public comment. Instead, SRIC would support a public comment period of at least 120 days, so that there would be time for public participation in the actual audit or inspection and opportunity to comment after such an audit is completed. Moreover, the EPA decision should be subject to judicial review, as is the LANL debris waste decision. (1168)

Response to Comments 2.F.1 through 2.F.4:

EPA rejects any suggestion that the process for approval of shipment of wastes should be conducted without public participation. EPA does not believe, however, that the 30-day comment period provided in proposed Conditions 2 and 3 is insufficient. Considered in relation to the 120-day comment period allowed on the entire certification decision, EPA considers a 30-day comment period on these specific and focused quality assurance and waste characterization determinations to be sufficient.

EPA is not in a position to state that the audits or inspections themselves will be open to public participation. These approval processes will be conducted on DOE property and will be subject to the security procedures and access limitations imposed by DOE. In the past, the New Mexico Environmental Evaluation Group (EEG), an independent technical oversight group authorized by Congress, has attended waste generator site inspections.

EPA declines to modify the proposed approval process by delaying the comment period until after the issuance of an audit report. EPA does not believe it is prudent to commit to a strict sequence of events that will be adhered to for every approval. In some cases, the Agency may place records of a completed audit or inspection in the docket prior to or during the public comment period. However, in other cases, the Agency believes that the public comment period may better serve the public if it allows them to provide comments on DOE's documentation prior to an audit or inspection. In this way, public comments could inform EPA's inspection criteria and process, or provide information on which EPA may take action to follow up on the audit or inspection. Therefore, the Agency does not believe that it is prudent to specify when the comment period may occur in relation to an audit. Furthermore, EPA declines to make any statement regarding whether the approval decisions are subject to judicial review. Jurisdiction of U.S. Federal Courts is governed by the enactments of the U.S. Congress.

Nevertheless, in response to comments requesting changes or clarifications to EPA's waste generator site and waste stream approval processes, EPA made necessary changes to the proposed conditions. In order to clarify EPA's original intent in the compliance criteria regarding approving site-specific activities, EPA is amending the body of 40 CFR Part 194 to include the site-specific approval process. [62 FR 58804, 58815] Thus, the procedures for demonstrating compliance with the proposed Conditions 2 and 3 are incorporated in the final rule as a new section at 40 CFR Part 194: Section 194.8, "Approval Process for Waste Shipment from Waste Generator Sites for Disposal at the WIPP." Also, in response to comments advocating greater transparency in the approval process, EPA has clarified that scheduled audits or inspections for the purpose of approving quality assurance programs at waste generator sites will be announced by notice in the Federal Register [§ 194.8(a)]; this is consistent with EPA's commitment to do so for audits and inspections of waste characterization programs at generator sites. [Section 194.8(b)] Providing notice of such inspections will alert the public to upcoming EPA approval activities and allow for more informed public participation. In no case will EPA make a decision on approval of site-specific quality assurance or waste characterization programs before providing a minimum 30-day public comment period on documentation of the program plans, or before conducting an audit or inspection at the relevant site. [Preamble Section VI. B, "Significant Changes to the Final Rule in Response to Comments"]

EPA must also clarify the commenter's misperception that each waste stream must be separately approved by EPA. In the process set forth in Conditions 2 and 3, EPA will be making determinations as to whether DOE has demonstrated that the requirements of Sections 194.22(a)(2)(i) and 194.24(c)(3)(5), concerning quality assurance and waste characterization, respectively, have been met for all transuranic waste to be shipped to the WIPP. With respect to waste characterization, EPA will be determining whether DOE has (1) provided adequate information on the process knowledge to be used, (2) demonstrated application of quality assurance processes to the utilization of such process knowledge, (3) implemented a system of controls to confirm on an ongoing basis the amount of each waste component to be emplaced in the repository, and (4) demonstrated application of quality assurance processes to such system of controls. Thus, to the extent that these waste characterization procedures are applicable to multiple waste streams, EPA will not be conducting separate waste stream-specific approvals.

Issue G: EPA's decision on PICs documentation must have a 120-day comment period and be subject to judicial review.

1. Regarding proposed Condition 4, SRIC believes that the PIC documentation must not only be placed in the public dockets, but it must notice the submission for 120 days of public comment regarding whether a modification is necessary. The EPA decision should be subject to judicial review. (1169)

Response to Comment 2.G.1:

Condition 4 states that EPA will conduct any necessary certification modification procedure in accordance with the provisions of 40 CFR 194.65 and 194.66. These provisions do not provide for any specified duration of the comment period. EPA will make a determination as to the appropriate length of the comment period at the time that it determines it necessary to conduct a modification rulemaking.

Issue H: EPA should include additional conditions on the certification.

1. It is unclear how you can assure the public that this facility is safe, indefinitely, when it has never been tested. If certification is granted, it should be a temporary, conditional certification which includes:

- All data collected on WIPP be public and unclassified;
- Recertification required with public hearings after 5, 10, 20, 50 and 100 years; and
- All waste be easily removable for 100 years and easily located for 1,000 years. (1197)

Response to Comment 2.H.1:

The suggested conditions are already addressed by the WIPP LWA, disposal regulations, WIPP compliance criteria, and terms of the certification. For example, EPA has committed to maintain public dockets which will contain all significant information submitted to EPA and relevant to EPA's initial certification decision, re-certifications, or potential modification, suspension, or revocation of a certification. [Section 194.67] These dockets, located in Washington, DC and in Carlsbad, Santa Fe, and Albuquerque, New Mexico, have the express purpose of making information related to the WIPP -- including data collected on its performance -- available to the public.

EPA is required to conduct a recertification every five years until the end of the decommissioning phase (not simply at 5, 10, 20, 50 or 100 years after opening) to determine whether the WIPP continues to be in compliance with the disposal regulations. [WIPP LWA, Section 8(f)] Under the terms of the WIPP LWA, such a recertification shall not be conducted by rulemaking and are not subject to judicial review. Despite this, in the WIPP compliance criteria, EPA chose to bind itself to a number of public participation measures related to a recertification. These measures include docketing information, publishing a Federal Register notice, and providing a public comment period, at a minimum. The Agency does not believe it is necessary or prudent to bind itself to hold public hearings on recertification decisions since the efficacy of such hearings it is not clear at this time; however, the Agency is certainly not precluded from doing so, and could consider any requests to do so at the time of a recertification. For further discussion of EPA's public participation measures, see the Response to Comments, Section 1 for general issues. [Docket: A-93-02, Item V-C-1]

Finally, EPA's assurance requirements address the desire for future societies to be able to locate and possibly retrieve waste in the disposal system. Section 194.46 of the compliance criteria implements the assurance requirement regarding removal of waste, Section 191.14(f). Consistent with the approach advocated by the commenter, the removal of waste assurance requirement is intended to encourage disposal in which "the physical location of most the wastes [is] reasonably predictable after disposal," rather than disposal methods such as deep injection of wastes, in which waste might move considerable distances. [47 FR 58201, 50 FR 38072] DOE has demonstrated that it will be feasible to remove waste, using currently-available technology, for at least 100 years after the disposal system is sealed. Refer to CARD 46 and the Response to Comments, Section 15 for further information. [Docket: A-93-02, Item, V-C-1]

EPA believes that the WIPP compliance criteria at 40 CFR Part 194 address the issues raised by the commenter, and that it is not necessary to add additional conditions to the certification.

Section 3 Content of the CCA -- § 194.14

Issue A: WIPP site geology has been incorrectly assessed.

1. DOE still has a poor understanding of the geology of the site. In their arrogance, they haven't bothered to do the testing and exploration necessary to truly characterize the site. Instead they relied on more assumptions about the site, the waste and the interactions between the repository and the waste and you let them do this too. When information that clearly threatens the acceptance of the repository like the Hartman scenarios brought to your attention, you manipulate technicalities so this can be ignored. The site is obviously flawed, water seeping in flowing down shafts. There are fractures, probable karst, huge brine reservoirs, massive resource extraction all around it. (417)

2. I want to see complete geological information about the WIPP site, using unbiased scientists. The site has been incorrectly assessed especially regarding fractures and dissolution conduits. (522)

3. The EPA regulations for storing radioactive waste at WIPP seem, as written, to assume that what is dry land now will remain that way. . . Neither the United States Congress, the DOE, nor the EPA can predict geological conditions at the WIPP site 244,000 years (or even 10,000 years) from now. . . [A]reas with known ground water today ought not even be considered as suitable for radioactive waste storage. The very existence of salt deposits is testimony to earlier existence of marine waters, the evaporation of which left solid salts behind. Oceans covered and receded from that geographical area several times during the earth's geological history. . . We may not even have to wait many thousands of years before the WIPP site is once again submerged.

4. We are going to try to use a site that floods, experiences earthquakes, has poor transportation routes and ad nauseam. . . Any thinking individual would close down this effort to use the Carlsbad site. (891)

5. They have not done the geological investigation of the site that they should. There are many questions and unknowns at the site still, after 20 years. (897)

6. The WIPP site, and the CCA, are different in several respects from geological disposal projects and assessment documentation in other countries: The WIPP site is located in an area where mineral resources are being actively and extensively exploited (at 30). (1064)

7. The EEG agrees with the EPA's conclusion that deep dissolution of the Salado Formation salt is not likely to be a threat to the WIPP repository. (1223)

Response to Comments 3.A.1 through 3.A.7:

(Comments 3.A.1, 3.A.2, and 3.A.4) Section 194.14(a)(2) of the Compliance criteria require DOE to describe the geology, geophysics, hydrogeology, hydrology, and geochemistry of the disposal system and its vicinity. EPA has determined that DOE has satisfied this requirement. Thus, EPA concludes that DOE has adequately assessed the site characteristics for the purposes of performance assessment and use in comparison with EPA's radioactive waste disposal standards. This information was provided in CCA Chapter 2, Chapter 6, Appendices GCR, MASS, HYDRO, DEF and others. EPA reviewed this information and the results of EPA's review is provided in CARDs 14, 23, 32 and 33 as well as the preamble to EPA's proposed rule. [62 FR 58798] A summary of DOE's geologic and hydrogeologic characterization is provided below.

DOE provided adequate information regarding the geologic history of the area around the WIPP site in Chapter 2 of the CCA, Section 2.1.2 [Docket: A-93-02, II-G-1, pp. 2-11 to 2-12], Appendix GCR, Section 3.6 [pp. 3-83 to 3-108], Section 4.5 [pp. 4-79 to 4-88], and HYDRO. [pp. 10-22] DOE summarized the major geologic events that have occurred over time in a 200 mile radius (320 kilometer) surrounding the WIPP site. DOE indicated that the WIPP is located in the Delaware Basin of New Mexico and Texas. The Delaware Basin contains thick sedimentary deposits (15,000 - 20,000 feet) that overlay 1.1-1.5 billion year old metamorphic and igneous basement rock. Since the Permian age (~200-250 million year old) Salado was deposited, minimal structural deformation has occurred in the Delaware Basin. Reflecting the limited tectonic activity in the Delaware Basin, the sedimentary rocks of the Delaware Basin are nearly horizontal with a slight west to east dip of about 1 degree.

DOE provided adequate information regarding the stratigraphy and lithology of the rock units surrounding the WIPP in Chapter 2.1.3 [pp. 2-12 to 2-64], as well as in Appendices GCR [Section 4, pp. 4-1 to 4-94], FAC, HYDRO [pp. 10-21], and other supporting references, including Appendix SUM, Sections 1.3 [pp. 6-10] and 6.3.5. [pp. 6-28 to 6-37]

DOE indicated that the most significant non-tectonic features in the vicinity of the WIPP site are related to Castile structures (i.e., disturbed zones) and evaporite dissolution. These processes are described in detail in Chapter 2, Sections 2.1.3.3 [p. 2-24] and 2.1.6 [pp. 2-80 to 2-93] and Appendices DEF.2 - DEF.3. [pp. DEF-1 to DEF-33] DOE indicated that the major geomorphic process in the vicinity is dissolution. To the west, the slight dip in the beds has exposed the Salado to dissolution processes; however, DOE estimated that the dissolution front will not reach the WIPP site for hundreds of thousands of years. Near-surface dissolution of evaporitic rocks (e.g., gypsum) have created karst topography west of the WIPP site, but DOE contended that karst processes do not appear to have affected the rocks within the WIPP site itself. DOE indicated that while deep dissolution has occurred in the Delaware Basin, the process of deep dissolution would not occur at such a rate at the WIPP that it would impact the waste containment capabilities of the WIPP during the regulatory time period.

DOE provided adequate information regarding the tectonic setting and site structural features in Chapter 2.1.5 [pp. 2-68 to 2-80] and Appendix GCR, Section 4.4. [pp. 4-53 to 4-79] DOE concluded that the WIPP site is located in an area with no evidence of significant tectonic activity and a low level of regional stress. DOE indicated that evidence exists which demonstrates that the WIPP area has been tectonically stable since the Permian period. DOE provided information regarding the seismic history of the WIPP site within Chapter 2.6 [pp. 2-180 to 2-205] and indicated that the current WIPP location was selected because of the absence of tectonic activity, faulting, and igneous activity. The seismic information included a description of earthquake activity and predictions of ground motions that may affect the stability of the WIPP repository.

DOE provided adequate information regarding the geomorphology and topography of the WIPP site in Chapter 2.1.4 [pp. 2-64 to 2-68] and provided information regarding the soil characteristics in the vicinity of the WIPP in Chapter 2.1.3.10. DOE concluded that the WIPP site is located in the Pecos Valley section of the southern Great Plains physiographic province. DOE indicated in Chapter 2.1.4.2 [p. 2-67] that the most prominent physiographic feature near the site is Livingston Ridge, which is a west facing escarpment located approximately 4 miles (6.4 kilometers) northwest of the center of the WIPP site. It marks the edge of Nash Draw, which is a shallow 5-mile-wide (8 kilometers), 200-300 feet (61 to 91 meters) deep feature caused, at least in part, by subsurface dissolution and the accompanying subsidence of overlying sediments. DOE indicated that Livingston Ridge is the approximate eastern boundary of terrain that has undergone erosion and/or solution collapse.

DOE provided adequate information regarding natural resources in the vicinity of the WIPP site in Chapter 2.3 [pp. 2-145 to 2-161] and indicated that the consideration of resources was an important part of the siting criteria for the WIPP. Several siting criteria emphasized the avoidance of resources that would impact the performance of the disposal system. DOE defined both economic (mineral and nonmineral) and cultural resources that may exist at or beneath the WIPP site. Due to the depth of the disposal horizon, only the mineral resources are of significance to predicting the long-term performance of the disposal system. DOE indicated that some of the geologic formations below the repository area contain oil and gas, resources that are currently being exploited in the Delaware Basin. In addition, potash is found within the Salado that contains the WIPP waste area; however, the waste area lies below an area where there are no economically minable reserves. According to DOE's analysis, most of the water in the vicinity of WIPP is highly saline, with the closest dependable potable aquifer associated with the Capitan Reef at the edge of the Basin.

DOE provided adequate information regarding the hydrogeologic characteristics of the geologic units in the disposal system in Chapter 2.2.1 [pp. 2-97 to 2-145], Appendix FAC, Sections 7 and 8 [pp. 7-1 to 8-18], Appendix GCR, Section 6 [pp. 6-1 to 6-62], and HYDRO. [pp. 22 to 75] For each of the geologic units in the vicinity of the WIPP disposal system, DOE provided information regarding hydraulic conductivity, storage coefficients, transmissivity, permeability, thickness, matrix and fracture characteristics, and hydraulic gradients in a summary table provided to EPA in a letter dated February 14, 1997. [Docket: A-93-02, Item II-I-08] This summary table was included in as Figure IV-10 of the Technical Support Document for Section 194.14: Content of Compliance Certification Application. [Docket: A-93-01, V-B-03] The CCA also provides detailed groundwater hydrology information for geologic units that could be expected to transmit radionuclides to the accessible environment.

DOE determined that the Castile, Salado, Rustler and Dewey Lake hydrological systems are the most important to disposal system performance and modeling. [Chapter 2.2.1, p. 2-97] The Castile provides a hydrologic barrier between the Bell Canyon and Salado and contains high-permeability zones with pressurized brine. DOE considered the Salado to be the most significant hydrologic barrier between the repository and more transmissive beds. At the WIPP site, the Rustler Formation contains two transmissive members: the Culebra and the Magenta. DOE stated that the Dewey Lake is not an extensive aquifer at the WIPP site, though DOE reports groundwater movement in a fractured zone of the Dewey Lake off-site of the WIPP.

DOE indicated that the low permeability Salado has limited water (in the form of brine) available to dissolve the halite or to transport radionuclides. If fluid is available to move through the Salado and potentially transport radionuclides, DOE contended that the major pathway for flow and transport is believed to be the more permeable anhydrite interbeds. While more permeable than the halite, the Salado anhydrite interbeds are still very impermeable ($\sim 10^{-19}$ m^2 permeability for the anhydrite versus $\sim 10^{-21}$ m^2 permeability of the halite) to fluid flow.

To assess the capability of the WIPP site to contain radionuclides over 10,000 years, DOE considered the primary geologic units of concern to be (from below the repository to the surface):

- ♦ Castile Formation-- consisting of anhydrite and halite with pressurized brine pockets found locally throughout the vicinity of the WIPP site.
- ♦ Salado Formation-- consisting primarily of halite with some anhydrite interbeds and accessory minerals and approximately 2,000 feet (600 meters) thick.
- ♦ Rustler Formation-- containing salt, anhydrite, clastics, and carbonates (primarily dolomite), with the Culebra member of the Rustler as the unit of greatest interest.
- ♦ Dewey Lake Red Beds Formation (Dewey Lake) -- consisting of sandstone, siltstone and silty claystone.

DOE did not consider most of the geologic units above the Salado to be likely pathways for radionuclides because of their low permeability. According to DOE, the ~8 meter thick Culebra is the major potential pathway for contaminants above the Salado.

40 CFR 194.14(a)(3) requires that a CCA include a description of the presence and characteristics of potential pathways for transport of waste from the disposal system to the accessible environment. In reviewing the CCA information applicable to Section 194.14(a)(3), EPA sought information supporting the conceptualization of the disposal system and the major site-related characteristics included in the performance assessment (PA) modeling. DOE provided a description of the presence and characteristics of potential pathways for the transport

of waste from the disposal system to the accessible environment in Chapter 2 and Appendix DEF. The potential pathways identified by DOE were: breccia pipes and deep dissolution along the Bell Canyon-Castile interface; lateral dissolution along the Rustler-Salado contact and within the Rustler; and shallow dissolution, including the development of karst and dissolution of fracture fill in Salado marker beds and the Rustler.

DOE identified and described numerous potential pathways and concluded that the potential for significant fluid migration to occur through most of these pathways is low. However, DOE also concluded that fluid migration could occur within the Rustler and Salado marker beds and included this possibility in PA calculations.

EPA agreed with DOE's conclusion that karst features and breccia pipes are not potential pathways. EPA also concluded that deep, lateral, and shallow dissolution pathways will not serve as significant potential radionuclide pathways and that the potential for significant fracture-fill dissolution during the regulatory time period is low.

EPA noted that the potential for fluid migration through Salado marker beds and the Culebra member of the Rustler was acknowledged by DOE and included in the PA calculations. While the Dewey Lake is a potential underground source of drinking water [Chapter 8.2.2], DOE's modeling has identified that radionuclides will not reach the Dewey Lake, thus removing the formation as a unit needing consideration as a pathway. [Docket: A-93-02, Item II-G-26] EPA concluded that Salado marker beds and the Culebra Dolomite were adequately identified and characterized to the level necessary for PA calculations.

DOE evaluated fluid injection in connection with the scope of the performance assessment but rejected the scenario on the grounds of low consequences. EPA evaluated DOE's Hartman Scenario and also performed an independent fluid injection analysis; see EPA Technical Support Document for Section 194.32: Fluid Injection Analysis. [Docket: A-93-02, Item V-B-22] The results of these studies show that effective permeability in marker beds is probably lower than that used in the PA, and that other factors (such as injection rate, injection interval, etc.) also play a very important role in fluid injection. EPA agrees that under very unrealistic conditions, modeling can show fluid movement toward the WIPP under an injection scenario. These conditions include those modeled by Bredehoeft, such as steady-state flow, two well scenarios, and pulsing flow. However, when modeling assumes more realistic but still conservative conditions, fluid movement sufficient to impact disposal performance of the WIPP does not occur.

In addition, EPA believes that geologic and hydrogeologic conditions in the Hartman area are different than in the WIPP area, which also precludes one-to-one comparison of conditions at the WIPP and at the Bates lease. For example, the Castile Formation is not present in the Bates area, but over 1,000 feet of Castile is present in the WIPP area. Also, the present oil well completion practices in the Delaware Basin are substantially improved. Injection rate, pressure, target and fluid volume related regulations are different and are closely monitored by the State agencies. EPA concludes that the model representation in DOE studies, including two-dimensional analysis, appears to be appropriate for the intended use, because the model uses radial flaring in the z direction to capture compatible volume in the 360° flow to compensate for 3D simulation.

EPA also requested [Docket: A-93-02, Item II-I-17] that DOE consider different factors in its fluid injection modeling. [Stoelzel and Swift, 1997, Docket: A-93-02, II-I-36] Refer to the discussion in Docket: A-93-02, Item V-B-2, CARD 32, Section 194.32(c). EPA concluded that DOE's initial modeling studies [Stoelzel and O'Brien, 1996, Docket: A-93-02, II-G-1, CCA ref. #611] and supplemental modeling studies [Stoelzel and Swift, 1997 and Docket: A-93-02, Item II-I-36], together with EPA's own fluid injection analysis [Docket: A-93-02, V-B-22] all indicate that DOE's screening of fluid injection from consideration in PA is appropriate. EPA also notes that DOE considered waterflooding for the undisturbed scenario (historical, ongoing, and near future time frame) and screened it from consideration based upon consequence. In so doing, DOE is not required by the compliance criteria to evaluate this FEP for the long-term future.

(Comment 3.A.3) This comment was interpreted to mean that the WIPP will not meet EPA's radioactive waste disposal standards due to the potential occurrence of flood and earthquakes, and because the transportation routes to the WIPP are inadequate. Evaluation of the adequacy of the transportation routes to the WIPP, and the design configuration of the WIPP surface structures (relative to flooding and earthquakes), was not within the authority of EPA for Certification of Compliance under 40 CFR Part 194. The 40 CFR Part 194 Criteria for the Certification and Re-certification of the WIPP Compliance with the 40 CFR Part 191 Disposal Regulations apply only to the disposal system. The disposal system is defined in 40 CFR 191.12(a) as "any combination of engineered and natural barriers that isolate spent nuclear fuel or radioactive waste after disposal." The term disposal is defined in 40 CFR 191.02(l) as "permanent isolation of spent nuclear fuel or radioactive waste from the accessible environment with no intent of recovery. For example, disposal of waste in a mined geologic repository occurs when all of the shafts to the repository are backfilled and sealed."

With respect to the disposal system, DOE has adequately assessed the site characteristics related to the potential occurrence of floods and earthquakes for the purposes of performance assessment and use in comparison with EPA's radioactive waste disposal standards. This information was provided in several locations of the CCA, including Chapter 2 [pp. 2-180 to 2-206] and Chapter 3. [pp. 3-12 to 3-14] EPA reviewed this information and the results of EPA's review are provided in CARD 14 [Docket: A-93-02, Item V-B-02] as well as the preamble to EPA's proposed rule. [62 FR 58798 - 58800, October 30, 1997]

DOE provided adequate information regarding the features of the WIPP that would minimize potential for flooding of the disposal system during the operational phase in Chapter 2, Section 2.2.2 [p. 2-144], and Chapter 3, Section 3.1.3. [pp. 3-11 and 3-12] DOE indicated that the WIPP facility does not lie within the 100-year floodplain and that there are no major surface water bodies within five miles (8 kilometers) of the site. The general ground elevation in the vicinity of the WIPP surface facilities is approximately 3,400 feet (1,036 meters) above mean sea level, while the elevation of the 100-year floodplain of the Pecos River is approximately 3,000 feet (914 meters). DOE has employed a system of berms and ditches to divert storm-water runoff away from the surface facilities. Each of the four shafts that connect the disposal system to the ground surface are equipped with a reinforced concrete shaft collar designed to prevent surface runoff from entering the shaft. DOE described the shaft seal system that will be constructed to complete the disposal system in Chapter 3, Section 3.3.1. [pp. 3-15 to 3-27] The purpose of the shaft seal system is to limit fluid flow within the four shafts after the WIPP is decommissioned. EPA has reviewed this information and concluded that the potential for flooding at the WIPP site is extremely low. [Docket: A-93-02, Item II-B-3, pp. 94-104]

DOE provided adequate information regarding the seismic history of the WIPP site within Chapter 2.6 [pp. 2-180 to 2-205] and indicated that the absence of tectonic activity, faulting, and igneous activity was a factor in the selection of the WIPP site. Many years of seismological monitoring, microseismal studies and geologic study demonstrate that there are no probable sources of large earthquakes at or near the WIPP site. [Docket: A-93-02, Item II-G-1, Chapter 2.6] The only sources of significant earthquakes in the region lie far to the west of the site along the Rio Grand rift or to the south along major plate tectonic features in Mexico, although measurable earthquakes have occurred closer to the WIPP. [Docket: A-93-02, Item II-G-1] The seismic information included a description of earthquake activity and predictions of ground motions that may affect the stability of the WIPP repository. With respect to the potential effects of earthquakes on the disposal system, the intensity of ground shaking is the primary cause of destruction, and it is vastly different in the underground than on the surface. Moreover, the effects of earthquake in pre- and post- mining operation (sealing) periods and pre- and post-creep closure periods at WIPP will be substantially different. In addition, the ductile nature of a salt deposit makes it deform differently than typical hard rocks and the magnitude of displacement due to rupture (if any) will be less. The natural characteristics (barriers) of the underground repository in the bedded salt will help to withstand seismic activities. EPA reviewed DOE's earthquake (seismic) scenario in Technical Support Document for Section 194.14: Content of Compliance Application, Section IV.B.4.f, and concluded that seismic activity would not affect the containment capability of WIPP. [Docket: A-93-02, Item V-B-3]

(Comment 3.A.5) EPA acknowledges that natural resources are present in the WIPP vicinity; oil and gas drilling occurs in the WIPP area, and potash reserves are also present. However, EPA has also required DOE to consider resource extraction in performance assessment modeling by assuming that drilling and mining will occur within the WIPP boundary. [§ 194.32(a), (b)] DOE summarized its modeling effort in Chapter 6 of the CCA. [Docket: A-93-02, Item II-G-1] As indicated in Chapter 6.4 [*ibid.*], DOE modeled human intrusion through the WIPP repository and evaluated the effects of deep drilling into the WIPP repository as well as the effects of potash mining on the transmissivity of the Culebra. The principal impact on WIPP resulting from the likely presence of oil and gas resources beneath the site will be the possible penetration of waste panels by exploration boreholes. [§ 194.33(b)(1)] DOE was required to estimate the rate at which exploration boreholes would be drilled and the probability that such boreholes would penetrate the repository. [§ 194.33(b)] DOE was required to assume that its active institutional control of the WIPP would not extend beyond 100 years. [§ 194.41] DOE was also required to predict the radionuclide releases that would result from borehole penetrations after 100 years, and include those in the overall releases that might occur from the site. DOE was then required to show that those releases are less than the maximum allowable releases that would provide adequate protection to public health. [§ 194.33] DOE performed all of these activities as summarized in Chapter 6.4 of the CCA. EPA concluded that the presence of natural resources and the impact that drilling and mining for these resources would have on the WIPP's containment capability was accounted for in performance assessment modeling and concluded that the performance of these activities will not impact the containment capabilities of the WIPP.

Issue B: Karst at WIPP

1. If karst exists at the WIPP site, DOE's ground water modeling is entirely inappropriate. (9)

2. The presence of karst formations throughout the WIPP site area, ongoing resource drilling and the methods used, whether they be air injection or brine, have not been adequately answered. (283)

3. I'm real familiar with that southeastern part of the state. I spent a lot of time there. What causes all them sink holes? Have you ever watched the Pecos River all the way down? Once in a while you'll get a fissure or sink hole and that river will stop. You don't know where it's going. Is it going to the salt beds? If it does, within 30,000 years you don't think it is going to? (364)

4. I know the Capitan Reef that's basically made of karst features, limestone, porous materials that water dissolves. (533)

5. Karst [formations] and the more than 120 oil and gas wells around the site with many more approved for the future are other reasons of great concern. (543)

6. If there's karst, if that was found at the site, then the site wouldn't be good as a repository. Some young scientist began working on karst experiments down there, just staked their whole life on it, I believe, and along with other scientists later on in the state, I know that they have presented their karst data, but it appears that DOE and evidently the EPA and whatever connection there is, didn't do the research. (562)

7. Karst, it sounds like a dirty word, doesn't it?. K-a-r-s-t. According to the Oxford English Dictionary, karst is a region with underground drainage and many caverns caused by the dissolution of rock. That's what underlies these salt beds. (592)

8. During the recent public hearings in New Mexico on EPA's proposed certification of compliance, several individuals commented that the WIPP site is unsuitable for use as a geologic repository. Specific objections included the claim that the site is subject to karst dissolution that could endanger the ability of the bedded salt formation to contain waste in the long term. Subsequent to the EPA field visit, the EPA published its notice of final no-migration determination for the WIPP Test Phase (55 Federal Register, No. 220, p., 47700, November 14, 1990). On p. 47714 of the notice, . . . EPA states "EPA has concluded that karst is not now an issue at the WIPP, and is unlikely to become one for many thousands of years, if ever." Dr. Jerry Boak hit the nail in the head when he pointed out that those who oppose the WIPP keep bringing up questions that have already been answered repeatedly. The ongoing question about karst is a case in point. EEG even pointed out years ago that the WIPP is not in a karstic zone. Moreover,

the anomaly between groundwater flow and salt concentration is readily explained by the differential porosity of the rock. All this is “old news.” (675)

9. In order to discount the existence of karst conditions at the WIPP site, DOE attributes “fracturing and disruption of Rustler strata” to dissolution of underlying Salado salt. No such correlation has been demonstrated. (881)

10. There is obviously karst groundwater recharge and flow in the vicinity of the site. This issue does not appear to have been adequately addressed by the DOE. Karst landscapes are the most vulnerable in the world to groundwater contamination. I strongly recommend that a karst hydrogeology investigation be performed, including dye tracer studies, to insure that karst groundwater flow in the vicinity of the site is adequately understood before this project is built at this location. One does not locate a hazardous waste site in below, or near, karst without an intensive karst hydrogeologic investigation. (1076)

11. The presence of karst conditions at the WIPP site add complexity to any flow analysis in the Culebra. For example, increased precipitation would cause significantly faster flow to the accessible environment through these karst formations than is modeled in the Performance Assessment for undisturbed performance, disturbed performance, and compliance with ground water protection requirements. (1202)

<u>Response to Comments 3.B.1 through 3.B.11:</u>

(Comments 3.B.1, 3.B.2, 3.B.5, 3.B.6, 3.B.7, 3.B.8, 3.B.9, 3.B.10 and 3.B.11) DOE acknowledges and EPA agrees that karst terrain is present near the surface in the vicinity of the WIPP site boundary. [CCA Chapter 2.1.3.4 and Chapter 2.1.6.2, p. 2-87 to 2-93, and Appendix DEF 3.3] Near-surface dissolution of evaporitic rocks (e.g., gypsum) has created karst topography west of the WIPP site. Nash Draw, which (at its closest to WIPP) is approximately one mile west of the WIPP site, is attributed to shallow dissolution and contains karst features. EPA recognized the potential importance of karst development on fluid migration. Karst terrain typically exhibits cavernous flow, blind streams, and potential for channel development that would enhance fluid and contaminant migration. However, in response to Comment 1202, EPA has found no evidence of direct precipitation-related flow increases typical of karst terrain. In fact, EPA’s Office of Solid Waste performed a field investigation and found no evidence of large channels or other karst features through which precipitation would flow swiftly. [Department of Energy Waste Isolation Pilot Plant; Notice of Final No-Migration Determination, 55 FR 47714, November 14, 1990]

EPA reviewed information and comments submitted by DOE [CCA Chapter 2.1.6.2, p. 2- 87 to 2-93, and Appendix DEF3.3, p. DEF-29 to DEF-30] and stakeholders [Docket A-93-02, Item II-D-102 and Comment 236 A-61.3] regarding the occurrence and development of karst at the WIPP. EPA agrees that karst features occur in the WIPP area but concluded that karst features are not pervasive over the disposal system itself. Available data suggest that dissolution-related features occur in the immediate WIPP area (e.g., WIPP-33 west of the WIPP site), but these features are not pervasive and are not associated with any identified preferential groundwater flow paths or anomalies. [CARD 14, Section 14.B.5, p. 14-24, Docket: A-93-02, Item V-B-02] In response to Comments 1202 and 1076, EPA points out that data from Sandia National Laboratories tracer tests do not indicate the presence of anomalous cavernous-type flow; for example, the interpretation of the H2 hydropad, located just west of the waste panel area, is one of single (matrix) porosity, not channeling. This interpretation is discussed in Integration of Interpretation of Tracer Tests Performed in the Culebra Dolomite at the WIPP Site by Jones et al., 1992. [Docket: A-93-02, Item II-G-1, Ref. No. 343, p. 6-21] Neither EPA, nor commenters, have identified specific, obvious karst recharge points.

EPA reviewed information pertinent to the potential development of karst in the WIPP area. [CARD 14, Section 14.B.5, p. 14-24, Docket: A-93-02, Item V-B-02; Technical Support Document for Section 14: Content of Compliance Application, Docket A-93-02, Item V-B-03, Section IV.B.3.t and IV.C.3] EPA believes that the near continuous presence of the more than half-million year old Mescalero Caliche over the WIPP site is a critical indicator that recharge from the ground surface to the bedrock hydrologic regime has not been sufficient to dissolve the caliche at the site. If active dissolution of the evaporites in the subsurface were occurring in the WIPP area, it would be expected that collapse features would be evident in the Mescalero above the area where the dissolution is, or has occurred. As noted above, EPA has found no evidence of direct precipitation-related flow increases typical of karst terrain, and no field evidence of large channels or other karst features. The relative pervasiveness of the Mescalero Caliche over a long period of time is also an indication that there has been an arid climate and very low recharge conditions over a long period of time at the WIPP site. Caliche only develops in environments where there has been little recharge. In addition, since Caliche is an evaporative precipitate, it is very soluble and for caliche to persist over a long period of geologic history, the relationship between evapotranspiration, run-off and precipitation must have remained in favor of evaporation. This, combined with DOE's near-future precipitation assumptions, led EPA to conclude that karst feature development will neither be pervasive nor impact the containment capabilities of the WIPP during the 10,000 year regulatory period.

(Comments 3.B.3 and 3.B.4) Solution and collapse in the Pecos River Valley, its tributaries and on the Capitan Reef are products of ancient geomorphologic processes which were not present at the WIPP site and are unrelated to it. The Capitan Reef, which encircles the Delaware Basin but which is not considered part of the Delaware Basin, is composed of limestone and does not extend to the WIPP site. The massive thickness of the Capitan Reef, relative strength of the Capitan Limestone, and availability of freshwater contribute to dissolution of the Capitan. The karst terrain preserved on the Captain Reef is of the same geologic age as the dissolution of the sinkhole at WIPP-33, that is, more than half a million years old. However, the Capitan Reef is not in the immediate vicinity of WIPP and DOE does not need to consider Capitan Reef dissolution features on WIPP's performance.

Dissolution in the major drainage features of the site region is related to the infiltration of groundwater into the sub-channel regions of perennial through-flowing streams, which formerly occupied the second and third order tributaries of the Pecos River. The only remaining active member of this ancient regional drainage system is the Pecos River which is marginal in this arid region and owes its persistence to its headwater in the well-watered high mountains of the southern-most Rocky Mountains. Some dissolution continues in these relict stream valleys because of their tendency to capture local runoff and because of the chaotic fracture permeability caused by the extensive paleo-dissolution from an earlier humid phase of climate (more than 500,000 YBP). None of the incised and collapsed members of the relict drainage system of the region occurs on the WIPP site and present climatic conditions can not create any new features of this kind since the arid climate at the site results in high evapotranspiration rates. With the high evapotranspiration rates, rainfall which does percolate into the Mescalero Caliche is drawn up again by capillary forces and plant root processes, but does not regularly infiltrate into the deep subsurface. The lack of rainwater infiltration into the deep subsurface limits the potential for dissolution processes to occur at the WIPP site.

(Comment 3.B.9) DOE attributes fracturing within the Rustler strata to a variety of processes, including loading/unloading, dissolution at the top of the Salado, and distribution of fracture fill material. [Docket: A-93-02, Item II-G-1, Chapter 2.1.3.5, p. 2-38] DOE has indicated that it rules out intraformational post-depositional dissolution of the Rustler Formation as a cause of Rustler salt distribution and fracture formation based on work by Holt and Powers [*ibid.,* Appendix DEF, Section DEF3.2], who believe that syndepositional/immediate post depositional dissolution occurred. EPA believes that a combination of processes, including post-depositional dissolution of Rustler halite, contributed to fracture development. [Docket: A-93-02, V-B-3, Section IV, B.3.j] EPA points out that lateral intra and inter formational dissolution processes, while probably ongoing to some degree, are not of sufficient magnitude to cause massive subterranean dissolution typical of karst terrain. [Docket: A-93-02, Item V-B-02, Section IV.D.2]

Issue C: Presence/Absence of Mescalero Caliche

1. I found that about 15 percent of the Caliche was missing. It is not a barrier at all to rainwater infiltration. In fact, it actually helps, because the rainwater flows along the surface, infiltrates into these holes at which time it seeps through the Dewey Lake Red Beds underneath the Caliche where that hard cemented Caliche protects it from evaporation. Now, the Department of Energy told the Environmental Protection Agency that the Caliche is a cemented surface and that it is typically present at the WIPP site. An umbrella with holes in it is typically present but water still gets through. (301)

2. DOE also said that the Mescalero Caliche is expected to be continuous over large areas and that WIPP data are limited mainly to boreholes. . . All together 15.3 percent of the Caliche surface was absent with surficial sand in direct contact with the Dewey Lake Redbeds. A smooth continuous Caliche surface cannot be expected. The effect is more like Swiss cheese. (604)

3. Radiocarbon dates as young as 11,250 years B.P. (Before present) have been reported for Mescalero Caliche (Phillips, 1987, p. 67). Thus, the conclusion that Livingston Ridge assumed its present position hundreds of thousands of years ago is unsubstantiated. (871)

Response to Comments 3.C.1 through 3.C.3:

EPA does not conclude that the Mescalero Caliche is a 100% continuous, impenetrable surface. However, EPA believes that the near continuous presence of the more than half-million year old Mescalero Caliche over the WIPP site is an indicator of an arid climate at the site. Caliche is the precipitate of trace minerals contained in rainwater with some minor additional constituents leached from shallow soils. It develops in an environment in which evapotranspiration greatly exceeds the average rainfall and where the upper part of the soil column exhibits relatively low permeability. Caliche also only develops in environments in which there is little recharge. Infiltration carries these minerals downward to the saturated zone where they cannot accumulate. In regions having actively forming caliche, virtually all rainfall either runs off or is removed from the shallow soil by evapotranspiration. [Hunt, 1996] Appendix CLI [p. 3] of the CCA indicates that the present annual freshwater pan evaporation rate at the WIPP is approximately 108 inches (274 cm) per year, the average annual rainfall is approximately 12.6 inches (32 cm) per year, and that an average of 96% of precipitation is lost to evapotranspiration. Further, since caliche is an evaporative precipitate, it is very soluble. For caliche to persist over a long period of geologic history, as in the case of the Mescalero Caliche, the relationship between evapotranspiration, runoff and precipitation must have remained in favor of evaporation. Rainfall percolates into the caliche and is drawn up again by capillary forces and plant root processes, but does not regularly infiltrate into the deep subsurface. The caliche may locally retard infiltration and abet runoff, but its principal significance is that it is an indicator of an arid climate and very low recharge conditions over a very long period at the WIPP site.

In response to Comment 3.C.3, EPA points out that caliche deposition is an ongoing process which has persisted over the entire period during which the southwestern high desert has been arid. The evapotranspiration rate has exceeded the effective precipitation rate for more than 500,000 years in the WIPP region and Caliche has been formed at varying rates throughout that entire period. [Swift, 1994, pp. 83-84] Relatively young (11,250 years) dates for caliche do not indicate the maximum age of the caliche, only that a relatively young layer of the accumulated material was sampled. EPA concluded that this date (11,250 years) cannot even be considered a minimum age, as caliche is forming in the Mescalero Caliche complex at the present time. EPA has concluded that the date cited in the comment has no relationship to the maximum age of the Mescalero Caliche or Livingston Ridge.

References

Swift, P.N., 1994: Long-Term Climate Variability at the Waste Isolation Power Plant, Southeastern New Mexico, USA. Environmental Management, Vol. 17, No. 1, pp. 83-97.

Hunt, Charles B., Surficial Deposits of the United States, Van Nostrand Reinhold Company, Inc., 1996

Issue D: Existing borehole data is inconsistent with DOE's modeling.

1. Existing borehole data is inconsistent with DOE's modeling and is not addressed in the CCA. (10)

Response to Comment 3.D.1:

The comment does not identify the existing borehole data that is referenced nor does it explain how such data is inconsistent with DOE's modeling. EPA believes that this comment refers to a belief that the Rustler/Salado formations exhibit dissolution features at locations H1, H3, H6, and WIPP wells 13, 18, 19, 21, 22, 23, and 25, and that these wells provide evidence of active karst at the WIPP site with the Culebra dolomite member as the unit of most interest. Figure 2-2 in CCA Chapter 2 provides the location of these boreholes.

EPA believes it important to clarify what is meant by "karst", and the importance of timing relative to karst development. Karst is defined, in Bates and Jackson, 1980 [Docket: A- 93-02, II-G-1, Ref. No. 37, p. 280] as "a type of topography formed over limestone, dolomite, or gypsum by dissolution that is characterized by sinkholes, caves, and underground caverns." This topographic modification can happen at any point in geologic time, and "karst" features can then be covered by sediments that lithify to rocks. Also, these *paleo*karst features can continue to change as the rock column undergoes consolidation, lithification, or other geologic modifications through time. If a modern karst system is currently developing at WIPP, all rocks from the ground surface downward, would be impacted by the dissolution process, whether it be from dissolution of soluble intervals or from collapse of non-soluble rocks due to removal of soluble material.

Numerous geologic investigations have been conducted in the vicinity and across the WIPP site to assess the occurrence of dissolution (karst) including, for example, Anderson, 1978 [Docket: A-93-02, Item II-G-1, Ref. 12], Bachman,1976 and 1987 [Docket: A-93-02, Item II-G-1, Refs. 22 and 27, respectively], and Borns et al, 1983. [Docket: A-93-02, Item II-G-1, Ref. 79] Detailed geologic analysis of subsurface strata to assess the presence of dissolution-related features has been conducted. [Holt and Powers, 1988, Docket: A-93-02, Item II-G-1, Appendix FAC] The presence of active karst features at the WIPP site has also been investigated by EPA. EPA conducted a field investigation during the summer of 1990 to assess the occurrence of karst features as part of its WIPP Test Phase No Migration Variance determination. As a result of that field investigation and detailed examination of site geologic and hydrologic information, including core data and hydrologic (i.e., water level) information, EPA concluded that "karst is not now an issue at the WIPP, and is unlikely to become one for many thousands of years, if ever." [Department of Energy Waste Isolation Pilot Plant; Notice of Final No-Migration Determination, 55 FR 47714, November 14, 1990]

DOE has asserted [Appendix FAC, pp. iii-v] that many brecciated units present in the Rustler Formation can be attributed to syndepositional (i.e., accompanying deposition of the sediment) and immediate post-depositional processes, such as slumping of sedimentary strata, as well as dissolution that occurred immediately post-depositionally. DOE does not believe that salt/soluble bed distribution need be attributed to more recent dissolution. EPA has examined geologic and/or hydrologic data for H1, H3, H6, and WIPP wells 13, 18, 19, 21, 22, 23, and 25, available through geologic borehole logs and associated records, available core data, and geologic interpretive reports [Appendix FAC, Docket: A- 93-02, II-G-1] and concludes that the syndepositional and post-depositional processes (including dissolution soon after deposition) could account for some of the observed sedimentary fabrics. For example, the exhaust shaft includes a brecciated zone that could have been formed due to post-depositional slumping and/or dissolution, but this unit is immediately covered by undisrupted strata. [Docket: A-93-02, Item II-G-1, Ref. 309, Figure 11] The contact between this brecciated zone and underlying/overlying units is gradational (indicating that no large time or sedimentologic “breaks” between depositional and brecciation events is apparent), supporting the conclusion that the brecciated feature formed at the same time (or immediately after) the rock units immediately surrounding the brecciated zone were deposited. EPA does not agree with DOE’s assertion that the distribution of salt in the Rustler is only a depositional feature because Rustler transmissivity (which is related to fracture occurrence in the Rustler [Figure 2-30, Docket: A-93-02, Item II-G-01] generally corresponds to the occurrence of salt in the Rustler. [Figure 13, Appendix HYDRO, Docket: A-93-02, Item II-G-1] This implies that some post-Rustler dissolution has occurred which impacts the fracturing in Rustler rocks. However, the evidence observed by EPA and described above indicate that a complex history of deposition and dissolution has occurred in the WIPP area, but many Rustler features (e.g. the breccia zone in the exhaust shaft, or at WIPP-18, where anhydrite/clay-rich strata may be halite dissolution residues) were formed during unit deposition or immediately post-depositionally over 200 million years ago. Other Rustler features (e.g. salt distribution in the Rustler) could have occurred sometime after the Rustler was deposited, but there is no evidence to indicate that ongoing dissolution of soluble material in the Rustler or at the Rustler-Salado contact will modify the existing transmissivity to the extent that PA will be affected.

EPA also agrees that significant karst development and associated dissolution features are present in the WIPP vicinity, the most striking of which is Nash Draw. However, there is no indication that *modern* karst is present across the WIPP site such that it would impact the modeled transmissivities. EPA examined geologic and hydrologic data, including field observations offered by stakeholders, DOE, and other EPA offices [Notice of Final No-Migration Determination, 55 FR 47714, Nov.14, 1990**]** EPA found no evidence of significant karst features, such as large channels, dolines, sinkholes, or collapse breccias (other than those at, for example, at WIPP-33 and Nash Draw) in the immediate WIPP vicinity. This does not mean that EPA believes karst processes are not active in the WIPP area. Clearly, dissolution of soluble beds can and does occur in the WIPP area; however, the location of the most pervasive dissolution is in Nash Draw, approximately one mile from the land withdrawal area boundary and miles from the footprint of the WIPP repository itself.

DOE further discussed the rate and extent of dissolution processes in supplemental information provided in a letter dated June 13, 1997. [Docket: A-93-02, Item II-H-44] Dissolution processes can and do occur in the Rustler, particularly in Nash Draw, where an hypothesized “dissolution front” along the Rustler-Salado contact may occur. [Appendix DEF, p. DEF-25 to DEF-29] EPA concluded [CARD 14, p. 14-29, Docket: A-93-02, Item V-B-2, Section 14.B.5] that while dissolution may occur along the Rustler Salado contact, it would not impact the WIPP’s containment capabilities during the regulatory time period because it would not travel rapidly enough to dissolve the Salado or adversely disrupt the Rustler Formation. EPA concurs that the presence of fractures and related fracture fill that could be attributed to dissolution/precipitation could significantly impact groundwater transport in the Rustler. However, geologic and hydrologic data obtained at the WIPP indicate that fracturing is not uniformly pervasive throughout the WIPP area. DOE has modeled the presence of fracturing using a dual porosity model, and has accounted for fracture occurrence variability by developing transmissivity fields based upon measured field data which reflect the varying transmissivity values.

EPA concludes that dissolution has occurred in the WIPP area outside of the WIPP site, as evidenced by karst features like Nash Draw. It is possible that dissolution has occurred at the WIPP site sometime in the distant past (i.e., greater than 200 million years ago for strata-bound features) associated with another geologic setting than that currently present at WIPP; however dissolution in the Culebra is not an ongoing process at the WIPP site. Thus DOE's modeling (which assumes no karst within the WIPP site boundary) is consistent with existing borehole data and other geologic information.

Issue E: Karst features could be obscured due to filling by wind-blown sand.

1. A continuous flow of surface sand is obscuring the most obvious karst features at the WIPP. (11)

2. It can never be stated categorically that "there are no examples of karstic features" within the WIPP site. A nearly continuous mantle of desert soil and windblown sand up to 13.5 feet thick covers the entire WIPP site and vicinity, obscuring all but the largest and most obvious karst features. (860)

Response to Comments 3.E.1 and 3.E.2:

The comments were interpreted to mean that if surface karst features such as topographic depressions were present in the WIPP site area, it is possible that these features could be obscured due to filling of the topographic depression by wind-blown sand. EPA acknowledges that the sandy soil and unconsolidated material present above the Mescalero Caliche layer in the WIPP area could possibly obscure minor karst features, such as pitting of the surface of the Mescalero Caliche caused by slow downward solution upon the Mescalero Caliche (e.g., dolines). However, if large scale features indicative of active dissolution of evaporites in the subsurface were occurring in the WIPP site area, the surface topographic expression of the karst feature (i.e., topographic depression created by collapse of rock above the area where dissolution is or has occurred) would be evident, like Nash Draw, despite the presence of a wind blown sandy soil. Even if karst features at the surface were obscured, it is the nature of the groundwater flow that is important. Hydrological data from the many site investigation wells [Figure 2-2 of CCA Chapter 2, p. 2-13] do not indicate groundwater flow typical of karst. CCA Chapter 2.2.1.4.1.2, pp. 2-18 to 123, provides a summary of findings from these studies and notes several references. For example, well H-7 is located in Nash Draw, a large karst feature west of the WIPP. The transmissivity ($1x10^3$ square feet per day or $1x10^{-3}$ square meters per second) of the Culebra in Nash Draw is typically 100 times or more higher than in wells on the WIPP site, indicating that karst processes have not affected Culebra groundwater flow at the

WIPP site as they have in Nash Draw. [Figure 2-30, p. 2-121 of CCA Chapter 2 for well locations in reference to Culebra transmissivities]

Issue F: Nash Draw is closer to WIPP than asserted in the CCA.

1. Nash Draw, a known karst feature, is much closer to the WIPP than is asserted in the CCA. (12)

2. WIPP 33 used to be in the WIPP site and then they reduced the boundaries of the WIPP site without moving the waste disposal area. So the WIPP site isn't any farther from karst than it used to be, just the boundaries are different. But all three of these depressions are closer to the WIPP site boundary than the original one which was drilled. The Department of Energy finally this year in its response to CARD admits that these are all sink holes and that proven Karst features extend within 1,000 feet of the current reduced WIPP site boundaries. (292)

3. DOE states that Nash Draw is "some 6 miles (10 kilometers) to the west of the Land Withdrawal Area". This is an erroneous statement. . . The truth is that the fluvial incisions of Livingston Ridge, which mark the eastern boundary of Nash Draw, reach to within one mile (1.6 kilometers) of the northwest corner of the WIPP site, and to within 1.2 miles (1.9 kilometers) of the southwest corner of the WIPP site, 400 feet from the WIPP site turnoff. (862)

Response to Comments 3.F.1 through 3.F.3:

Chapter 2.1.4.2 [p. 2-67] of the CCA indicates that Livingston Ridge marks the eastern edge of Nash Draw. Livingston Ridge is considered the edge of the surface expression of Nash Draw and it is approximately 1 mile (1.6 kilometers) from the WIPP boundary. Chapter 2.1.4.2 [p. 2-67] of the CCA does not explicitly state the distance from the WIPP Site Boundary to Livingston Ridge. However, the location of Livingston Ridge with respect to the WIPP Site Boundary is shown on Figure 2-18 [p. 2-69 and an attachment to Volume I of the CCA] and on a topographic map attached to the end of Volume I of the CCA. The maps show that Livingston Ridge is approximately 1 mile (1.6 kilometers) northwest of the northwest corner of the WIPP boundary. While Appendix DEF 3.2 does state that Nash Draw is about 5 miles (8 kilometers) west of the site, EPA did identify that the range of distances to Nash Draw from the WIPP site boundary is about 1 to 5 miles (1.6 to 8 kilometers). [Technical Support Document for Section 194.14: Content of Compliance Application, Section IV.B.3.s.ii, Docket A-93-02, Item V-B-03] While the major dissolution features of Nash Draw are several miles away from the site, and the edge of Nash Draw is closer than the 5 miles stated in Appendix DEF 3.2, this does not change the CCA performance assessment results. DOE states, and EPA agrees, that collapse feature(s) related to dissolution are present at WIPP-33. [Appendix FAC, p.s iv and 9-5, Docket A-93-02, Item II-G-1] DOE acknowledges [CCA Chapter 2.1.6.2.1] that WIPP-33 is closer to the WIPP site than Nash Draw and represents the edge of the subsurface karstic features. Based on Figure 2-2 [p. 2-13] of the CCA, WIPP-33 is located approximately 2,800 feet (0.85 kilometers) west of the western WIPP boundary. Based on location data from Table 1 of Appendix HYDRO [p. 92] of the CCA, WIPP-33 is located 2,427 feet (0.74 kilometers) east from the west Section Line of Section 13, Township 22 south, Range 30 east. Since the west section line of Section 13 is located 1 mile (1.6 kilometers, 5,280 feet) west of the WIPP boundary, WIPP-33 is located 2,853 feet (0.87 kilometers) west of the WIPP boundary.

Issue G: An on-site investigation of karst at WIPP was not conducted.

1. Harry Legrand never conducted on-site investigation of karst at the WIPP site, despite DOE's contention. Moreover, this alleged investigation is heavily weighted by DOE in the CCA. (13)

Response to Comment 3.G.1:

The commenter is incorrect; the investigation by Harry Legrand is not heavily weighted by DOE in the CCA as it references Harry Legrand only once, in Appendix DEF 3.3 -- Shallow Dissolution, and he is briefly discussed in one paragraph. His report is listed in report EEG-32 [Docket: A-93-02, Item II-A-41], "The Rustler Formation as a Transport Medium for Contaminated Groundwater" by Chaturvedi and Channell. [1985] In that report, Harry Legrand discusses his trips to the site "during the week of July 12 and the week of September 6, 1982," and his findings from his review of karst and the WIPP. The basis of DOE's conclusion on karst is discussed in Appendix DEF and discusses findings from a number of DOE reports.

EPA reviewed information and comments submitted by DOE [CCA Chapter 2.1.6.2, p. 2- 87 to 2-93, and Appendix DEF3.3, p. DEF-29 to DEF-30] and stakeholders [Docket A-93-02, Item II-D-102 and Comment 236 A-61.3] regarding the occurrence and development of karst at the WIPP. See CARD 14 [Docket: A-93-02, Item V-B-2] and Technical Support Document for § 194.14: Content of Compliance Certification Application. [Docket: A-93-02, Item V-B-3, Section 2.0] EPA did not rely on Harry Legrand's investigation in its determination that karst exists in the WIPP region but that karst features are not pervasive at the WIPP site and will not impact the containment of radioactive waste.

Issue H: WIPP well data and Nash Draw

1. Karst features at WIPP-33 have not been investigated, but DOE contends that karst does not extend beyond WIPP-33. (14)

2. It turns out that WIPP 13 is connected to Nash Draw. When they pumped water out of WIPP 13, they measured the water levels in a number of wells to see if there was a response, if that water level dropped as well. Then they stopped pumping at WIPP 13 to see how long it took for the water levels to raise again in other wells. These wells are four miles away. The response time was 26 hours. This is an existing hydraulic connection between WIPP 13 deep within the WIPP side where the Magenta dolomite is shattered, and WIPP 25 which is in Nash Draw which even DOE admits to be Karst. More frightening than that, there was also a response time in one of the WIPP shafts in the center of the WIPP site. They measured a response there. (298)

Response to Comments 3.H.1 and 3.H.2:

(Comment 3.H.1) Numerous geologic investigations have been conducted in the vicinity and across the WIPP site to assess the occurrence of dissolution (karst) including, for example, Anderson, 1978 [Docket: A-93-02, Item II-G-1, Ref. 12], Bachman ,1976 and 1987 [Docket: A-93-02, Item II-G-1, Refs. 22 and 27, respectively], and Borns et al, 1983. [Docket: A-93-02, Item II-G-1, Ref. 79] Detailed geologic analysis of subsurface strata to assess the presence of dissolution-related features has been conducted. [Holt and Powers, 1988, Docket: A-93-02, Item II-G-1, Appendix FAC] The presence of karst features at the WIPP site has also been investigated by parties other than DOE. EPA conducted a field investigation during the summer of 1990 to assess the occurrence of karst features as part of its WIPP Test Phase No Migration Variance determination. EPA traveled to the WIPP site and inspected geomorphologic features that commenters believed were evidence of dissolution and karst development. EPA concluded that "karst is not now an issue at the WIPP, and is unlikely to become one for many thousands of years, if ever." [Notice of Final No-Migration Determination, 55 FR 47714, November 14, 1990] In addition the Environmental Evaluation Group prepared its own analysis of karst features at the WIPP and concluded "that while the WIPP is located in a karst region, the groundwater is not abundant and is of poor quality and while pathways of higher permeability may be present, solution channels as potential pathways for fast movement of water do not appear to be present." EEG also stated that, "...the karst phenomena do not appear to warrant rejection of the WIPP site." [Docket A-93-02, Item II-D-102, p. 4]

(Comment 3.H.2) DOE's multipad pumping test at WIPP-13 is discussed in Reference No. 42. [pp. 36-38, 48, and 61, Docket A-93-02, Item II-G-1] DOE indicates that the calculated transmissivity using WIPP-25 data indicates an apparent transmissivity of 650 ft^2/day. The transmissivity between well WIPP-13 and well WIPP-25 is described as "apparent" since the Culebra is a heterogeneous water bearing unit. The responses measured in observation wells to pumping tests in heterogeneous systems cannot be rigorously interpreted using the standard analytical techniques developed for homogenous porous media. Application of analytical techniques to data from heterogeneous media results in quantitative evaluations of average hydraulic properties between pumping and observation wells that are non-unique in the sense that they are representative only of the responses observed when a hydraulic stress is imposed at a certain location. These "apparent" hydraulic properties do, however, provide a qualitative understanding of the nature and distribution of hydraulic properties within the tested area. [Reference No.42, p. 61, Docket: A-93-02, Item II-G-1] The apparent transmissivity between WIPP-13 and WIPP-25 is higher than the calculated transmissivity at WIPP-13 (69 ft^2/day) calculated using the actual WIPP-13 drawdown and recovery data and higher than the transmissivity calculated at WIPP-25 (270 ft^2/day) reported in Table 7, p. 105 of Appendix HYDRO of the CCA. DOE states "This may reflect either the presence of a zone with extremely high transmissivity between WIPP-13 and WIPP-25....or a general diminution of the magnitude of the pressure front from WIPP-13 as it began to expand westward into the high transmissivity region represented by Nash Draw." [Ref. No. 42, Docket: A- 93-02, II-G-1, p .48] These data indicate an increased transmissivity westward, but pressure response time is not a solute transport time. Also, this transmissivity variation is consistent with the modeled and regional calculated values, and is delineated on maps and in model data within the CCA. [Figure 2-30, Appendix TFIELD] DOE has modeled the identified transmissivity distribution in its PA calculations and has shown that releases from the WIPP to the Culebra do not exceed regulatory limits. Further, the ground water flow direction in the Culebra in the vicinity of the WIPP is toward the south. Well WIPP-25 is located west, which is cross-gradient, of well WIPP-13. This means that ground water in the Culebra would not naturally flow from WIPP-13 to WIPP-25.

Issue I: Ground water flow at WIPP is related to flow at Nash Draw.

1. I know the Department of Energy says in their Supplemental Environmental Impact Statement that ground water flow at WIPP is unrelated to ground water flow at Nash Draw. This statement has always been unsubstantiated and now it is disproven. (299)

2. Since April 1979, when the Draft Environmental Impact Statement (DEIS) was issued, DOE has proceeded on the assumption that Culebra ground water from the WIPP site would discharge at Malaga Bend on the Pecos River. DOE now concedes that it will not. This admission invalidates the WIPP performance assessment, which charts all flow paths southward toward Malaga Bend only. (873)

Response to Comments 3.I.1 and 3.I.2:

EPA is basing its decision to certify WIPP on the record associated with the CCA, not the Supplemental Environmental Impact Statement, and it is unclear what Commenter 299 is using to "disprove" DOE's approach to modeling ground water flow at WIPP. As described below, the ground water basin model described by DOE in Chapter 2.2.1.4 [pp. 2-114 to 2-131] and Chapter 6.4.6 [pp. 6-122 to 6-131] does not assume that ground water flow at WIPP is unrelated to ground water flow in Nash Draw.

DOE considers the Rustler, Dewey Lake, Santa Rosa, and overlying units to form a ground water basin with boundaries coinciding with selected ground water divides. The model boundary follows Nash Draw and the Pecos River valley to the west and south and the San Simon Swale to the east. [Docket: A-93-02, Item II-G-1, Ref. #147, p. 8] The boundary continues up drainages and dissects topographic highs along its northern edge. [*ibid*, p. 8] These boundaries represent ground water divides whose positions have remained fixed over the past several thousand years and are assumed to remain fixed for 10,000 years into the future. [*ibid.*, p.11] DOE considers the lower boundary of the ground water basin to be the upper surface of the Salado. [*ibid.*, p.11]

Nash Draw and the Pecos River are areas where discharge to the surface occurs. Hunter 1985 [Docket: A-93-02, Item II-G-1, Ref. #320] described discharge at Surprise Spring and into saline lakes in Nash Draw. She reported ground water discharge into the Pecos River between Avalon Dam north of Carlsbad and a point south of Malaga Bend as approximately 32.5 cubic feet per second (0.92 cubic meters per second), mostly in the region near Malaga Bend.

As stated in Appendix MASS 14.2: "Modern-day flow velocities in the Culebra at the WIPP site can be understood and simulated using the ground water basin conceptual model. The generally north-to-south flow is a result of the modern-day depth of the water table and the basin-scale distribution of hydraulic conductivity. Flow in wetter climates would rotate toward Nash Draw to the west. Flow in the Culebra directed away from Nash Draw is not supported by this model."

DOE models Nash Draw as a no-flow boundary, and EPA concludes that this is appropriate given that it is a discharge area. EPA has evaluated DOE's ground water basin model and agrees with its use in PA because it uses technically appropriate and realistic boundary conditions to simulate ground water flow within the Culebra in the WIPP area. [Refer to Docket: A-93-02, Item V-B-7, pp. 1-87 through 1-120, for further discussion of the ground water basin model and radionuclide transport.]

Issue J: Well WIPP-14

1. The Department of Energy in its response to CARD actually fell short of denying this is a sink hole. They made a few arguments but didn't actually deny that water flows into WIPP 14 and disappears into the depression. Now, the WIPP 14 drill hole is 98 feet outside the WIPP site boundary, but the depression is 600 feet in diameter. It straddles the WIPP site boundary. This is karst within the WIPP site. (293)

2. Beneath the Caliche at WIPP 14 is 71.4 feet of mud containing fragments of gypsum and anhydrite. It's not solid rock at all. CARD interprets this as cave fillings beneath an obvious sink hole and the Department of Energy has yet to offer another explanation.194.14. (294)

3. Not only does DOE fall short of denying that WIPP-14 is a sinkhole; the CCA confirms it. CARD has since discovered this passage in Appendix DEF (p. DEF-30): "Only a few small clusters of shallow dolines on the Mescalero caliche have been identified on the Los Medanos plateau east of Livingston (sic) Ridge." DOE refers the reader to Figure DEF-7, where the karst features are depicted with three black dots: at WIPP-33, WIPP-13, and WIPP-14. (853)

4. [A]t WIPP-14 the Culebra is directly underlain by 71.4 feet of mud with gypsum and anhydrite fragments, interpreted by CARD as transported cave sediments into which collapse of overlying strata has not yet occurred and through which ground water can flow almost unimpeded. . . Culebra dolomite was not deposited and lithified on top of 71.4 feet of mud; it was formed as a residue of salt dissolution. DOE has not offered an alternative explanation for the presence of mud beneath the Culebra, an occurrence reported nowhere else east of Nash Draw. (870)

<u>Response to Comments 3.J.1 through 3.J.4:</u>

(Comments 3.J.1, 3.J.2 and 3.J.3) EPA has examined geologic data in and around the WIPP site, and has recognized that dissolution-related features are present in the WIPP area. DOE acknowledges that some scientists believe that dissolution is apparent at WIPP-14. For example, DOE states, on p. DEF-30 [Appendix DEF, Docket: A-93-02, II-G-1] that LeGrand identified a "prong of dissolution extending from Nash Draw towards the site of WIPP-14." EPA recognizes that topographic depressions are present immediately north of the WIPP site, in the WIPP-14 area examined by LeGrand, and one such topographic feature, as mapped in the CCA [Figure DEF-7 and 2-18], appears to abut the WIPP site boundary.

Although DOE did not provide an explicit explanation of WIPP-14, they identified only a minor topographic depression, and that "there is no evidence of collapse at the surface [at WIPP-14]." [Docket: A-93-02, Item II-G-1, Ref. 26, pp. 25 and 26] DOE also stated that "WIPP-14 contained no subsurface cavities." [*ibid.*, p. 25] Without direct evidence of cavernous porosity and subsequent collapse of overlying beds that would be associated with a karst origin of this feature, this interpretation is consistent with available data. There is no evidence that potential dissolutional features are the result of ongoing karst processes that would result in cavernous porosity and solution pipeways and caves.

The presence of "mud" at WIPP-14 is unlikely. DOE states [Docket: A-93-02, Item II-G-1, Ref. 26, p. 26] that "the stratigraphic succession at WIPP-14 is comparable to that in other drillholes." The Santa Rosa sandstone occurs from 15.4 to 141.0 feet below ground surface (bgs), and the Dewey Lake Redbeds occur from 141.0 to 638.7 feet bgs. Remaining strata are comprised of the Rustler Formation from 638.7 feet bgs to the top of the Salado at 951.6 feet bgs. "Mud" is not identified, but perhaps the commenter is referring to units such as the Unnamed Lower Member, or the Rustler-Salado contact area. [Appendix BH, p. 51 of the CCA]

(Comment 3.J.4) The commenter states that the presence of dissolution residue implies a region through which ground water can flow almost unimpeded, and its presence implies the impending collapse of the Culebra. The comment also states this material is the result of transport of "cave sediments" into a cavern. EPA does not agree with this interpretation, as the presence of material such as this can be created in situ and need not be "transported"; Further, if impending collapse were likely to occur, open void space should be present, or soluble minerals (with sufficient water to quickly dissolve these minerals) must be observed. Neither are present and imminent collapse will not occur. EPA does agree that such material could have been impacted by dissolution, but EPA also points out that hundreds of millions of years have gone by since deposition of the Salado, and dissolution could have occurred in the far distant past.

The residuum is largely composed of silt and clay and could have very low permeability. As such, it is not a region through which "nearly unimpeded flow" can occur. Residuum is, when confined by lithostatic load, capable of supporting the overlying rock and its presence does not imply the existence of void space into which the Culebra Formation will collapse or into which sediment has been transported. No such void space waste is present in WIPP-14. [Bachman, 1985, Docket: A- 93-02, II-G-1, Ref. 26, p. 26]

WIPP-14 is within the rock volume tested by the WIPP-14 multipad pumping test [SAND 87-1456] and although it did not serve as an observation well during that test, the rock penetrated by WIPP-14 is represented in test results. No anomalous hydrologic conditions were observed indicative of cavernous porosity. EPA also concluded that a solution feature serving as a point of intensive recharge or of anomalous horizontal flow, if present, would be in the WIPP-13 multipad test which analyzed the effects (14 observation wells).

Issue K: DOE never collected hydrologic data in known Karst features at the WIPP site.

1. The Department of Energy has performed multi well pump tests at the WIPP site. They have almost 40 test wells now mostly in the wrong locations. I hasten to point out that even though open caverns were discovered at WIPP 33, and a mud filled cavern was discovered at WIPP 14, these were not turned into hydrologic test wells. The Department of Energy never collected hydrologic data in known Karst features at the WIPP site. Even so, they have discovered hydrologic connections between certain drill holes. (295)

2. I also correlated all of the bore hole data from all the WIPP bore holes and discovered that there were zones both above the Magenta dolomite and below the Culebra dolomite in members of the Rustler formation that were thought not to be a problem, not to be part of the ground water flow system. These zones were characterized by consistent inability to recover a core sample from the drill hole because the rocks were so unconsolidated. Sometimes there were complete washouts where the drilling fluid was lost as it flowed into those cavernous zones, and as you see, they snake entirely across the WIPP site, including most of the drill holes I have already shown you. So that opens one more question about shallow ground water hydrology. If there are cavernous zones snaking across the WIPP site, penetrating the WIPP shafts and connecting to Nash Draw, are these ancient features left over from the ice ages or do they carry water today? (300)

3. [E]vaporite rocks are not typically fractured, so a consistent lack of core recovery in horizons identified by the drill loggers containing dissolution residues is a clear indication of unconsolidated or cavernous zones capable of transmitting water with little resistance. (866)

Response to Comments 3.K.1 through 3.K.3:

(Comments 3.K.1 and 3.K.2) The commenter states that DOE never collected hydrologic data in known karst features in the WIPP site. EPA believes that the available evidence demonstrates that, while there is karst present in the vicinity of the WIPP, none has been identified within the boundaries of the WIPP land withdrawal area. Also, while DOE did not collect hydrologic data at WIPP-33, DOE did collect hydrologic data in Nash Draw (located west of the site boundary) and the Culebra transmissivities from Nash Draw were much greater than those at the WIPP site. Well H-7 is located in Nash Draw, a large surface karst feature west of the WIPP. The transmissivity ($1x10^3$ square feet per day or $1x10^{-3}$ square meters per second) of the Culebra in Nash Draw is 100 times or more higher than in wells on the WIPP site, indicating that karst processes have not affected Culebra ground water flow at the WIPP site as they have in Nash Draw (see Figure 2-30 of CCA Chapter 2 for well locations in reference to Culebra transmissivities).

DOE performed numerous aquifer tests in the Rustler Formation (e.g., hydropads H-3, H-11, and H-19), as well as tracer tests at six locations (H-2, H-3, H-4, H-6, H-11 and H-19 hydropads). [CCA Chapter 2.21.4.1.2; Appendix MASS 15] DOE's data indicate that the Rustler is a fractured dolomite with nonuniform properties both horizontally and vertically, and "hydrologic connections" are noted between boreholes, which is consistent with this interpretation.

However, no data acquired to date indicate that there is cavernous porosity at the WIPP site that would act as "open caverns" or large channels, as the commenter suggests.

(Comment 3.K.3) EPA disagrees with the commenter's statement that evaporite rocks are not fractured. While this is the case for halite (e.g., the Salado), anhydrites are also produced via evaporation and are less ductile than salt and subject to fracturing. Evaporite rocks (anhydrite) may be fractured due to volume changes resulting from diagenetic processes that occur immediately after deposition during the process of lithification which converts sediment to rock. Tectonic processes, which do not need to be strong enough to cause faulting or folding, may also fracture rock.

EPA points out that solution residues are usually composed mostly of fine grained geologic materials such as clay and silt and are, because of their composition, generally of low permeability. EPA concludes that the presence of features which imply paleo-dissolution do not imply high permeability or high flow rates. Core loss is a common occurrence in the drilling of all kinds of rocks, sometimes associated with fracture and other causes related to drilling technology, as well as the occurrence of soft or incompetent rock. EPA concludes that to interpret all zones of lost core as zones of high permeability is inappropriate, as other rock features, which have nothing to do with cavernous porosity, contribute to core loss.

The WIPP Conceptual Model Peer Review Panel (July, 1996) [Appendix PEER] found that there existed in the hydrologic testing database a more than adequate basis for modeling flow at the site which represented all of the possible flow mechanisms in the Culebra. Because of the very large volumes of rock included by the multi well tests, the very long period of observation and the large number of individual well tests, the panel believed that the WIPP site and vicinity, which is one of the best characterized sites in the world, offered sufficient data to develop a sound Culebra numeric model. The results of numerical flow modeling based on this extensive database were used in over 100 model realizations which compared the measured head data to calculated equipotential fields and to independent modeling of the site hydrology by the USGS. [CCA, Appendix T FIELD]

The Peer Review Panel accepted the numerical flow model of the site hydrology because it represents all manner of flow mechanisms present in the Culebra as identified by the in situ measured characteristics of the site. No hypothetical flowpaths or mechanisms have any effect on the outcome of the model, and the claims of rapid flow related to dissolution in the Rustler rocks also have no impact on the representativeness of the model. [Peer Review Panel Report, July, 1996; Appendix PEER]

Issue L: Gypsum filling in the fractures can be dissolved.

1. I know that the Department of Energy in a response to a legitimate concern by the EPA not to worry that there are gypsum fillings in the fractures, not to mention the caverns in the Rustler

formation. But don't worry, this gypsum will not dissolve because the water that might dissolve it will be saturated with gypsum. Let's use our heads here. Rainwater is not saturated with any mineral. It becomes saturated with gypsum only when it dissolves enough gypsum to become saturated. It is absolute folly to assume that these fractures will not become larger over time, that the fillings will not be dissolved away, that gypsum caves such as found at WIPP 33 will not become larger over time. (304)

2. DOE convinced EPA that dissolution processes are not presently occurring in the Rustler formation and that conditions are not expected to change during the regulatory period, that is, in the next 10,000 years. DOE's argument is that infiltrating waters that would cause the dissolution would become saturated with respect to gypsum and therefore would be unable to dissolve. The truth is that infiltrating ground water will not be saturated with gypsum until it has dissolved enough gypsum to become saturated. Presently some Rustler ground water is saturated with respect to gypsum and some is not. Concentrations of dissolved calcium and sulphate vary not only from well to well, but also from time to time. (608)

3. EPA states that it agrees with the elimination of dissolution of Culebra fracture fillings as a FEP, based on arguments appearing in Appendix SCR.1.1.5.1 (CARD 14 at 14-33) but also relying on post-CCA submissions by DOE (id.). This issue was addressed by Prof. Roger Y. Anderson (II-H-03, II-H-05, II-H-20). Anderson has pointed out that the historic dissolution at the WIPP site has broadly been interpreted as post depositional and is an ongoing process (II-H-03 at 2). He has stated that, with wetter climate, additional undersaturated waters will have the capacity to dissolve components of the Rustler (id.). (983)

4. From an organizational point of view, DOE’s hydrogeological consultants have emphasized hydrostratigraphic modeling, but they have neglected the implications of dissolution, less amenable to modeling, features arguably first in importance in terrain as novel as that at WIPP. Alternative geological conditions and hydrological implications were certainly debated-over the years, but the numerical inclinations of the many prevailed over the qualitative preferences of the few, to favor a layer-cake model they were capable of solving, given the paucity of data. Too little credence was given to the implications of field observations, such as the obvious sinkholes in and west of the LWA, as well as in Nash Draw, or to deductions from the discontinuous Mescalero Caliche. The techniques of drilling, coring and logging were inherited from potash explorations requiring only rock composition, so the geologists and hydrologists were inattentive to the need for and feasibility of obtaining data relevant to the hydrology. The geometry of Rustler and Dewey Lake fractures and dissolution features varying across the site were neglected, to the detriment of the hydrological testing and modeling efforts that followed. (1321)

<u>Response to Comments 3.L.1 through 3.L.4:</u>

These comments are interpreted to mean that the lack of gypsum fillings in the Rustler has caused or will cause openings that will affect ground water flow in the Rustler Formation at the WIPP site. EPA agrees that post-depositional dissolution of halite has probably occurred in the past, and cycles of fracture filling and dissolution are evident in the rock record. [Docket: A-93-

02, Item II-G-1, Appendix FAC] Also, while EPA does not believe that dissolution and precipitation are occurring at appreciable rates at WIPP, soluble minerals in the rock column above the Culebra and very slow Culebra recharge (lateral and vertical) would facilitate slow saturation of infiltrating waters. For example, The Forty Niner Member, the Tamarisk Member and the Unnamed Lower Member of the Rustler Formation at the WIPP site are comprised of numerous gypsum interbeds. The Mescalero Caliche also contains significant trace amounts of gypsum. EPA believes that there is abundant gypsum available to saturate slowly infiltrating water. Further, ground water contained in the Rustler rocks has migrated to its present location within permeable members of the Rustler Formation over possibly thousands of years; for example, the Culebra is still responding to changes in precipitation from the end of the last ice age. [CCA Appendix MASS 14.2] The slow lateral and vertical movement of water allows sufficient time for very slow dissolution (and subsequent saturation) and precipitation to occur in the system. EPA agrees that mineral dissolution and precipitation may occur at the WIPP site, but concludes that the rate of this dissolution is imperceptibly slow. The presence of different geochemical facies in the Rustler Formation also implies that little mixing through lateral flow is occurring. Because of the slow response time of the system to recharge, dissolution will not impact site hydrologic conditions or the WIPP's containment capabilities during the 10,000 year regulatory period

Geochemical and hydrogeologic data from tracer tests does not indicate that large scale dissolution in the Culebra is occurring as suggested by the comments. EPA has examined ground water modeling performed by DOE and agrees with the Conceptual Peer Review Panel [Docket: A-93-02, Item II-G-1, Appendix PEER] that the hydrologic model used by DOE adequately represents site conditions. The Peer Review Panel drew this conclusion based on the tremendous amount of hydrologic data from which the model was developed. EPA points out that although Comment 1321 states that no site-specific hydrologic data have been collected, in fact numerous well borings were installed at or near the WIPP [Appendix BH], specifically to obtain hydrologic data (e.g., GMP wells). The geochemistry of the Culebra is highly variable throughout the WIPP area, and has been described by DOE as four zones with varying calcium sulfate (gypsum) concentrations. [Docket A-93-02, Item II-I-31] DOE indicates that previous interpretations by Anderson (1995) indicated that this water quality variation showed the calcium sulfate concentration to be undersaturated in an area of higher transmissivity south of WIPP, implying dissolution. More recent calculations [Docket A-93-02 Item II-G-1, Ref. No. 590] take into account competing ions, and do not support Anderson's implications that calcium sulfate dissolution is ongoing in the area.

DOE addressed the effects of wetter climate conditions and the effect of previous dissolution of fracture infillings in the Culebra on recharge rates and ground water flow velocities in Corbet's SECOFL3D analyses [Docket: A-93-02, Item II-G-1. Ref. 147] of the regional ground water basin model. However, DOE's modeling efforts in SECOFL3D did not explicitly consider the potential increase in the dissolution of the fracture infillings in the Culebra as a result of the introduction of ground water that is less saturated with respect to gypsum.

In a letter dated January 24, 1997 [Docket: A-93-02, Item II-I-03, Enclosure 2], DOE provided additional information at EPA's request [Docket: A-93-02, Item II-I-01] regarding the transmissivity (Note: transmissivity is equal to the permeability multiplied by the aquifer thickness.) uncertainty resulting from potential fracture infilling dissolution. Specifically, documentation supporting DOE's analysis was contained in a Sandia National Laboratories memorandum dated January 16, 1997, Corbet et al. [Docket: A-93-02, Item II-I-03, Enclosure 2] included in DOE's response. Additional documentation was found in Corbet and Knupp's SECOFL3D analysis of the regional ground water basin model. [Docket: A-93-02, Item II-G-1. Ref. 147]

The Corbet et al. memorandum states that it is "not possible, at this time, to absolutely rule out some change to the hydraulic properties of the Culebra over the next 10,000 years," and also acknowledged that dissolution has taken place in the Culebra's fracture infillings. It concluded, however, "For any climate scenario, it is likely that ground water is saturated with respect to gypsum before it reaches the Culebra and will not dissolve additional gypsum from the Culebra," and "Although flow in the Culebra responds rapidly to changes in recharge at the water table, perhaps in hundreds of years, recharge takes tens of thousands of years to reach the Culebra." Thus, DOE found that it was not necessary to model the Culebra with higher transmissivities to account for the potential for fracture infilling dissolution. Accordingly, DOE only modeled a range of transmissivities that were measured in situ in the Culebra.

Since DOE's arguments are somewhat qualitative in nature EPA also relied upon more quantitative aspects of the CCA to make a determination that the potential changes in the transmissivity of the Culebra have been adequately addressed in the Performance Assessment Modeling including the following: 1) other Culebra parameters that would have the same effect on radionuclide transport, as an increase in permeability, were statistically sampled in the CCA; 2) DOE made adjustments to the transmissivities in the Culebra to account for the potential effects of mining subsidence; 3) results of the CCA indicate that the risks associated with radionuclide transport through the Culebra are relatively insignificant when compared to those related to spallings. A thorough analysis of the treatment of Culebra transmissivity in performance assessment modeling is provided in Sections 1.4, 2.4, and 4.4 of CARD 23. [Docket: A-93-02, V-B-2]

Issue M: Rainwater has infiltrated to the Rustler formation to dissolve the salt and carry it away and it ultimately ends up in the salt lake.

1. The rainwater has infiltrated to the Rustler formation to dissolve that salt and carried it away and it ultimately ends up in the salt lake. The Department of Energy quotes the studies of Dennis Powers and Robert Holt who work together as a team, they are both on the DOE payroll, and they are the only ones of whom I'm aware who deny this. Who is to say that the salt and the Rustler formation was never deposited in the first place, therefore, it was never dissolved away, not to worry, there's never been any dissolution in the Rustler formation. How then did concentrations of dissolved salt at 11,000, 13,000, 18,000, even 45,000 milligrams per liter, that is four and a half percent, how did that much salt end up in test wells in the Rustler formation

where there's no salt in the Rustler formation? The salt has all been dissolved away across the western part of the WIPP site. Not only that, but some of the top of the Salado salt has been dissolved away at the WIPP site, and the Department of Energy denies this too. (305)

Response to Comment 3.M.1:

The commenter believes that the presence of dissolved salts in the Rustler Formation ground water and lack of bedded Rustler salt is evidence of contemporary Rustler salt dissolution. EPA agrees that bedded salt thickness in the Rustler Formation varies laterally across the WIPP area, but EPA believes that evaporite distribution in the Rustler is likely due to both depositional processes and post-depositional dissolution. EPA does not believe that ongoing dissolution is sufficient to disrupt the Culebra hydrologic system beyond that modeled in PA since in the performance assessment modeling, DOE assumed that the hydraulic conductivity of the Culebra could increase up to 1,000 times present day values due to the effects of potash mining. [CARD 23, Response to Issue L, Docket: A- 93-02, II-B-01] However, slow moving ground water in the Culebra can become saturated with soluble minerals, and sufficient salt and other soluble minerals are present in the Rustler Formation (e.g., Forty-Niner Member, Tamarisk Member and the Unnamed Lower Member) to adequately explain the high total dissolved solid concentration in Rustler ground water. The existence of a salt lake in the WIPP region is due to multiple sources: Rustler discharge, potash mine effluent, and evaporation.

Issue N: There is no evidence that karst found at WIPP-33 extends into the WIPP site because DOE has not done the necessary testing.

1. DOE states that there's no evidence from hydraulic conductivities that the karst development found at WIPP-33 extends into the WIPP site. The truth is that WIPP-33 was never converted to a hydrologic test well and so there are no multi well pump tests designed to determine whether or not the five water filled caverns WIPP-33, two in Magenta dolomite, two in Forty-niner gypsum and one in Dewey Lake siltstone are hydraulically connected to the WIPP site. If there's no evidence, this is because DOE has not done the necessary testing. Absence of evidence is not evidence of absence. (609)

Response to Comment 3.N.1:

DOE identified that WIPP-33 exhibited karst features. The commenter states that no hydrologic testing was done to determine whether or not the void spaces are hydrologically connected to the WIPP site. While WIPP-33 was not turned into a hydrologic test pad, DOE does have hydrologic wells from karst areas, e.g., wells H-7 and WIPP-25. Void spaces in the Culebra Dolomite (including fractures), are part of the hydrologic model of the Culebra Formation, are represented in the results of hydrologic testing, and are considered in the performance evaluation of the site. No cavernous flow has been detected on the WIPP site. Hydrologic testing has been conducted in numerous locations at the WIPP [CCA Chapter 2.2.1.4.1, Appendix HYDRO, Appendix MASS 15], and has been conducted near wells suspected of being in areas of dissolution (i.e. between WIPP-13 and WIPP-25). Tests confirm that transmissivities in the Culebra vary significantly from east to west in the WIPP area, and this was modeled by DOE in its PA calculations (see Appendix TFIELD for a discussion on how DOE incorporated the transmissivity data into the PA calculations). EPA concludes that sufficient hydrologic testing has been performed to indicate that subsurface karst features affect flow in Nash Draw but not at the WIPP site itself, and that these results have been integrated into the transmissivities modeled in the performance assessment.

Issue O: DOE's Rustler conceptual model is inconsistent with hard data.

1. Corbett and Knupp's characterization of ground water flow paths in the Culebra is inconsistent with hard data. (17)

2. DOE cannot rely on speculation that there are three distinct areas of recharge at unknown locations distant from the WIPP site. DOE must either accept that recharge to the Dewey Lake Redbeds and the Rustler Formation occurs at the WIPP site itself, wherever the Santa Rosa sandstone is not present, or admits that it lacks a rudimentary understanding of the regional ground water system. (874)

3. Extensive reports on hydrogeologic flow in and around the WIPP site indicate that the CCA models characterizing hydrogeologic flow are at odds with DOE's own physical data. In the early 1980's Dr. Gibbons and Dr. Barrows both presented studies which concluded that the hydrogeology in and around the WIPP site involved multiple flow patterns which were probably too complex to characterize with a single model. (1201)

4. The EPA proposed rule mentions this issue [Culebra geochemical facies] in FR, p. 58799; CARD 14-28; and TSD V-B-3, p. 82, but simply cites the additional information provided by the DOE (Docket Item II-1-31) and the conclusion that "it was sufficient to explain Culebra geochemical facies within the WIPP area" (CARD 14-28). No discussion of the new hypothesis and the EPA conclusion is provided. There is also no discussion of how the new conceptual model may affect any assumptions made in the containment requirement compliance calculations. (1236)

Response to Comments 3.O.1 through 3.O.4:

EPA believes that Comment 3.O.1 was made in reference to geochemical characteristics of Culebra ground water which were interpreted to be inconsistent with the current ground water flow direction. DOE indicated in CCA Chapter 2.4.2.1 [pp. 2-166 to 2-169] that there is considerable variation in the ground water chemistry of the Culebra. DOE provided information supplemental (see below) to the CCA pertaining to ground water flow and geochemistry within the Culebra member of the Rustler. In the CCA, DOE did not use the ground water basin model to explain geochemical conditions within Culebra ground water and current ground water flow directions and velocities [CCA Chapter 2.2.1.4.1.2]; instead, the CCA stated that previous models had not been able to "consistently relate hydrogeochemical facies, radiogenic ages and flow constraints in the Culebra [CCA Chapter 2.2.1.4.1.2, p. 2-123] (in the discussions of Culebra geochemistry, DOE has used the term "facies" interchangeably with the word "zone" to refer to lateral changes in hydrogeochemical conditions within the Culebra).

In a letter dated May 14, 1997 [Docket A-93-02, Item II-I-31, No. 1] DOE submitted additional information that described the Culebra hydrochemical facies with respect to potential ground water infiltration rates, Culebra flow velocities, and geochemical facies. This information, together with the ground water basin conceptual model [Chapter 2 of the CCA, pp. 2-114 to 2-124, Docket: A-93-02, II-G-1] describes DOE's understanding of current and historic ground water flow and recharge. In this letter, DOE explained that it modified the conceptualization of Culebra ground water flow in the CCA. Essentially, DOE's conceptual model of flow in the Culebra has the flow changing directions over time, depending on climatic conditions. In wetter climates, such as in the Pleistocene, DOE believes that Culebra ground water flowed in a more westerly direction. It now flows primarily in a southerly direction. This new conceptualization of current Culebra geochemistry and ground water flow thus provides an explanation of the Culebra geochemical data in the context of Culebra ground water flow. This was not presented in DOE's October, 1996 CCA submission.

The Peer Review Panel accepted the numerical flow model of the site hydrology [WIPP Peer Review Panel Report, July 1996] because it includes numerous flow mechanisms represented by extensive in situ measurements of the hydrologic characteristics of the site. The model is supported by the information contained in Appendix T FIELD. [Docket: A-93-02, Item II-G-1] The Culebra Formation is conceptualized as a confined system, which does not receive significant local recharge from other members of the Rustler Formation via vertical fractures or dissolution features which hydrologically interconnect members of the Rustler Formation. For example, the hydraulic heads of the Culebra and Magenta Dolomite members of the Rustler formation have different values with different flow directions. EPA concluded that the complexity of flow within the Culebra is adequately represented by the numerical flow model based on hydrologic testing and no reinterpretation of the mechanisms or rates of flow within the site has any impact on the representativeness of that model.

The new conceptualization in which the Culebra geochemistry and flow are discussed is referred to as the ground water basin model. This model offers a three dimensional approach to treatment of Supra-Salado rock units, and assumes very slow vertical leakage between rock units of the Rustler exists (where hydraulic head is present). In the ground water basin model used in compliance calculations, flow in the Culebra is considered transient. This differs from previous interpretations, wherein no-flow was assumed between Rustler units. The model assumes that the ground water system is dynamic and is responding to the drying climate that has occurred since the late Pleistocene period. DOE assumed that recharge rates during the late Pleistocene period were sufficient to maintain the water table near land surface, but the recharge rates have since dropped significantly. Therefore, the impact of local topography on ground water flow was greater during wetter periods, with discharge from the Rustler to the west. Flow is dominated by more regional topographic effects during drier times, with flow to a more southerly direction as is the case in the current situation.

In the CCA, DOE identified four hydrogeochemical facies within the Culebra in the WIPP area in CCA Chapter 2.4.2.1 [p. 2-166] and Figure 2-40 [p. 2-167]:

- ♦ Zone A - saline (2-3 molal) NaCl brines, Mg/Ca ratio of 1.2 to 2;

- Zone B - dilute (<0.1 molal) CaSO4 - rich ground water;
- Zone C - variable composition (0.3-1.6 molal); Mg/Ca ratio 0.3 to 1.2; and
- Zone D - high salinities (3-7 molal); K/Na weight ratios (0.2).

In Docket: A-93-02, Item II-I-31, No. 1, DOE concluded that Facies A ground water flow is slow, has not changed over the last 14,000 years, and probably recharged more than 600,000 years ago. Vertical leakage occurs to Facies A, and both lateral and vertical ground water flow rates are extremely low. Facies B occurs in an area with greater vertical fracturing in the Culebra, and therefore exhibits more vertical infiltration and more rapid lateral flow in the Culebra. According to DOE, flow in Facies B is currently to the south (it may mix with Facies C water to the southeast) but was more toward the west during wetter climates; vertical infiltration from the Dewey Lake to the Culebra Facies B is assumed by DOE to have occurred during wetter climates in an area south of the WIPP site. DOE theorized that Facies C water was not diluted to create Facies B water. Facies C occurred "in between" Facies A and B, and ground water flow entered the Culebra prior to the climate change (to drier conditions) 14,000 years ago. Facies C ground water flow is to the south at WIPP, where DOE theorized that it joins with a small amount of Facies A solute being transported from the east. Ground water flow rate in Facies C is faster than in A but slower than in B, and the proposed recharge area from the Dewey Lake to the Culebra was to the northeast of the WIPP site. DOE theorized that Facies C ground water infiltrated into the Dewey Lake and then interacted with anhydrite and halite along its path to the Culebra, where it mixed with smaller amounts of Facies A water. With information submitted in May 14, 1997 letter [Docket A-93-02, Item II-I-31], DOE concluded that the presence of anhydrite within Rustler units does not preclude slow downward infiltration, as had been previously argued by DOE.

In the 1992 PA [DOE 1992], DOE believed the geochemistry of Culebra ground water was inconsistent with flow directions. This was based on the premise that Facies C water must transform to Facies B water (e.g. become "fresher"), which is inconsistent with the observed flow direction. According to the information submitted in the May 14, 1997 letter [Docket A-93-02, Item II-I-31], DOE now contends that the observed geochemistry and flow directions can be explained with different recharge areas and Culebra travel paths.

Hydrochemical facies within the Culebra were not adequately described with respect to origin in the CCA. In the May 14, 1997 letter [Docket A-93-02, Item II-I-31, No. 1], DOE submitted additional information that described the Culebra hydrochemical facies with respect to potential ground water infiltration rates, Culebra flow velocities, and geochemical facies. EPA examined DOE's explanation, together with ground water flow and ground water quality data presented in the CCA and associated references. EPA also evaluated the ground water basin model as a conceptualization and as it was applied in the CCA. [CARD 23, Docket: A-93-02, Item V-B-2, Sections 23.A.1.3.2.2 and 23.A.1.4] EPA concluded, based on its evaluation, that DOE's explanation of ground water flow in the Culebra is an acceptable interpretation of the hydrologic and geochemical data, and any new interpretations provided by DOE following submission of the CCA did not impact the contaminant capabilities of WIPP.

(Comment 3.O.2) EPA accepts that recharge to the Dewey Lake Redbeds and the Rustler Formation occurs at the WIPP site. In the May 14, 1997 letter [Docket A-93-02, Item II-I-31, No. 1], DOE submitted additional information that described the Culebra hydrochemical facies with respect to potential ground water infiltration rates, Culebra flow velocities, and geochemical facies. In this letter, DOE explained that it modified the conceptualization of Culebra ground water flow in the CCA in the ground water basin model. The ground water basin model recognizes the possibility of localized downward infiltration, and DOE has included ground water recharge (e.g., Dewey Lake) areas local to the WIPP in its ground water basin modeling for the Culebra Member of the Rustler formation. DOE assumed that the water table would rise in response to increased recharge caused by up to twice the normal site precipitation (Docket: A-93-02, II-G-1, CCA Chapter 6.4.9). EPA evaluated the ground water basin model as a conceptualization and as it was applied in the CCA. [CARD 23, Docket: A-93-02, Item V-B-2, Sections 23.A.1.3.2.2 and 23.A.1.4] EPA concluded, based on its evaluation, that DOE's explanation of ground water flow in the Culebra is an acceptable interpretation of the hydrologic and geochemical data.

Issue P: DOE's estimate of the age of ground water is based on an unreliable methodology.

1. DOE estimates Culebra ground water is 12,000 years old, however, this estimate is based on a methodology that is not reliable (see EEG #35 & #39) and can, in fact, only date water as being more than 52 years old. (18)

2. DOE claims that Culebra ground water is more than 12,000 years old. Even if every Culebra test well were tested and found not to contain tritium, this would only mean that Culebra water, at these specific locations, is at least 52 years old. Stable isotope signatures and radiocarbon dating are not reliable means of determining the age of ground water. DOE says that recharge rates "in excess of 12,000 years are consistent with the flow pattern predicted by the ground water basin modeling." A flow pattern, even if correct, reveals nothing about the age of the water. Not all Culebra water at WIPP is saturated with respect to gypsum. The lowest reported concentrations of dissolved gypsum in the Culebra test wells within the WIPP site vary by a factor of seven. Undersaturation with respect to halite can and should be attributed to short residence times. (875)

3. The EEG has never accepted the bases for the assumption of the Rustler water being "fossil" water, having been recharged under climatic conditions significantly different from the present. Since the EPA has accepted this hypothesis as postulated by the DOE, it is important to state the reasons in detail for the EEG believing that the Rustler water is a mixture of "old" and "new" water, including modern day meteoric recharge. (1231)

4. The EEG (Chapman, 1986) compiled stable isotope data from throughout southeastern New Mexico and compared them to data from the WIPP area. The stable isotopic compositions of most samples of ground water from the Rustler Formation were found to be similar to the composition of other, verifiably young, ground water in the area. Though the stable isotope data cannot indicate ages for water in the various aquifers, neither did the data show any distinction between most Rustler ground water and verifiably young ground water. (1232)

5. Based on the data contained in Lambert (1986), the EEG came to a different conclusion. In all cases, where ^{14}C could reasonably be expected to give useful results, it did so. Although there were only a limited number of uncontaminated samples, the geographic distribution of the resultant ages is hydrogeologically reasonable. (1233)

<u>Response to Comments 3.P.1 through 3.P.5:</u>

The Environmental Evaluation Group (EEG) Report No. 35 [Docket A-93-02, Item II-G-1, Reference No. 118] states that available isotopic data at the WIPP site are quite similar to "verifiably young ground water" [p. 49] found elsewhere in the WIPP area. The author provides tritium unit data for wells outside of the Delaware Basin [Table 3], noting that the presence of tritium over 4 tritium units indicates that the ground water has been in contact with the atmosphere sometime during the last 30 years. The author provides oxygen and deuterium values for these wells outside of the Delaware Basin and other wells nearer the WIPP, concluding that "the isotopic composition of most of the samples of ground water from the Magenta and Culebra aquifers, and for the Rustler/Salado interface zone west of the WIPP site are similar to that of other ground water in southeastern New Mexico." [p. 63] The author then extends this analogy, implying that since the tritium values for ground water outside of the basin indicates potential recent meteoric recharge, then all ground water in the study, including that at WIPP, received recent (i.e., post 1952) meteoric water recharge (i.e., ground waters that originated at the ground surface) because the WIPP area and other isotopic values are similar. Tritium values are used to identify ground water which has received meteoric recharge after 1952 since the main source of tritium is atmospheric testing of thermonuclear weapons which began in 1952. The author concludes, however, that these cannot indicate ages for water in the various aquifers, but can point to isotopic similarities. The author further concludes that "the age of water in the Rustler Formation and the presence or absence of modern recharge cannot be determined on the basis of stable isotopic composition alone." [p. vi]

EPA agrees with these conclusions. In addition, EPA believes that the use of data outside of the Delaware Basin acquired in different hydrologic systems, recharge/discharge points, etc. cannot be extended without reservation to the WIPP site. Similarities of ground water quality and isotopic composition do not definitively indicate similar ground water "age", as implied by the commenter. Ground water data obtained near WIPP is not universally "similar" to that elsewhere in southeastern New Mexico, and in fact numerous data points fall well outside of the meteoric water line, implying that the characteristics of this ground water -- including its "age" are in fact dissimilar to that of those units in southeastern New Mexico. EPA also notes that later reports [Lambert and Harvey, 1987, Docket: A- 93-02, II-G-1, Ref. No. 378] conclude that tritium samples from WIPP-area wells indicate little meteoric input in the last 40 years. EPA concludes that the extension of regional data to site-specific WIPP conditions is not an absolute "measure" of ground water "age" at the WIPP, and there is in fact no data in the cited reports that directly indicate that WIPP ground water is less than 46 years in age. The 46 year time frame represents the approximate amount of time since the start of atmospheric thermonuclear weapons tests.

The commenter also indicates that DOE's methodology for determining ground water "age" in the Culebra is flawed. This is presumably in reference to radiocarbon dating (which indicate the age of Rustler ground water to be approximately 12-16 thousand years old), or uranium isotope data, which DOE believes indicates a long ground water residence time (10-30 thousand years) based on U234/U238 ratios. Chapman [EEG Report No. 39, Docket A-93-02, Item II-G-1, Reference No. 119] did not agree that the isotope residence time and ground water age could be equated, but did agree that such ratios can occur in areas of low transmissivity where the travel and subsequent residence time are low. [p. v] EPA has examined these data and arguments by stakeholders, and believes that while there is validity to arguments that downward infiltration of surface meteoric waters occurs at WIPP, the rate of such infiltration is probably low. In the CCA [Appendix CLI, p. 20], DOE states "Questions about recharge to the Rustler Formation and the true age of WIPP-area ground water remain unanswered. In the absence of definitive data, this report makes no assumptions about ground water age." DOE, therefore, does not take a definitive stand that ground water is 12,000 years old, as stated by the commenters.

EEG Report No. 39 [Docket A-93-02, Item II-G-1, Reference No. 119] indicates that general geochemical data imply more recent or different recharge events than DOE was advocating at that the time this EEG report was written. [1988] DOE has since modified its perception of the hydrologic system at WIPP to include downward infiltration events, although such events are not modeled to occur rapidly (i.e., tens of years). DOE has developed the ground water basin model [Docket A-93-02, Item II-I-31], which examines ground water flow within the Rustler and identifies potential recharge locations that takes into account the geochemical characteristics of Culebra ground water. This model recognizes four different ground water geochemical zones that differ in geochemical characteristics, recharge rates, and recharge locations. This new interpretation allows for very slow vertical infiltration to the Culebra through overlying beds, although the primary "source" of ground water will be lateral flow from the north of the site. EPA reviewed DOE's conceptualization of ground water flow and recharge, and believes that it provides a realistic representation of site conditions because it conceptualizes slow, downward infiltration of meteoric water. EPA agrees that the absence of tritium in ground water only indicates that ground water has not been recharged in the last 50 years. EPA also recognizes that age dating techniques provide data that have been interpreted differently by others. [Chapman D] However, EPA examined all data pertaining to ground water flow in the Rustler, and believes DOE's <u>total</u> conceptualization adequately described system behavior for the purposes of performance assessment. [Docket: A-93-02, Items V-B-3, Section IV.C.1.i and V-B-7, Section 3.0]

(Comment 3.P.5) DOE concluded and EPA agreed that ^{14}C dates from samples taken in wells not contaminated by organic additives in drilling fluids supported minimum ground water ages of around 13,000 years. [Fred Phillips, 1987; Review of Lambert 1986 to Chapman, WPO 26144, Docket:A-93-02, V-B-1] Vertical recharge to the Culebra from any source of younger water might be capable of reducing minimum age dates but can not cause anomalous older waters to occur. The consistently old ^{14}C ages, the very low probability of significant recharge from the site surface [LeGrand in Chaturvedi and Channell, 1985, EEG-32, Docket: A-93-02, Item II-A-41] and the absence of point sources of local recharge in the hydrologic testing results strongly refute arguments that Culebra water is "young." The DOE site flow model includes flow within the Rustler Formation. The numerical site flow model accepted by the Conceptual Models Peer Review Panel [July, 1996] is based on abundant in situ hydrologic data and does not imply or permit the presence of strong local sources of recharge of young meteoric water through the parts of the Rustler which overlay the Culebra.

References

Phillips, F. M., of Daniel B. Stephens & Assoc. and New Mexico Tech - Letter reviewing Lambert 1986 to Chapman, covered by letter from Robert Neill stating general agreement with the technical conclusions, WPO 26144

LeGrand, H.E., 1982 and 1983, Consultant reports appended to: The Rustler Formation as a transport medium for contaminated ground water. Chaturvedi and Channell, 1985. EEG 32 (Docket: A-93-02, Item II-A-41).

Issue Q: The source of ground water flow into Laguna Grande de la Sal is uncertain.

1. DOE keeps saying that it is not clear why ground water flows must discharge into Laguna Grande de la Sal, but it is the lowest point in the area and the estimated annual flow of 6,000,000 cubic meters of water into Laguna Grande must come from somewhere. (15)

2. 390 cubic feet/second (approximately 350,000,000 cubic meters per year) water flow into Laguna Grande de la Sal is not due to potash mining, but from natural sources. (19)

3. The amount of water flowing into this lake, about 6 million cubic feet per year, tells you the amount of water in the ground water aquifers that flow throughout the watershed, including the WIPP site. It is about 100 times as much water as the Department of Energy cares to admit to. This means that there is about 100 times as much rainwater recharge to the ground water aquifers as the DOE cares to admit to. That's why you have underground streams flowing across the WIPP site and flowing into Nash Draw. The Department of Energy must account for this water. They have been allowed to model the WIPP site only so far as the WIPP site boundary and to ignore all natural features beyond the boundaries. (291)

Response to Comments 3.Q.1 through 3.Q.3:

These comments were interpreted to mean that the commenters believe DOE is uncertain of the source of the water flowing into Laguna Grande de la Sal, and ground water flow to the spring may be via conduit-type flow due to the presence of karst features.

In the CCA's description of ground water flow in units above the Salado provided in Section 2.2.1.4 [p. 2-114], DOE acknowledged that Nash Draw and the Pecos River are areas where discharge of ground water to ground surface occurs, and specifically references Surprise Springs and the saline lakes in Nash Draw. Surprise Springs discharges into Laguna Grande de la Sal.

In the discussion of the Culebra hydrology provided in Section 2.2.1.4.1.2 [p. 2-120] of the CCA, DOE also indicated that flow in the Culebra is dominantly lateral and southward except in discharge areas along the west or south boundaries of the ground water basin. Based on information provided in Appendix HYDRO [pp. 47 to 55; Docket A-93-02, Item G-II-1], regarding the"brine aquifer," which occurs within the Rustler-Salado Contact Zone residuum west of the WIPP area in Nash Draw, DOE also documented that the sources of water in Laguna Grande de la Sal were precipitation, surface drainage, ground water inflow from upper units above the brine aquifer and possibly inflow from mining activities that take place further north in Nash Draw. DOE further indicated that discharge of ground water into Laguna Grande de la Sal is by flow of seeps and springs, particularly along the northern end of the lake, and Surprise Springs is specifically identified by DOE as a potential ground water discharge point.

However, in Appendix HYDRO [p. 49], DOE indicated that because sodium and chloride concentrations in samples from Surprise Spring and samples of Culebra and Rustler-Salado contact residuum water collected from test-hole WIPP-29 (located near Surprise Spring) are different, the Culebra and the Rustler-Salado contact residuum are not the source of water in Surprise Springs. Appendix HYDRO [pp. 53 and 61] also indicated that the discharge point for the ground water within the Culebra and the Rustler-Salado contact residuum is located south of Laguna de la Sal, near Malaga Bend. In summary, DOE acknowledged within the CCA that sources of water in Laguna Grande de la Sal included discharge of ground water from the units above the Salado, although DOE does not necessarily agree that the Culebra is the sole source of this discharge.

In addition, DOE's model domain includes Laguna Grande de la Sal [Figure 2-29, Docket A-93-02, Item II-G-1], and the model boundary extends well beyond the WIPP site boundary. EPA has evaluated DOE's ground water basin model, and concludes that it uses appropriate and realistic boundary conditions to simulate ground water flow within the Culebra in the WIPP area [CARD 23, Docket: A-93-02, Item V-B-2, Sections 23.A.1.3.2.2 and 23.A.1.4] and Technical Support Document: Ground water Flow and Contaminant Transport Modeling at WIPP [Docket: A-93-02, Docket V-B-7] for further discussion of the ground water basin model). EPA also examined the information regarding the hydrology of the units above the Salado Formation and DOE's conceptualization of the ground water flow model, including supplementary information submitted in letters dated May 2, 1997 [Docket A-93-02, Item V-B-6] and May 14, 1997 [Docket A-93-02, Item II-I-17, Section 3.0], and concluded that the information is adequate.

In summary, DOE acknowledged within the CCA that sources of water in Laguna Grande de la Sal included discharge of ground water from the units above the Salado. EPA believes that the presence of springs and seeps along the northern end of Laguna de la Sal is not by itself an indication of the presence of karst topography or channelized flow through an aquifer. Rather, the seeps and springs represent the locations where the ground water table/potentiometric surface intercepts the ground surface. Based on WIPP field observations and site-specific hydrologic information, EPA concludes that there is no indication that any cavernous or other karst-related flow is present at the WIPP. EPA disagrees with the comments and concurs with DOE's conceptualization of ground water flow in the Culebra which includes the presence of fractures within the Culebra, as well as recharge and discharge areas for ground water that are more consistent with potential discharge to areas west of the WIPP.

Issue R: DOE's mapping is crude.

1. DOE's mapping is crude and ignores the importance of small scale features. (22)

Response to Comment 3.R.1:

The primary requirement for the contour interval for topographic map(s) of the vicinity of the disposal system as specified in 40 CFR § 194.14(h) is that the contour interval shall be sufficient to show clearly the pattern of surface water flow in the vicinity of the disposal system. DOE provided four topographic maps, including two U.S. Geological Survey 15 minute quadrangle topographic maps of Livingston Ridge and Los Medanos as attachments to Volume I of the CCA, to show the pattern of surface water drainage in the vicinity of the WIPP. The two 15 minute quadrangle maps each covered an area of 7.5 miles by 8.5 miles (12 kilometers by 13.7 kilometers) at a contour interval of 10 feet. EPA reviewed the topographic maps provided in the CCA and determined that the maps were of appropriate scale to show features at the WIPP.

Issue S: Culebra ground water is potable within the WIPP site.

1. Culebra ground water is potable within the WIPP site, contrary to DOE assertions. (21)

Response to Comment 3.S.1:

Appendix USDW of the CCA includes data concerning the potability of Culebra ground water. Table USDW-2 presents data indicating that of 21 wells located within the WIPP boundary that have been sampled (with a total of 55 samples collected), 20 contained levels of total dissolved solids (TDS) that exceeded the minimum standard for potability (10,000 mg/l, p. USDW-19-USDW-22). The one well that did not exceed the standard, H-02b, had a TDS concentration of 8,890 milligrams per liter (mg/l). The commenter has not submitted any data or information demonstrating or indicating that these data are incorrect.

Issue T: Ground water flow directions are not consistent with observed hydraulic heads.

1. DOE's ground water flow directions are not consistent with observed hydro heads (i.e., ground water typically does not flow upgradient). (23)

Response to Comment 3.T.1:

EPA agrees that ground water typically does not flow upgradient, but DOE's flow directions are consistent with observed heads. EPA assumed that this comment refers to the Culebra, since it is the most transmissive unit above the repository and has the most hydrologic measurements. Hydraulic heads of the Culebra are presented in Chapter 2.2 of the CCA. CCA Figure 2-31 is a map of hydraulic heads in the Culebra. The hydraulic heads generally decrease from the north

(932 meters) to the south (912 meters). From this map it can be inferred that water will flow from the north to the south, and this is where DOE's modeling indicates that the primary direction of flow is expected. DOE presents examples of expected travel paths (from north to south) in LaVenue et. al. [1990; Figure 5.24 in CCA Reference 393] and in the 1992 Performance Assessment. [Figure 6.8-8 in volume 4 of Reference 563]

Issue U: Fracture distribution in the Culebra is complex and the Culebra should not be modeled as a single-porosity media.

1. The Culebra should not be modeled as a single-porosity media subject to Darcy's law. (24)

2. The pattern of fracture distribution and corresponding transmissivity values distribution in the Culebra is too complex to be explained away in a simple statement like "density of open fractures in the Culebra decreases to the east," and as expected, has become more complex with additional data acquisition. (1230)

Response to Comments 3.U.1 and 3.U.2:

The CCA does not model the Culebra as a single-porosity media. It is modeled assuming dual porosity, and the calculated transmissivity values are based on actual well data, which reflect Culebra fracture distribution at the WIPP. These were used to develop the transmissivity fields used in PA. [Docket: A- 93-02, II-G-1, Appendix TFIELD, and Chapter 6.4.6.2.1] This dual porosity conceptual model recognizes that both matrix and fracture flow occur at the site. The use of dual porosity assumes ground water flows through fractures, but allows solutes to diffuse into the matrix. The Culebra is conceptualized as a heterogenous porous media represented by variations in transmissivity, with two types of porosity (matrix and fracture). [Section 6.4.6.2 of the CCA, p. 6-124] However, DOE did not model channelized flow characteristic of a karst terrain within the Culebra, as geologic and hydrologic data do not support the presence of such features. EPA agrees that the conceptualization should consider the possibility of both fracture and matrix flow within the Culebra, as the geologic data present substantial evidence to indicate that fractures occur within the Culebra at the WIPP site. However, EPA also agrees that this conceptualization need not address channel flow, as no evidence of such flow has been observed or measured at the WIPP.

Issue V: Culebra ground water is not saturated with gypsum.

1. Culebra ground water is not saturated with gypsum. (25)

Response to Comment 3.V.1:

EPA believes that this comment is made in reference to a high transmissivity zone or "finger" extending northward in the south central portion of the WIPP site. EPA interprets this comment to express concern that since ground water in this high transmissivity area does not exhibit saturation relative to gypsum, ongoing dissolution could be occurring. EPA recognizes that ground water quality in the Culebra is highly variable throughout the WIPP area, and has been described by DOE as four zones with water quality ranging from highly saline (up to 7 molal sodium chloride) to dilute (less than .1 molal), with varying calcium sulfate (gypsum) concentrations. [Docket A-93-02, Item II-I-31] One of these zones, described as being of variable composition, occurs in an area where a relatively high transmissivity zone of the Culebra occurs, and it is assumed that this comment is posed to question whether ongoing dissolution of the Culebra can be occurring. DOE indicates that previous interpretations by Anderson [1995] indicated that calcium sulfate concentration was undersaturated, implying dissolution. More recent calculations [Docket A-93-02, Item II-G-1, Reference number 590] take into account competing ions, and do not support Anderson's implications that calcium sulfate dissolution is ongoing in this area. Further, data also indicate that ground water infiltrating vertically through the Rustler to the Culebra is saturated with respect to gypsum. [Docket A-93-02, Item II-G-1, Reference No. 590]

EPA has reviewed this information, and concludes that ongoing dissolution of anhydrite in the Culebra is probably not a pervasive process, and waters entering the Culebra via vertical infiltration are likely saturated with respect to calcium sulfate. EPA concludes geochemical data indicate that while Culebra ground water geochemistry is variable in the WIPP vicinity, areas that were previously thought to be unsaturated with respect to calcium sulfate (gypsum), such as the zone south of WIPP, in fact contain much more calcium sulfate than originally identified. EPA also concludes that the conceptualization that gypsum saturation will increase in slowly infiltrating surface water is supported by the presence of gypsum-rich strata in supra-Salado rock units.

Issue W: There are still unexplained water level rises in the Culebra.

1. EPA's requirement that DOE address unexplained water level rises in the Culebra has not been met. (48)

2. [O]ther fluid injection issues that have either not been fully addressed or in which there appears to be a misunderstanding of the issue including, for example, the yet to be explained water level rises in the Culebra Aquifer, the likely expansion of solution brine wells in the Delaware Basin, and the likely initiation of solution mining activities in maturing potash mines. (702)

3. The EEG has not considered the effects of Culebra water level rises in the context of their potential impact on the performance of the WIPP. Because the EEG did not address the question of whether Culebra water level rises matter to WIPP performance, it has once again raised the issue of Culebra water level rises without considering or even mentioning the complete record of the DOE's technical basis for its treatment of water level rises in the CCA. The DOE is candid that the water level rises observed at H-9 are unexplained (CCA Chapter 2). However, the specific water level rise at H-9 is but one of many possible water level fluctuations that might occur in the near future. DOE recognizes that prediction of future water level changes in the Culebra while resources are continuing to be extracted is impossible. To evaluate the effects of water level fluctuations in the Culebra in general, as part of its FEP screening, the DOE conducted a bounding analysis of the possible effects of water level rises (CCA Appendix SCR).

This analysis concluded that the potential effects of water level rises in the Culebra are of low consequence to the performance of the disposal system. There is no compelling WIPP safety or compliance issue associated with determination of the cause(s) of water level rises in the vicinity of H-9. (923)

4. Silva (1996, 125) found that a comparison of the injection history of the salt water disposal well and the water level rises at H-9 strongly suggested communication between the injection well and the Culebra Aquifer. The DOE still has not submitted an explanation of the water level rises to the EPA and EPA does not appear to require one for the certification of the repository. (1265)

Response to Comments 3.W.1 through 3.W.4:

EPA acknowledges that DOE has not provided an explanation for the water-level rises in the Culebra in the vicinity of the H-9 hydropad, as described in CCA Chapter 2.2.1.4.1.2. [p. 2-124] Although the water level changes have not been explained, EPA believes that the magnitude of the water-level rises are already accounted for in the water level variations that have been incorporated into the PA modeling. This minimizes the need to establish the cause of the anomalous water level changes. In addition, the unexplained water-level rise occurred in the vicinity of a hydropad that is located approximately 6.5 miles (10.46 kilometers) south of the southern boundary of the Land Withdrawal Act boundary, which is far from the maximum downgradiant extent of the modeled 10,000 year ground water flow. As a result, EPA believes that the water level rises will not impact the results of the PA. In addition, actinides are not expected to travel very far during the regulatory time period due to retardation, an anomalous water level rise over 6 miles south of WIPP would not affect plume configuration.

Comment 3.W.3 suggests that the history of water level rise at H9 is the result of injection from a nearby injection well. It is important to note that LaVenue modeled the possible change in water level at H9 if the entire volume of injected water in Todd 26 Federal #3 well were injected into the Culebra near H9. [EE-62, DOE/AL 58309-62] This is an almost impossible scenario which was undertaken to gauge possible relative magnitudes of effect. EPA emphasizes that this exercise does not establish that injection in that well was the source of water level rise in H9. It only assessed the impact that injection in a nearby well could have on the water level in a well similar to H9. This analysis showed little impact from fluid injection. The cause of water level rise in H9 has not been clearly identified, and it is possible [Beauheim, DOE AL/58309-62, Docket: A-93-02, V-B-1] that the cause lies in the complex interactions of man-made perturbations in the hydrologic environment of the site, but a clear connection to any one activity has not been established. EPA points out that this well is over six miles south of the WIPP site, and anomalous water level rises in this well will not impact WIPP disposal system performance.

Issue X: WIPP does not conform to NAS recommendations.

1. The WIPP locality does not conform to National Academy of Science (NAS) recommendations. The Pilot Plant is not suitable for long-term confinement of radioactive

material as determined by hydrogeologic studies and by the incursion of oil well drilling and production activities. (132)

Response to Comment 3.X.1:

EPA believes that this comment has misinterpreted the NAS recommendations in the report "The Waste Isolation Pilot Plant: A Potential Solution for the Disposal of Transuranic Waste." On p. 6, the NAS reports: "Provided the WIPP repository is sealed effectively and undisturbed by human activity, the committee knows of no credible or probable scenario for release of radionuclides." On p. 80 in the Summary of Committee Opinions on Key Issues the report states: "Taking into account all of the above considerations, the committee is confident in its judgment that DOE should be able to demonstrate that radionuclide releases at WIPP will be within the limits allowed by EPA for both the undisturbed and disturbed cases, even with the severe criteria defined in 40 CFR 194. The associated health risks are likely to be well below the levels under international standards." The Agency believes that these comments from the NAS report contradicts the commenter's statements. See also Issue 1.F.

Issue Y: It is possible that contaminated radioactive water could leave the site and go into the salt water lake outside of WIPP and into the Pecos River.

1. One is that you're building it over an area that is water filled. You have running aquifers under the repository and specifically, I think DOE's own figure recently is that they admitted that there is a brine reservoir that extends to 40 percent, the channels right underneath. That coupled with the studies by Richard Phillips, who is a hydromorphologist, shows that in the event of the E1, E2 scenario or in the event of any driller after 100 years that would reach the site, that there is a very high probability of the water leaving -- of contaminated radioactive water leaving the site and going into the salt water lake that is outside of the salt and outside of the WIPP area and then into the Pecos River. (285)

Response to Comment 3.Y.1:

Ground water is present in all rocks below the water table to varying degree, and the WIPP site is no exception. DOE recognized the potential presence of brine reservoirs below WIPP and included this in PA and subsequent EPA-mandated PAVT modeling. All probable intrusion scenarios have been thoroughly and adequately evaluated by both DOE and EPA and were found not to generate releases of radionuclides which exceed regulatory limits. [CCA Chapter 6; CCA Appendix SCR; EPA CARD 32, Docket: A-93-02, V-B-2] The probability of brine underneath the repository is uncertain and EPA has addressed this in numerous locations [40 CFR Part 194, 62 FR, pp. 58799-58800; CARD 14 Section 14.B.5, Docket: A-93-02, II-B-01]; a fixed value is not appropriate for such an uncertain parameter.

Water in salt lakes near WIPP (but outside the site boundary) is the result of ground water discharge as well as surface water run-off and/or mining activities; however, ground water flow from WIPP is primarily to the south of the site. In addition, the performance assessment shows that there are no releases to the accessible environment from the ground water pathway. Lastly, DOE has considered human intrusions in which brine is released to the surface [Direct Brine Release Conceptual Model; CCA Chapter 6.4; Technical Support Document for 194.23: Models and Computer Codes, Section 1.3.4, Docket A-93-02, Item V-B-6] and the releases from this pathway are below EPA's containment requirements. [CCA Chapter 6.5]

Issue Z: There is nothing to prevent rainwater from reaching the Rustler formation.

1. So if its dune sands are not a barrier to infiltration and if the Dewey Lake Red Beds are not a barrier infiltration and if the Mescalero Caliche is not a barrier to rainwater infiltration, there's nothing preventing rainwater from reaching the Rustler formation. That is why the Rustler water in the area which I have mapped as the recharge area is so much fresher than water in the eastern part of the WIPP site. (302)

2. I would reemphasize for the record is that all five strata at the WIPP site show waterflow and there's nothing to prevent rainwater recharge, so taking that, water is going to get in. I'm not even talking about the high probability of oil and gas exploration, and I restate the fact that there are 120 working wells within two miles of the WIPP site right now. (331)

3. A few of the statements accepted by the EPA are that the Mescalero Caliche covers the WIPP site and prevents rainwater infiltration; that the Dewey Lake Red Beds have not produced water in the WIPP shaft or in test wells above the waste panels; and that there is no evidence of dissolution in the Rustler or Salado formation within the WIPP site. (335)

4. DOE's fallback position is that the Rustler anhydrites, siltstones and claystones are confining layers, barriers to rainwater infiltration. In performance assessment, the Forty-Niner, Tamarisk and lower unnamed members of the Rustler formation are assigned a permeability of zero despite occasional reports of Rustler claystones producing water at rates equivalent to the Caliche or magenta dolomite. CARD has correlated and presented borehole data showing washouts and consistent loss of core in two distinct horizons of Rustler mudstone in the Forty-Niner Member, about 20 feet above the Magenta and in the Lower Unnamed Member immediately beneath the Culebra. These are not occasional occurrences. (606)

5. DOE claimed that Magenta dolomite is unfractured at WIPP. This claim was later modified to read that the Magenta has no hydraulically significant factors at WIPP. The truth is that in the WIPP air intake shaft much of the Culebra dolomite exhibits extensive subvertical to vertical fracturing. About half the fractures are filled with gypsum and the rest are open. (607)

6. The notion that rainwater (even at enhanced rainfall rates) will infiltrate into the Salado formation ignores the two aquifers in the Rustler formation. If rainfall were to penetrate to the Rustler, it would certainly be incorporated into these aquifers and not penetrate further into the Salado. The experience at Hanford has been that, in this type of desert environment, rainfall

infiltrates no further than the roots of the desert plants, and is returned to the atmosphere by evapotranspiration. (678)

7. DOE admits that ground water geochemistry in the Culebra can only be explained by "vertical leakage," synonymous for rainwater recharge. But DOE remains committed to a minuscule rate of rainwater recharge to the Culebra that is unrealistic in view of the geochemistry. Within the WIPP site, total dissolved solids (TDS) vary by a factor of 25 (8,890 mg/l at H-2 to 230,000 mg/l at H-15). Dissolved sodium and chloride (NaCl) also vary by a factor of 25 (4,835 mg/l at H-2 to 124,100 mg/l at H-5), well below saturation (318,000 mg/l NaCl). Such a discrepancy cannot be explained by a recharge rate of 0.2 to 2.0 mm/yr, requiring transit of "several tens of thousands of years," as assumed by DOE. (859)

8. [EPA should consider] . . .the issue of dissolution in the Culebra, which has been discussed by two eminent scientists -- Dr. Roger Y. Anderson and Dr. Fred Phillips who are far more qualified than EPA's staff or consultants. Nonetheless, EPA has rejected the data of Dr. Anderson (II-H-03, II-H-05, and II-20) and apparently has not considered Dr. Phillips' data which was provided to EPA on February 16, 1995 at 214-217 (Docket: A-92-56, IV-E-1). (1120)

Response to Comments 3.Z.1 through 3.Z.8:

DOE has included ground water recharge in its ground water basin modeling for the Culebra Member of the Rustler formation. The ground water basin model provides an explanation of existing ground water quality that incorporates differential recharge rates, recharge locations, and associations with varying transmissivity zones. This information, in turn, can be used to understand the nature of Culebra recharge, including the precipitation that reaches the Culebra. In summary, the geochemistry of the water indicates that it has been isolated or subject to very limited recharge. (Note that in the discussions of Culebra geochemistry, DOE has used the term "facies" interchangeably with the word "zone" to refer to lateral changes in hydrogeochemical conditions within the Culebra.)

DOE identified four different hydrogeochemical facies within the Culebra in the WIPP area [Chapter 2.4.2.1, p. 2-166 and Figure 2-40, p. 2-167]:

- Zone A - saline (2-3 molal) NaCl brines, Mg/Ca ratio of 1.2 to 2;
- Zone B - dilute (<0.1 molal) $CaSO_4$ - rich ground water;
- Zone C - variable composition (0.3-1.6 molal); Mg/Ca ratio 0.3 to 1.2; and
- Zone D - high salinities (3-7 molal); K/Na weight ratios (0.2).

DOE concluded that Facies A ground water flow is slow, has not changed over the last 14,000 years, and probably recharged more than 600,000 years ago. Vertical leakage occurs to Facies A, and both lateral and vertical ground water flow rates are extremely low. Facies B occurs in an area with greater vertical fracturing in the Culebra, and therefore exhibits more vertical infiltration and more rapid lateral flow in the Culebra. According to DOE, flow in Facies B is currently to the south (it may mix with Facies C water to the southeast) but was more toward the west during wetter climates; vertical infiltration from the Dewey Lake to the Culebra Facies B is assumed by DOE to have occurred during wetter climates in an area south of the WIPP site. DOE theorized that Facies C water was not diluted to create Facies B water. Facies C occurs "in between" Facies A and B, and ground water flow entered the Culebra prior to the climate change (to drier conditions) 14,000 years ago. Facies C ground water flow is to the south at WIPP, where DOE theorized that it joins with a small amount of Facies A solute being transported from the east. Ground water flow rate in Facies C is faster than in A but slower than in B, and the proposed recharge area from the Dewey Lake to the Culebra was to the northeast of the WIPP site. DOE theorized that Facies C ground water infiltrated into the Dewey Lake and then interacted with anhydrite and halite along its path to the Culebra, where it mixed with smaller amounts of Facies A water. Within information submitted in a letter dated May 14, 1997 [Docket A-93-02, Item II-I-31], DOE concluded that the presence of anhydrite within Rustler units does not preclude slow downward infiltration. EPA has examined these data and concluded that this is a plausible explanation of the water quality characteristics of the Culebra. In terms of recharge rates, it is assumed that Comment 859 considers the distinct hydrogeochemical facies to be the result of rapid vertical infiltration. However, the distinct hydrogeochemical zones coincide with areas of suspected higher/lower vertical transmissivity and slow, but varying recharge rates could account for the observed water quality.

(Comments 3.Z.1 and 3.Z.4) DOE concluded that, based upon the definition of USDW presented in 40 CFR § 191.22, four formations could potentially be USDWs in the WIPP area: the Culebra, Magenta, Dewey Lake, and Santa Rosa (the Capitan Aquifer was also identified as a potential USDW but is not present at the WIPP). [CCA Chapter 8.2] As such, DOE acknowledges the water-bearing capabilities of the Dewey Lake, and has considered this possibility in performance assessment evaluations. Currently, the Dewey Lake Redbeds Formation has a water table with a hydraulic head that has been estimated by DOE to be about 940 to 980 meters [CCA Chapter 2.2.1.4.2.1], but water can only be produced at scattered sites; many wells in the Dewey Lake cannot produce water. The Mescalero Caliche, a surficial deposit, is an indicator of long-term arid conditions; however, DOE does consider a wetter Dewey Lake in its conceptual model. [*ibid.*] Still, according to the ground water basin modeling, recharge to the Culebra still takes thousands of years

(Comments 3.Z.2, 3.Z.3, 3.Z.4, 3.Z.5, 3.Z.6 and 3.Z.8) Geologic data indicate that stratigraphic features within the Rustler are present that contribute to core loss upon drilling. DOE acknowledges and EPA agrees that members of the Rustler Formation are indeed fractured, including the Magenta to a lesser extent than the Culebra, but the presence of fractures within units is not an immediate measure of the vertical transmissivity of those units. In CCA Chapter 2.2.1.4.1.4, DOE does state that "The Magenta does not have hydraulically significant fractures in the vicinity of the WIPP." This is a reasonable interpretation of the hydrologic data gathered at the WIPP site which indicates that the Magenta can be conceptualized as having matrix flow rates at one to two orders of magnitude less than the Culebra. [CCA Chapter 6.4.6.4]

The simplifications made by DOE to model the Culebra, including assumptions regarding low permeability intervening beds, are appropriate given hydrologic data at the site. [CCA Chapter 6.4.6; Docket: A-93-02, Item II-I-08] Comment 331 infers that the presence of fractures allows for immediate infiltration of surface water to soluble salts of the Salado Formation. There is no evidence to indicate that pervasive infiltration and subsequent dissolution of the Salado Formation or Rustler Salts is a rapid, ongoing occurrence in the WIPP area. Further, ground water quality differences between the more permeable units of the Rustler Formation support relative hydrologic isolation, or at least very slow vertical infiltration that has not allowed for extensive geochemical commingling of ground waters in these units. EPA concludes that while fractures are present in Rustler Formation units and slow vertical infiltration does occur, there is no evidence that indicates fractures are conduits for immediate dissolution of Rustler or Salado salts.

The presence of fractures does not necessarily imply that fractures play a strong role in formation hydrology. Fracture filling, fracture connectivity and the state of stress in the rock strongly control whether or not fractures are hydraulically active. Hydrologic testing implies that fractures in the Magenta are not hydrologically active. All evidence implies that the permeability of all of the rocks in the Rustler Formation above and below the Culebra are relatively low. The gypsiferous members of the Rustler (Forty Niner, Tamarisk and Unnamed Upper) isolate both of the fractured dolomite (Magenta and Culebra) and prevent significant vertical flow between stratigraphic members.

The very low or nonexistent rate of recharge from the site surface implied by the climatic regime and demonstrated by the widespread occurrence of the Mescalero Caliche diminishes concern about rapid vertical recharge to the Culebra. The Culebra is a confined aquifer, which indicates that the middle Rustler evaporite (gypsiferous) members above the Culebra have not been penetrated by dissolution to such a degree that they no longer act as confining layers to the Culebra. The effective confinement of the relatively permeable Culebra is a very important aspect of the site hydrology and its demonstration is based on what may be the most extensive hydrologic database in existence.

(Comment 3.Z.2) Resource extraction has been included in performance assessment modeling, in which DOE was required to evaluate the effects of deep drilling into the WIPP repository as well as the effects of potash mining on the transmissivity of the Culebra. EPA evaluated (see Section 32 and Section 33 responses to comments) numerous drilling-related issues, such as fluid injection [Docket A-93-02, Item V-B-22], carbon dioxide injection (refer to Comment Nos. 8.S.1, 8.S.2, and 8.S.3), solution mining, and brine mining, and has concluded that these activities will not impact the containment capabilities of the WIPP.

(Comment 3.Z.3) EPA recognizes that the Dewey Lake contains a productive zone of saturation, probably under water table conditions, in the southwestern to south-central portion of the WIPP site. [Chapter 2.2.1.4.2.1, p. 2-131] The productive zone is approximately 180 to 265 feet (55 to 81 meters) below ground . The Dewey Lake is not an aquifer in most areas near the WIPP site, but this does not mean that water cannot be present in the unit. DOE indicated, in the CCA, Chapter 2.2.1.4 [Docket A-93-02, Item II-G-1] that the Dewey Lake is the uppermost important layer in the hydrological model and that changes in the water table in the Dewey Lake in the future, due to wetter conditions, were included in the conceptual model. DOE interpreted ground water flow to be to the southwest at about 25 meters per mile (15.5 meters per kilometer). DOE estimated the saturated hydraulic conductivity of the Dewey Lake to be $3x10^{-3}$ feet per day (10^{-8} meters per second) and even assumed that the Dewey Lake is an underground source of drinking water (USDW) in their bounding analysis in the compliance assessment. EPA has evaluated data pertaining to the Dewey Lake and concurs with DOE's assessment that this unit is water-bearing in the WIPP region. EPA participated in WIPP site visits to observe shaft features [Docket A-93-02, Item V-B-3, Attachment 1], and notes that ground water inflow to the shafts primarily from the Salado Formation is evident, but also notes that ground water in the Dewey Lake is monitored in well WQSP-6a, well within the WIPP site.

Issue AA: Effect of hitting a brine pocket

1. What they say is only the Culebra dolomite at about this level of the Rustler will carry ground water and that waste can never get up from the repository into the Culebra dolomite and, therefore, the WIPP site is safe. We know that underneath the WIPP repository is a high pressure brine reservoir. It was actually penetrated by the WIPP flow drill hole one mile north of the center of the site. It's an Artesian brine reservoir. That means it is under so much pressure that it gushes to the land surface. (306)

2. DOE has also failed to address concerns about the geologic configuration and hydrology of the site even though it was originally thought that the site contained only dry salt. It has since been found to also house brine which is seeping into the repository. The danger from a pressurized brine reservoir at the site is so great that the repository location has been moved twice, once in 1978 and once in 1981. (542)

3. I guess there's a pressurized brine reservoir beneath WIPP which if there are micro fractures in there... (600)

4. I have many questions about WIPP. One of these is that the WIPP site is surrounded by natural resources. It is an area with a high concentration of drilling activity. The site rests on top of the pressurized brine reservoir. (619)

5. We recently learned of the existence of a brine lake at a level below the excavated area designed for waste storage. The origin of the lake has not been determined, and its future behavior is unknown. But what is known is that water travels. Will the water in this instance rise and dissolve the salt above it? If it also travels laterally, and if radioactive waste has leaked into it, such waste can be dispersed wherever the water goes. (821)

Response to Comments 3.AA.1 through 3.AA.5:

Because of the low permeability of the Salado and Castile Formations, there is no natural connection between a Castile brine pocket and the waste panel area. The brine pockets are under high pressure because the surrounding low permeability halite has trapped the brine, keeping it from migrating either laterally or vertically. These brines are also nearly saturated with respect to soluble minerals (e.g. halite), and dissolution of surrounding material will not occur. [Docket: A-93-02, Item II-G-1, Chapter 2, Table 2-5] However, in the case of a deep drilling intrusion that goes through a waste panel and into the Castile, it is possible that the drilling will intercept brine in the Castile and create a pathway for Castile brine to flow into the repository and interact with the waste. The probability of human intrusion through the WIPP repository to a Castile brine reservoir is a key component of performance assessment. EPA has long recognized the potential impact of drilling on the WIPP, and required DOE to assume that inadvertent and intermittent intrusion by drilling for resources (other than those resources provided by the waste in the disposal system or engineered barriers designed to isolate such waste) is the most severe human intrusion scenario. [Section 194.33(b)(1)] DOE included the impact that a pressurized Castile pressurized brine pocket would have on the WIPP repository if the pocket were encountered when a borehole was drilled through the WIPP. EPA did not agree with some of DOE's model parameters with respect to the Castile brine pockets; refer to response to Comments 3.BB for additional information.

EPA concurs with issues raised in Comment 3.AA.4 in that natural resources are present in the WIPP vicinity; oil and gas drilling occurs in the WIPP area, and potash reserves are also present. However, EPA has also required DOE to consider this in performance assessment by assuming that drilling and mining will occur within the WIPP boundary. DOE modeled human intrusion through the WIPP repository, which included the possibility that a pressurized brine pocket would be encountered. EPA concludes that the presence of natural resources and impact that drilling and mining for these resources would have on the WIPP's containment capability was properly accounted for in performance assessment modeling.

Issue BB: Brine pocket probability

1. In the CCA DOE has severely underestimated the likelihood of encountering a Castile brine reservoir, in disregard of data showing the presence of such brine reservoirs beneath WIPP. DOE also has underestimated the volume of such a brine reservoir, again in disregard of available data. (141)

2. Third I feel that your assessment with the brine reservoir does not extend underneath the WIPP site is insufficient. The EPA should insist on a study, with the 100 percent probability of drilling going through the WIPP site and what kind of consequences would result from that. (530)

3. EPA did not use the probability of one, that a pressurized brine reservoir underlies the waste rooms, even though that's the only assumption that you can use unless you kind of offer actual experimental truth that there is no brine there. (230)

4. CARD 23 (p. 23-140) states that EPA found no evidence of a 100 percent probability of encountering a brine reservoir at the WIPP. How can this statement be reconciled with the WIPP-12 data? (29)

5. The results of a Time Domain Electromagnetic (TDEM) survey within the repository footprint indicate the presence of a reflector at some locations at the depth of the Castile Formation, and this reflector may be the result of one or more brine reservoirs. Several interpretations have been made of the TDEM results to determine how much of the repository footprint may be underlain by one or more brine reservoirs. Examination of the geologic setting of known brine reservoirs elsewhere in the northern Delaware Basin suggests a strong correlation between brine reservoirs and deformation of the Castile Formation. Although data on the Castile Formation at the location of the repository are limited, the available data and information indicates that the Castile Formation is not deformed at this location, which strongly suggests that brine reservoirs are not present. Because of both these conflicting interpretations of the Castile Formation, the DOE has chosen to treat both the existence and physical properties of brine reservoirs probabilistically in performance-assessment analysis. (117)

6. The EEG raised a number of issues related to the Castile Formation brine reservoirs. The EPA has accepted all of the EEG suggestions except the one related to the assumption of the probability of encounter of brine reservoirs, and we disagree with the EPA on this issue. The CCA assumed 8% probability on the basis of faulty assumptions. The EEG recommended 100% probability on the basis that the WIPP-12 brine reservoir was large enough to most likely extend under the repository, a conclusion also confirmed by geophysical testing directly above the repository. The EPA has sampled on a range of 1 to 60%, but has provided no basis for assuming less than 60%. Based on the arguments that the geophysical (Time-domain electro-magnetic survey) data may be interpreted to indicate the brine to be under 60% of the repository, and that some boreholes adjacent to the brine producing boreholes are known to be dry, the EEG is willing to accept the assumption of fixed 60% probability of encounter, and recommends that a new performance assessment calculation be run with this fixed value. (708)

7. Examination of results of both the CCA and the PAVT indicates that the penetration of a brine reservoir by an intrusion borehole has very little impact on compliance with the containment requirements. Credible sensitivity analyses from the CCA and PAVT, conducted using different assumptions about the characteristics and probability of penetration of a brine reservoir, indicate that the possible presence of a brine reservoir below the waste panels does not significantly alter the predicted performance of the WIPP. More succinctly, the possible presence of brine reservoirs beneath the waste panels does not affect the safety of WIPP. (932)

8. The use of the phrase "the Castile brine reservoir" suggests that such a reservoir is known to exist beneath the repository. As discussed earlier in the preamble (IX.A., Site Characterization, paragraphs 11-14), there is significant uncertainty concerning the existence of a brine reservoir beneath the repository and, if such a reservoir exists, whether it would be intercepted by a borehole that also penetrates the repository. Accordingly, DOE suggests that EPA revise this phrase to read "a Castile brine reservoir" or "a pressurized brine pocket." (940)

9. There is a major issue involving EPA's determination of the likelihood of encountering a Castile brine reservoir. EPA has chosen a range of 1% to 60%, which it justifies with no reasoning at all (TSD V-B-6 at 1-135). EPA states that “[t]he low value was selected by the

Agency to represent a reasonable minimum that bounded the 1992 PA and the geostatistical study. Such statement is pure speculation, as support for including 1% as one measure of the probability of encountering brine. None of the data support such a quantity. Indeed, the geostatistical survey must be rejected, since the data surveyed is not required to report brine occurrences; the "subvertical fracture hypothesis" is just that -- a supposition based on no data; and the "low end of the range identified in WPO # 39121" is 10%, not 1%. Moreover, EPA cannot formulate its range in total disregard of data, such as the Final Report for Time Domain Electromagnetic (TDEM) Surveys at the WIPP Site, SAND87-7144 (1988), which data were interpreted in the 1992 PA to show an area between 25% and 55% underlain by brine reservoirs. EEG has suggested that a fixed value of 60% be assigned to the probability of intercepting a Castile brine reservoir (IV-D-12 at 12). We concur in this recommendation. (1042)

10. [In its proposed rule EPA did not use:]

* a probability of one that pressurized brine underlies the waste rooms; (1140)

11. There is not adequate data to support EPA's chosen probability (0.01 to 0.6) for hitting a brine pocket (at 58800, see also CARD 23-140). In fact, existing data demonstrate that a probability of 1.0 of encountering brine is realistic. (1147)

12. The CCA estimation of an 8% probability that oil and gas drilling will encounter the pressurized brine reservoir underneath the WIPP site is based on incomplete and inadequate data and does not even pass a common sense test. Data from WIPP-12 and Sandia's own survey indicates a greater likelihood of penetration. EPA should have assumed that the reservoir underlies the entire repository. (1209)

13. On what did EPA base its range for hitting a brine pocket? Given the results of the TDEM survey, the lower bound seems to low. (69)

14. EPA has dramatically underestimated the likelihood that drillers will hit highly pressurized brine reservoirs. EPA has not fully considered that drilling outside the WIPP site boundary would cause radioactive wastes that violate the disposal regulations. (268b)

15. DOE, in performance assessment, assumes that the probability of an oil exploration borehole intercepting a Castile brine reservoir beneath the repository is 8% (CCA p.9-167. Subsurface exploration at WIPP does not support this assumption. Three exploratory drill holes within the WIPP site (WIPP-12, WIPP-13, and DOE-1) were deep enough to have encountered brine in the Castile and one of them did (WIPP-12). In addition, a time domain electromagnetic survey was conducted by Earth Technology Corporation (SAND 87-7144) in an attempt to determine the distribution of Castile brine beneath the WIPP waste panels. Based on this data, Borns calculated that Castile brine underlies 10% to 55% of the waste panel area, with a mean of 25% (CCA, MASS Attachment 18-5). From the same data, the CCA estimates that Castile brine underlies 25% to 57% of the waste panels, with a median of 40% (CCA, p. MASS-105). DOE's assumption of 8% is neither realistic nor conservative. (1172)

16. EPA has sampled on a range of 1 to 60%, but has provided no basis for assuming less than 60%. Based on the arguments that the geophysical (Time-domain electromagnetic survey) data may be interpreted to indicate the brine to be under 60% of the repository, and that some boreholes adjacent to the brine producing boreholes are known to be dry, the EEG is willing to accept the assumption of a fixed 60% probability of encounter, and recommends that a new performance assessment calculation be run with this fixed value. (1281)

17. Secondly, there is poor justification for the 1% lower end of the EPA range for the probability of encountering a pressurized brine pocket. The 60% upper end is based on an electromagnetic survey of the WIPP site (CCA 2.2.1.2.2) that indicates brine is likely under about 60% of the repository. Most importantly, the probability of hitting brine under WIPP should be based on local WIPP information and not the entire Delaware basin. The calculated size of the WIPP-12 brine reservoir and the existence of boreholes around WIPP-12 that have not encountered brine in the Castile constrain the WIPP-12 reservoir such that the reservoir must extend under the repository (II-H-25). The brine indicated by the electromagnetic survey must be part of the WIPP-12 reservoir. Hence, the probability of encountering brine should be modeled as 60%. Thus, the PAVT under represents the probability of encountering a brine reservoir while overestimating the effect of the reservoir. (1309b)

Response to Comments 3.BB.1 through 3.BB.17:

(Comments 3.BB.1, 3.BB.2, 3.BB.3, 3.BB.4, 3.BB.5, 3.BB.6, 3.BB.7, 3.BB.8, 3.BB.9, 3.BB.10, 3.BB.11, 3.BB.12, 3.BB.15, 3.BB.16, and 3.BB.17) In the 1992 PA [Docket: A-93-02, II-G-1, Reference #563], Sandia National Laboratory (SNL) considered the probability of hitting a brine pocket under the waste area using an uncertain parameter that required sampling over a range of 0.25 to 0.62. This range of probabilities was based on geophysical work that suggested brine may be present. For the CCA PA, SNL conducted a new analysis based on a geostatistical analysis of oil and gas wells in the vicinity of WIPP.

EPA carefully evaluated the potential occurrence of brine pockets below the WIPP. EPA agrees that there is significant uncertainty concerning the existence of a brine reservoir beneath the repository. EPA found that, on a geostatistical basis, DOE believed the probability of a borehole encountering brine below a waste panel to be 8 percent [Powers et al., 1996, Docket: A-93-02, II-G-1, Ref. #516] partly because the brine is expected to be in fractures that are oriented vertically or slightly less than vertical. However, EPA noted [Technical Support Document for Section 194.14: Content of Compliance Application, Docket: A-93-02, Item V-B-3, section IV C(1)(e); Section 4.1, 4.4, 4.5 of Technical Support Document for 194.23: Parameter Justification Report Docket: A-93-02, Item V-B-14] that DOE's geologic and geophysical basis for the distribution (i.e., 8 percent probability) of Castile disturbed zone structures below the WIPP appeared questionable. [Chapter 2.1.6.1.3, p. 2-87, and Appendix DEF.2, pp. DEF-1 to DEF-18] EPA also found that DOE's discussion of the size, orientation, and repressurization potential of the Castile brine reservoirs was not well supported by the CCA. [Chapter 2.2.1.2.2, pp. 2-107 to 2-108, and Appendices DEF.2, pp. DEF-1 to DEF-18, and DEL.7.5, pp. DEL-81 to DEL-87] The probability value for encountering a brine pocket also was poorly supported, since other

DOE data imply this probability could be as high as about 60 percent. [Chapter 2.2.1.2.2, pp. 2-107 to 2-108]

EPA also considered the possibility [Technical Support Document for 194.14: Content of Compliance Application, Docket: A-93-02, Item V-B-3, section IV C(1)(e); Section 4.1, 4.4, 4.5 of Technical Support Document for Section 194.23: Parameter Justification Report, Docket: A-93-02, Item V-B-14] that the WIPP-12 brine reservoir may underlie 100% of the site and therefore the probability of encountering pressurized brine would be 100%. This consideration is based on the assumption that the WIPP-12 reservoir is cylindrical in shape as proposed by EEG, which EPA considers unlikely due to brine residing in vertical or subvertical fractures. Although EPA agrees that part of the WIPP-12 reservoir may underlie part of the site, the TDEM survey data [CCA Chapter 2.2.1.2.2; Technical Support Document for Section 194.14: Content of Compliance Application, Docket: A-93-02, Item V-B-3, section IV C(1)(e); Section 4.1, 4.4, 4.5 of Technical Support Document for Section 194.23: Parameter Justification Report, Docket: A-93-02, Item V-B-14] do not support speculation of a 100% probability of encounter. In view of the lack of support from the TDEM data and the other concerns expressed above, EPA did not believe that a 100% probability was supported by available data, and an upper bound value no higher than 0.60 was reasonable. EPA therefore directed DOE, in the EPA Mandated Performance Assessment Verification Test[5] (PAVT) [Docket A-93-02, Items II-G-26 and II-G-28], to change the probability of hitting a brine pocket from a constant of .08, to a range that incorporated low to moderate probabilities (0.01 to 0.6), and to sample this range.

As a result of the PAVT, EPA found that even when using a sampling probability that allowed for a greater number of possible brine pocket intrusions, the repository still meets the containment requirements. EPA concludes that the revised distribution sufficiently and accurately increased the probability of brine pocket occurrence consistent with that indicated by site data, and increasing the probability to 100% is not consistent with examined data. Because the increased probability did not impact repository performance, EPA concluded that the original brine reservoir characteristics were, in fact, acceptable. For more discussion on this topic, also see CARD 14 [Docket: A-93-02, Item V-B-2, section 14.B.5], EPA's Technical Support Document for § 194.14: Content of Compliance Certification Application [Docket: A-93-02, Item V-B-3] and the Section 4.1, pp. 18 and 19 of Technical Support Document for § 194.23: Parameter Justification Report. [Docket A-93-02, Item II-H-12]

Using a probability of one assumes absolute certainty that all exploratory boreholes that intersect the WIPP waste panels will also intersect a pressurized brine reservoir in the Castile Formation. EPA does not believe that assuming such certainty is reasonable. Adopting the other extreme,

[5] The EPA Mandated Performance Assessment Verification Test (PAVT) was conducted by DOE at the direction of EPA in order to verify that cumulative effect of changes in parameter values identified by EPA and changes to computer codes would not result in a mean CCDF that violates the containment requirements at 40 CFR 191.13. The PAVT calculations were conducted similar to the CCA calculations with the exceptions of the parameter changes and the modified computer codes. DOE demonstrated that the computer code changes were insignificant and that, even with EPA's directed changes in parameters, the disposal system still complied with the containment requirements.

that the probability is zero, also implies a certainty that is not reasonable. In fact, the available information suggests that brine reservoirs may be present beneath parts of the site may not be present beneath other parts. The most direct information on the presence of brine reservoirs beneath the repository is provided by TDEM data. As stated in Comment 1042, these data may be interpreted to indicate that brine reservoirs underlie as much as 55% of the repository, but using the same data brine reservoirs may also be interpreted to underlie as little as 10% of the repository. A geostatistical method used by DOE to estimate this percentage yielded a value of 8%. [Docket: A-93-02, V-B-1, WPO # 40199] An upper limit of 60% and a lower limit of 1% were selected for this parameter in the PAVT. The upper limit is slightly larger than the largest estimated value for this parameter, but is less than one because it is unreasonable to assume absolute certainty that a reservoir is there. The lower limit is slightly smaller than the smallest estimated value for this parameter, but is greater than zero because it is also unreasonable to assume absolute certainty that a reservoir is not there. Both the upper and lower limits used in the PAVT were also independently compared with the CCA value for brine pocket probability in EPA's sensitivity analysis. The results of that analysis showed that the CCDFs upon which regulatory compliance is based were not sensitive to changes in this parameter. [SA Report Table 3.5-1, Docket: A-93-02, II-I-13] Both the sensitivity analysis and the PAVT results therefore support EPA's conclusion that the original brine reservoir characteristics used in the CCA were, in fact, acceptable, as expressed in Comment 932. In regard to Comment 940, EPA agrees that language used should not imply the 100% probability that a brine pocket will be encountered.

(Comment 3.BB.13) In the PAVT, EPA assigned a range of values from 1 to 60% for the probability of hitting a brine pocket. [ID No. 3493, parameter PBRINE] Using data from the TDEM study [Docket A-93-02, Item II-G-1, Ref. #229], EPA developed probability distributions for four cases. These cases involved either the random or block models for correlation between adjacent TDEM measurements and assumed either the base of the Castile or the base of the Anhydrite III layer in the Castile as the cutoff point above which brine pockets may exist. Since the TDEM measurements showed no discernable spatial correlation in any direction at distances larger than the unit of the measurement grid (250 m), two bounding analyses were performed to reflect the uncertainty in the depth to the first conducting surface -- the random model and the block model. In the random model, all points in the disposal region have the same likelihood of being underlain by brine regardless of the proximity to any specific TDEM measurement locations with higher or lower than average elevation measurements. In the block model, the best estimate of the elevation of the first conducting layer is the elevation of the nearest TDEM data point. EPA found that it made little difference whether the random model or the block model was used to characterize correlation between the TDEM measurements.

However, the simulated probability distributions for encountering brine were highly sensitive to the geologic assumption of whether or not brine pockets exist below the bottom of the Anhydrite III layer. [SC&A, 1998, in Docket: A-93-02, Item V-B-1, Sections 5.3 and 6.0] Using the base of the Castile Anhydrite Layer III as the lowermost stratigraphic layer below which no brine pockets occur, the simulations show that the area of the WIPP repository underlain by a brine pocket varies from 1 to 6% of the excavated WIPP repository area. However, using the base of the Castile as the lowermost stratigraphic layer below which no brine pockets occur, the area of the excavated repository underlain by brine pockets increases to about 35 to 58%. According to the 1992 WIPP PA [Docket A-92-03, Item II-G-1, Ref. #563, Vol. 3, p. 5-4], Castile Formation brines are generally found in fracture zones in the anticlinal structures in the uppermost anhydrite layer (generally Anhydrite III). If it is assumed that brine is confined to the Anhydrite III layer, which is the more probable assumption based on geologic information, the maximum fraction of the repository area underlain by brine is 6%. However, if it is assumed that brine pockets can occur all the way to the base of the Castile (which is a conservative assumption since most occur in the Anhydrite III layer), then a 58% probability would be the maximum to assume. EPA selected 1% as the lower limit and 60% as the upper limit for the fraction of the excavated repository area underlain by brine in the PAVT. The upper value of 60% rounds up the highest value from the TDEM data, providing a more conservative range. The lower limit was selected by the Agency to represent a reasonable minimum that bounded the 1992 PA and the geostatistical study. A uniform distribution was mandated because the range of this parameter spans slightly more than an order of magnitude and the use of a uniform distribution will conservatively bias the sampling toward the high end.

EPA believes that this range adequately reflects the uncertainty in the parameter PBRINE and is a more appropriate representation of the concept of reasonable expectation than the fixed value of 8% used by DOE in the CCA.

The modeling in the CCA has not ignored events that will cause the radioactive release standards to be violated, nor has EPA ignored these events in its review of the CCA. EPA's review carefully scrutinized the likelihood that drillers would penetrate into pressurized brine reservoirs. EPA requested additional justification [Docket: A-93-02, II-1-01] for the probability of encountering brine pockets and reviewed the information. The consequences of drilling both inside and outside the WIPP boundary were considered by DOE in the CCA and by EPA in its review of the CCA.

EPA believes that the brine pocket parameters used in the PAVT are more appropriate than those used in the CCA. EPA does not agree that it can be stated with certainty that the WIPP-12 brine pocket extends under the repository. While it is therefore appropriate to consider the WIPP-12 brine pocket characteristics when developing parameter values and ranges for WIPP performance assessment, it would be inappropriate to use only the pressure or other characteristics of the WIPP-12 brine pocket and ignore all others.

In addition to the release processes mentioned in Comment 3.BB.14, the CCA evaluated a comprehensive set of features, events, and processes (FEPs) that may affect the future performance of the WIPP. The FEPs that were evaluated in the CCA were identified and evaluated by DOE in a process that initially included over 900 FEPs. The FEPs were assembled from waste facility performance evaluations from around the world, including the U.S., Canada, Sweden, Switzerland, the United Kingdom, and international agencies.

From the initial list of over 900 FEPs, the FEPs were screened down to approximately 240 FEPs that could potentially apply to the WIPP site. The screening process eliminated such FEPs as those that would apply only to spent nuclear fuel and not to the transuranic waste to be disposed at the WIPP. Other FEPs were eliminated based on site characteristics, such as the possibility of seawater intrusion: clearly these FEPs would have no place in the WIPP performance assessment. Refer to CARD 32, section 32.A.6 [Docket: A-93-02, Item V-B-2] and Technical Support Document for Section 194.32: Scope of Performance Assessments [Docket: A-93-02, Item V-B-21] for further information.

Finally, a screening of the 240 FEPs was conducted and the number was reduced to about 80. This final screening eliminated certain FEPs on the basis of reasoned arguments or existing data. The elimination of FEPs at this stage was done on the basis of three criteria: (1) negligible consequences, (2) very low probability (less than one chance in 10,000 of occurring during a 10,000-year period), and (3) regulatory requirements. Approximately 80 remaining FEPs were used in the performance assessment in the CCA. The original list of more than 900 FEPs and the screening to arrive at the final set are documented in the CCA in Appendix SCR, Attachment 1. [Docket: A-93-02, Item II-G-1] The entire process has been reviewed by EPA and the Agency concurs with the screening process used and information presented in the CCA.

Issue CC: Brine pocket characteristics (volume/compressibility)

1. In the CCA DOE has severely underestimated the likelihood of encountering a Castile brine reservoir, in disregard of data showing the presence of such brine reservoirs beneath WIPP. DOE also has underestimated the volume of such a brine reservoir, again in disregard of available data. (141)

2. The CCA states that the compressibility parameter for the Castile brine reservoir has been given a broad range "in an attempt to ensure that all possible values are encompassed" (at 6-163). Such an explanation is specious, since a broad range suppresses the actual value and assigns significant probabilities to values that are far from the actual value.(154)

3. Where is EPA's response to EEG's comment regarding WIPP-12 data? (28)

4. EEG has pointed out that the projected maximum artesian flow and the flow to the surface during drilling from a brine reservoir are also established in the CCA without reference to the values actually calculated for WIPP-12.(155)

5. EEG has pointed out that the projected maximum artesian flow and the flow to the surface during drilling from a brine reservoir are also established in the CCA without reference to the values actually calculated for WIPP-12. (1045)

6. The Castile brine reservoir itself is modeled in the CCA as having a volume of from 32,000 to 160,000 m^3 (CCA Table 6-26), whereas measured data show a volume of from 100,000 to 2,700,000 m^3 (at 2-108). The model is clearly inaccurate. The CCA does not seek to justify the values for brine reservoir volumes or the related probabilities (at 6-164). Thus, this part of the CCA model is unsupported. Further, DOE has not shown that to assume a smaller-than-realistic brine reservoir is a conservative assumption. (1043)

7. The CCA states that the compressibility parameter for the Castile brine reservoir has been given a broad range "in an attempt to ensure that all possible values are encompassed" (at 6-163). Such an explanation is specious, for the reasons stated above, viz: a broad range suppresses the actual value and assigns significant probabilities to values that are far from the actual value. (1044)

8. EPA's conclusion that the PAVT verifies that DOE's brine reservoir parameters are adequate (at 58800) is not justified, since EPA has not done PA runs changing various parameters to show that a brine reservoir is not significant in such a synergistic situation. (1148)

Response to Comments 3.CC.1 through 3.CC.8:

EPA agrees with the commenter that DOE's PA compressibility parameters for the Castile brine reservoir and representation of brine pocket size/volume in the CCA were not consistent with available information. EPA believes that Comment 3.CC.3 refers to the brine pocket volume. EPA also believes that the parameters of the Castile brine reservoirs are highly uncertain, particularly the rock compressibility and related brine pocket volume. In situations where the actual value of a parameter is not know, it is appropriate to statistically sample from a range of parameter values. EPA directed DOE in letters dated March 19, 1997 [Docket A-93-02, Item II-I-01, enclosure 3] and April 25, 1997 [Docket A-93-02, Item II-I-27, enclosure 2] to conduct new performance assessment modeling that includes modified parameter values. EPA required that the parameters regarding rock compressibility and porosity (e.g., Castile COMP_RCK), as well as how the brine pocket volume is sampled, be modified in the mandated Performance Assessment Verification Testing. [Docket: A-93-02, Items II-G-26 and II-G-28] Specifically, EPA required DOE to treat the rock compressibility as a sampled variable with a triangular distribution, a revised range of $2x10^{-11}$ Pa^{-1} to $1x10^{-10}$ Pa^{-1} (revised from $5x10^{-12}$ Pa^{-1} to $1x10^{-8}$ Pa^{-1} used in the CCA), and a revised mode of $4x10^{-11}$ Pa^{-1}. [Docket: A-93-02, Item V-B-14] This revised range was estimated by DOE and accepted by EPA based on an analysis of the Castile brine pocket encountered in borehole WIPP-12. [Docket: A-93-02, V-B-1, WPO#41887] This approach effectively modified the sampled brine pocket volume to include, more representatively, the possibility of higher brine pocket volumes like that at WIPP-12. EPA found that modification of these parameters did not result in PAVT CCDFs that exceed EPA's containment standards. As a result of the PAVT, EPA found that the original brine reservoir characteristics were, in fact, acceptable. For more discussion on this topic, also see CARD 14 [Docket: A-93-02, Item V-B-2, section 14.B.5], Sections IV.B.3.t and IV.C.1.f.ii of EPA's Technical Support Document for § 194.14: Content of Compliance Certification Application [Docket: A-93-02, Item V-B-3] and Section 3.11, 3.12, 3.13, 4.4, 4.5, 5.2, and 5.3 of the Technical Support Document for § 194.23: Parameter Justification Report. [Docket: A-93-02, Item V-B-14]

(Comments 3.CC.1, 3.CC.3, 3.CC.4, 3.CC.5, and 3.CC.8) EPA assumed that Comment 3.CC.3 is referring to Docket A-93-02, Item II-H-12 in which EEG made comments on the section regarding Brine Reservoir Assumptions in the CCA, specifically the volume of the brine pocket. With respect to WIPP-12 data, it is not clear to which EEG comment that this commenter refers. EPA addressed this issue in proposed CARD 14, Response to Comments, Issue T: The probability of encountering a brine reservoir during drilling and the reservoir's potential volume are underestimated. With respect to Comments 3.CC.4 and 3.CC.5, as stated above, EPA required DOE to use parameter values in the PAVT that were based on WIPP-12 data. The results of the PAVT indicated that the original brine reservoir parameters used by DOE were, in fact, acceptable. With respect to Comment 3.CC.8, EPA required DOE to simultaneously sample the key brine pocket parameters of compressibility and porosity, which changed the brine pocket volume, and the brine pocket probability of encounter. As already suggested by EPA's sensitivity analysis, which had indicated a low sensitivity to both changes in brine pocket volume and probability of encounter [Docket:A-93-02, V-B-13, Appendix PD, Sections PD-1.10 and PD-5.1], the PAVT results indicated that the effects of changing these key parameters simultaneously did not significantly affect the predicted isolation capability of the WIPP. [Docket: A-93-02, Items II-G-26 and II-G-28] In addition, EPA also evaluated changes in brine pocket pore pressure and found no sensitivity. [Docket: A-93-02, V-B-13, Appendix PD, Section PD-1.11] Based on these results, EPA has concluded that additional PA runs changing additional brine pocket parameters are unnecessary.

Issue DD: The Salado Formation will be wet.

1. Likewise the geological characteristics of the site are not fully known. First we heard the caverns were dry, now we know they contain a brine solution. (558)

2. Why are you urging the opening of WIPP when it's now clear that WIPP's location in the Salado formation is not dry but wet brine with the pressurized gases and karst formations that crack and fracture. Is it good science to disregard the geology of the WIPP site? Can the EPA certify the WIPP site when its geology has not been thoroughly explored or understood and people who have thoroughly explored it and spent years doing it are being ignored? Has DOE thoroughly tested the hydrology of the site? (571)

3. Now it turns out the salt is not all that stable and there's brine under it and moving through it. (569)

4. A salt formation with oil and gas drilling nearby is unstable. Ground water can enter the salt formation, form a salt slurry, corrode the waste containers and allow the waste to leave the area contaminating the nearby aquifers. (384)

5. The Carlsbad salt beds are not dry but have seepage which could corrode nuclear waste containers leading to the potential release. (554)

6. Is the waste being stored in wet brine or dry salt? (584)

7. Having contemplated the characteristics of the salt beds at WIPP, I conclude that it is a very unstable medium, associated with too much water to be suitable as a waste storage site. Other countries have selected a very stable medium for storage--granite, preferably high and dry. (822)

8. From the moment it became evident that the repository would collect appreciable brine during closure, the concept of nuclear waste disposal in plastic salt has remained indefensible. The NSF did not envision liquids when it recommended salt as a geologic medium for permanent containment of dry waste. Gaseous hydrofracture and discharge is not a fatal flaw, but escape of brine solutions in excess of what can be sequestered by engineered barriers in the repository cannot be prevented. (838)

9. When underground salt formations were considered in the mid-1950s to be the safest depository, that supposition was based on the theory that the salt beds would be dry. However now, 40 years later, we know that the salt beds at WIPP are not dry. Water is seeping into the WIPP storage areas at a rate of 8 gallons per minute. These wet salt beds will corrode the containers very quickly. (1091)

10. The basic premises of the WIPP were that the salt beds were supposed to be dry, and that salt creep would surround and encapsulate the waste canisters. But the WIPP is not located in a zone of pure salt. Brine is now “weeping” into the repository at a slow but significant rate. A ventilating system now evaporates the water, but after closure, the WIPP will be a wet repository. When the steel drums corrode, the result would be a slurry of brine and dissolved waste. (1191)

11. It is common knowledge that the rate of brine inflow from the Salado marker beds is low enough that brine dries up almost instantly due to ventilation in the WIPP mine. This would certainly be expected in the air intake shaft. If the rate of water inflow is large enough, as is being observed in the WIPP exhaust shaft at the level of Santa Rosa and Dewey Lake Formations for the past several years, then even a large blast of air does not completely dry up water. As far as brine inflow from the Salado Formation is concerned, the presence of salt encrustations (efflorescences) clearly indicates current brine seepage. The [EPA] inspection team’s conclusion therefore simply indicates the absence of understanding of the mechanics of brine drying up in the air intake shaft, rather than the absence of brine inflow. (1297)

Response to Comments 3.DD.1 through 3.DD.11:

EPA agrees that brine will enter the repository from the Salado Formation via anhydrite marker beds. Corrosion of containers occurs when in contact with brine, and gas generation progresses. In the discussion of the conceptual model [Docket: A-93-02, Item II-G-1, Section 6.0.2.3], DOE indicates that brine is expected to be present in the repository under most conditions and this brine may contain actinides. Corrosion of the waste containers, generation of gases during waste corrosion and microbial degradation, and the effects of these processes on the disposal system components have been addressed in the DOE PA and the EPA mandated PAVT. [Docket: A-93-02, Items II-G-26 and II-G-28] In addition, direct brine release through drilling and brine release to the Culebra is assessed. EPA concludes that DOE has adequately considered the presence of brine in PA modeling [Docket: A-93-02, Item V-B-02, CARD 23, Section 1.4] because DOE in its intrusion scenarios [Docket: A-93-02, Item II-G-1, pp. 6-71 to 6-78] included the possibility of encountering a brine pocket.

The presence of a pressurized brine reservoir beneath WIPP was addressed in the PA under the human intrusion scenarios whereby the reservoir is penetrated by a borehole and brine is subsequently released into and mixed with the waste and eventually discharged either into the Culebra or at the ground surface. Multiple intrusion events were considered (a maximum of six events) and complementary cumulative distribution functions calculated (CCDFs) that present the probability and consequence of intrusion events. [Section 6.5 of the CCA]

(Comments 3.DD.7, 3.DD.9 and 3.DD.10) EPA concurs that water-bearing units below the Salado Formation are present. In addition, the Salado and Castile Formations contain interstial brines. However, EPA also notes that the presence of brine within the Salado is a key element of performance assessment modeling; brine inflow is assumed to occur naturally and if a drilling intrusion intersects a brine pocket. The impact of these sources of brine inflow on container corrosion and subsequent gas generation is assessed. Therefore, although the commenter correctly notes that initial WIPP studies did assumed the salt to be “dry”, the presence of brine in the WIPP system has long been recognized and is accounted for in performance assessment.

(Comments 3.DD.1 and 3.DD.2) EPA disagrees that the geologic characteristics of the site are unknown, refer to the response to Issue 3.A. Further modern karst features are not present at WIPP to such a degree that the containment capabilities are impaired (refer to the response to Comment 3.D.1 in this section of response to comments). EPA does not agree that site hydrogeology is poorly tested; in fact, the Peer Review Panel [Appendix PEER of the CCA] concluded that the site hydrologic test data are more than sufficient to develop numeric site modeling codes. [Docket: A-93-02, Item II-G-1, Appendix PEER]

Issue EE: Waste could flow into the Pecos River from a flow path of water around the repository.

1. A huge number of scientists who have relied on DOE's actual data have demonstrated that there's a flow path of water from the waste around the repository. Should it escape, it will travel on those flow paths into the Pecos River which is only 15 miles away from the site. (379)

2. What about the water aquifers that drain into the Pecos River? What about it being exposed further more into the environment because of this? (514)

3. The underground cavern sites are not bone dry as stipulated by DOE. It is reported that while drilling they have hit brine -- twice -- thereby causing them to seek other nearby places to drill. It is believed that there may be a fresh water reservoir, also, that supplies water to a close by town. There are, also, underground rivers that connect up with the Rio Grande that would carry nuclear waste into Mexico and eventually into the Ocean Gulf. (1102)

Response to Comments 3.EE.1 through 3.EE.3:

(Comments 3.EE.1 and 3.EE.2) It is unclear to what Comment 3.EE.1 refers. EPA has reviewed DOE’s approach to assessing the direction of ground water flow and finds it satisfactory. [Docket: A-93-02, Item V-B-3, section 14.B.5] Site data indicate that hydraulic heads in the

Culebra generally decrease from north (932 meters) to south (912 meters). A map of hydraulic heads in the Culebra is provided in Figure 2-31 of the CCA. [Docket: A-93-02, Item II-G-2] Based on this map, it can be inferred that ground water will flow generally from north to south. [Appendix TFIELD 2.2.4] This general flowpath coincides with the direction of ground water flow indicated in DOE's modeling of the Culebra. [Appendix TFIELD] The models were used to predict the transport of actinides released from WIPP over a period of 10,000 years under a wide variety of possible scenarios.

EPA found that DOE has done a thorough analysis of ground water flow in the Culebra, which is the most likely unit in which contaminants would migrate. Key parameters in addressing direction of ground water flow in the DOE model include aquifer transmissivity [Appendix TFIELD], climatic change [Appendix MASS], and the effects of subsidence caused by mining in the McNutt member. [Appendix MASS] Transmissivity is defined by Lohman [1972] (Docket: A-93-02, V-B-1) as the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. All other factors being equal, ground water will tend to preferentially migrate along a pathway of higher transmissivity. Variability and uncertainty in the spatial distribution of transmissivity in the Culebra are addressed in the WIPP performance assessment calculations through the use of Monte Carlo techniques. A large set of transmissivity fields (100) were developed with each transmissivity field being a statistical representation of the natural variation in transmissivity that uses measured data according to certain criteria. Monte Carlo simulations using a large number of equally-likely transmissivity fields is a statistically valid method of characterizing the uncertainty associated with transmissivity in the Culebra.

(Comment 3.EE.2) Nash Draw and the Pecos River are areas where discharge to the surface occurs. Hunter 1985 [Docket: A-93-02, II-G-1, Ref. #320] described discharge at Surprise Spring and into saline lakes in Nash Draw. She reported ground water discharge into the Pecos River between Avalon Dam north of Carlsbad and a point south of Malaga Bend at approximately 32.5 cubic feet per second (0.92 cubic meters per second), mostly in the region near Malaga Bend. Thus, Culebra ground water from the WIPP site could eventually reach the Pecos River; however, only very small amounts of radionuclides would be expected to reach the WIPP site boundary in the case of human intrusion because of the retardation of actinides. [CCA Chapter 6.4.6.2; Docket: A-93-02, V-B-4] Even less would be expected to reach the Pecos River. DOE has demonstrated in the CCDF graphics in Section 6.5 of the CCA, and in the PAVT [Docket: A-93-02, II-G-26, and Docket: A- 93-02, II-G-28] that releases to ground water would not result in a mean CCDF that violates the containment requirements of § 191.13 at the WIPP boundary. Thus it is logical to assume that through dilution, and retardation of actinides, that the concentration of radionuclides would be lower further downgradient of the WIPP boundary.

In response to Comment 3.EE.3, EPA agrees that both the Castile and Salado Formations contain brine, but brine occurrence in both is included in performance assessment modeling. The closest "fresh water aquifer" is the Capitan, which provides water to the City of Carlsbad. [Appendix USDW, pg USDW-17] There are no known "under ground rivers" and EPA concludes that karst solution features which the commenter may be referring to are not pervasive enough at WIPP to impact WIPPs containment capability.

Issue FF: Bell Canyon aquifer is immediately below the WIPP site and the cities of Midland and Odessa have long-term agreements to use that water.

1. The Bell Canyon aquifer is the largest pool of fresh water in that area. It is immediately below the WIPP site. And the cities of Midland and Odessa have long-term agreements to use that water. (534)

Response to Comment 3.FF.1:

EPA agrees that the Bell Canyon occurs below WIPP, but it is not a drinking water source in the WIPP area. The WIPP site is located within the Delaware Basin and is approximately 90 and 105 miles west-northwest of the cities of Midland and Odessa, Texas, respectively, outside the Delaware basin. Those cities are located east of and outside of the Delaware basin and are not in the flowpath of ground water moving through the Bell Canyon beneath WIPP.

Generally, the water in the upper part of the Bell Canyon Formation are brines in which sodium and chloride are the predominant ions. Salinity of water in the Bell Canyon Formation increases as ground water moves across the Delaware Basin reaching dissolved solids concentrations in excess of 300,000 milligrams per liter (mg/L). [McNeal, 1965, cited in Docket A-93-02, Item G-II-1] Brines sampled from the upper portion of the Bell Canyon Formation at WIPP had dissolved solids concentrations ranging from 180,000 mg/L (test hole AEC-8) to 270,000 mg/L (test hole ERDA-10). [Docket A-93-02, Item G-II-1] These values are far greater than the standard of 10,000 mg/L used to define a USDW. Furthermore, the Bell Canyon aquifer has been extensively drilled in the Delaware Basin for potential oil and gas reserves and is also used for injection of oilfield brine.

Issue GG: If there's any question that the water table and aquifer would be contaminated, EPA should reject WIPP permanently.

1. If there's any question, any question at all that the water table and aquifer would be contaminated, the EPA should reject WIPP permanently. (615)

Response to Comment 3.GG.1:

EPA's radioactive waste disposal standards allow a limited amount of release of radioactivity to the accessible environment. [40 CFR Part 191] For WIPP, the accessible environment is the surface and a distance in the subsurface of about 2.4 kilometers from the location of the waste. EPA found that results of the CCA PA calculations indicate that the long-term releases to the accessible environment from the Culebra, the most likely ground water pathway for actinide migration, are zero for the 0.1 probability of release for both the PAVT [Docket: A-93-02, Item II-G-28] and the CCA. The long-term release from the Culebra is zero for the 0.001 probability of release for the CCA and only 0.0007 for the PAVT. The PAVT mean CCDF for total normalized releases to the accessible environment did not exceed or come within an order of magnitude of the EPA Limit. [Docket: A-93-02, Item II-G-28]

Issue HH: Shaft seal integrity over the 10,000 year period is questionable/WIPP is intrinsically safe.

Shaft liners

1. I found out lately that the Department of Energy attempted to seal three of their access shafts which were up to about 20 feet in diameter, and within two or three years three of those seals failed and water seeps in from the Rustler formation. They tell us that their next attempt at sealing the shafts will last for 10,000 years. (308)

Shaft seal design

2. The question has come up over and over again how effective are the man-made seals that are going to be put back into these shafts. The Department of Energy continually says oh, the seals are going to work. For purposes of our high-tech mathematical modeling and functions, the seals will work. Oh, but we're going to be continuously redesigning them for the next 20 years. (313)

3. I believe WIPP is very safe and that's based on about 11 years I spent working in the underground doing a variety of tests to show we could permanently isolate waste once the WIPP was full. I did a lot of tests where we drill a large diameter of bore holes into the sale, either vertically down or horizontal. Then we would go into those bore holes, they might be three feet or 30 inches in diameter, come of the bottom of the bore hole about three feet and installed various seals at various thicknesses roughly around three feet. Then we would drill a smaller hole into the side an pressurize the zone underneath this test seal to see how well it could hold fluids in. Through that access hole that came in there, we pressurized fluids up through the seal in such a way to assess the efficiency of the seal. There was some concern that after a long period of time the seal's integrity may degrade due to various factors. And we came and tested one of these seals nine years after we put it in and we brought the brine pressure up to 500 psi and watched it for about six months. We never saw any brine anywhere. . . I see the WIPP as intrinsically safe. I think that if some reasonable effort is made to seal the WIPP after it is filled with waste, I personally find it incredible that the waste will somehow get out to hurt somebody. (363)

4. DOE has not proven that they can seal the shaft, rooms for panels completely. They don't know exactly how waste and the repository conditions will interact. (378)

5. Other examples of conservatism in the process, you've heard about include the seal's design, highly redundant measures there. (390)

6. If the proposed seals represent an established design, then DOE should present precedents for them, with details of emplacement and performance, preferably during centuries of closure of salt, documenting containment of fluids under high pressures. (839)

Long-term effectiveness of shaft seals

7. Finally, DOE has not solved the problem of sealing the shafts leading into the repositories. There's currently no proven technology to seal shafts in salt formations. (493)

8. I demand that EPA prove that sealed shafts in salt will hold for even a relatively short period of time even if they are sealed with the best current methods much less -- they can't last for 10,000 years. Everyone knows full well that nothing the WIPP site does will last for even 1,000 years much less 10,000 years. Give me a break. The system of sealed shafts for borehole must be proven safe. (523)

9. [M]uch of the technology (especially for sealing the shafts, rooms and panels) is untried and untested in the real world. (898)

10. [M]ajor mistakes can be made on paper before something has been actually tested or used. This especially applies to the sealing systems at WIPP. Because we have no field tests of these systems, we won't know if we actually have the technical ability to seal shafts in salt until all the waste is in the ground and possibly destruction of the waste containers has occurred. (905)

11. Ultimately, waste containment at WIPP depends on DOE's ability to seal the WIPP shafts perfectly, forever, because the overlying Rustler aquifer is karstic and cannot be relied upon even to retard the migration of radionuclides. The "currently envisioned [shaft seal] design" does not "demonstrate" compliance with containment requirements. Until it is tested in the field, nothing is demonstrated. (1188)

12. CARD not only asserts that Rustler ground water <u>will</u> flow down the shafts; CARD observes that it does so already. (1189)

13. CARD is concerned that dissolution of halite in the WIPP shafts will exceed the rate of salt creep, and that the shafts will never seal. (1190)

Panel closures

14. In addition, the repository was further designed to compartmentalize the waste with the repository in eight separate panels with seven rooms in each panel. Seals are provided between panels with exits and entrances to every panel to help isolate the waste. And finally, techniques for sealing the shafts have been chosen that are exceedingly robust. Multiple commonly used materials are used with each one with low -- available technologies rather than new technologies were adapted at the WIPP to assure you really construct the seals. (249)

Response to Comments 3.HH.1 through 3.HH.14:

Shaft Liners

(Comments 3.HH.1 and 3.HH.12) Control of leakage into the shafts during active disposal operations, provided by shaft liners, is a much different problem than prevention of flow in the sealed shafts. The shaft seals, designed to isolate disposed wastes for at least 10,000 years, are only tangentially related to the shaft liners. In fact, large portions of the shaft liners will be removed prior to construction of the shaft seals, to ensure that the seal materials will be in direct contact with the surrounding Dewey Lake and Rustler Formations. Therefore, EPA concludes that the commenter's concerns regarding shaft liners cannot be extended to shaft seals.

Operation of the WIPP requires that leakage of water into the shafts must be limited to a rate which will not cause erosion, flooding or other safety problems. Water inflow must be restricted enough to avoid splashing of personnel, equipment or waste on the lifts, or wetting of the floor at the repository level. Chapter 3.1.3 [p. 3-12] of the CCA indicates that this objective has been met by lining the shafts from the surface to the top of the Salado Formation, and by injection of low-permeability grout into some portions of the adjacent formations. Wet areas can be observed at several locations on the liners above the Salado. Icicles form on the concrete walls of the upper section of the Air Intake Shaft in the winter, requiring occasional removal (if inspections or other work must be performed in the shaft below). EPA inspected the Air Intake Shaft and observed conditions there in 1997. [Docket: A-93-02, Item V-B-3, Attachment 1]

EPA acknowledges that ground water from the Rustler does leak into the shafts. However, leakage into the shafts has been controlled and limited to low rates in each shaft. Small amounts of water drip down and collect in the sumps at the bottom of each shaft. This leakage is not a serious problem, and is not considered evidence of liner "failure" by DOE or EPA. Finally, this leakage can be further controlled (by additional drilling and grouting) if conditions change, or if it is determined necessary or desirable to reduce existing inflow rates.

<u>Panel Closures</u>

(Comments 3.HH.4, 3.HH.9 and 3.HH.14) The panel closures are also required only during active disposal operations at the WIPP, and during preparations for final closure of the entire facility. As explained in detail in the CCA and the RCRA permit application, the panel closures are necessary to limit (not absolutely prevent) gas and volatile organic constituent (VOC) vapor "exhalation" from each closed panel, although they are included in PA modeling with respect to brine availability. The required performance of the panel closures for VOC mitigation could theoretically be provided by single sheets of permeable film or even paper, if some way could be found to anchor the film into the surrounding undisturbed salt formation. However, the salt will continue to creep inward, cracks will open in the expanding Disturbed Rock Zone (DRZ), and roof falls will eventually occur, unless a solid closure structure is placed in the drift. The intended dual function of each panel closure is to block ventilation air flow into and out of the panel, and to stop inward creep of the surrounding salt. As required by EPA, most of the existing DRZ in each panel entry and exit drift will be removed at each panel closure location, after the panel is filled with waste and the concrete block explosion-isolation wall is built. The massive panel closure structure will be large enough (about 25 feet in diameter and length) and grouted on the upper surfaces to efficiently block flow of gas and vapor, and strong enough (dense concrete enclosed in reinforced steel forms) to resist inward salt creep.

CCA Chapter 3.3.2 [pp. 3-27 to 3-33] and Appendix PCS provide a description of the panel closure system that DOE intends to emplace in the panel access drifts of the waste disposal panels after waste is emplaced in each panel. The CCA [Figure 3-5, p. 3-29, and Appendix PCS] provides four panel closure system design options identified as Options A through D. Each of the design options consists of a two component composite system. The first component consists of a rigid concrete component emplaced either with removal of the DRZ (Options C and D), or without removal of the DRZ (Options A and B). The second component is either an explosion-isolation wall (Options B and D) or a construction-isolation wall (Options A and C). The concrete barrier component is intended as the primary barrier for the flow of air, volatile organic compounds and brine through the panel access drift after closure of the waste disposal panel. DOE proposed [Appendix PCS, p. 2-29] that the concrete barrier be composed of standard concrete with a plain cement mix. The CCA indicated [Appendix PCS, p. ES-8 and 3-4] that the construction isolation wall is intended to comply with Mine Safety and Health Administration regulations to safely isolate abandoned areas from active workings using barricades of substantial construction and will be constructed of concrete block keyed into the salt. The CCA [Appendix PCS, p. ES-8] indicates that the explosion-isolation wall will be used for those panel closures where there is a potential for the occurrence of an explosive mixture of methane within the closed panel. The explosion-isolation wall is also constructed of concrete block, but will be thicker than the construction isolation wall to mitigate the effects of a postulated methane explosion.

DOE provided four options for panel seal closures in the CCA but did not specify which panel closure option would be used at WIPP. This lack of a specificity was pointed out in public comments. [e.g., Docket A-93-02, Item II-H-10] EPA reviewed the four panel closure system options proposed by DOE and considered the intended purpose of the panel closure system in preventing the existing disturbed rock zone (DRZ) in the panel access drifts from increasing in permeability after panel closure. EPA considers the panel closure system design identified as "Option D" in Figure 3-5 of the CCA [p. 3-29] to be the most robust panel closure design. Option D involves removal of the DRZ prior to construction of the concrete barrier portion of the panel closure system, thereby ensuring consistency in the initial characteristics of the interface between the Salado host rock and the concrete barrier component of the panel closure system and the resulting permeability of the DRZ surrounding the panel closure system. The consistency between the initial characteristics of the interface between the Salado host rock and the concrete barrier component of the panel closure system serves to support DOE's assumption that DRZ permeability will remain fixed as modeled in the PA.

EPA determined that implementation of Option D is adequate to achieve the long-term performance modeled in PA, since DOE provides information in Appendix PCS that shows that the use of a concrete barrier component is capable of providing resistance to inward deformation of the surrounding salt and prohibiting growth of the DRZ from its initial state. However, DOE would have to replace the fresh water concrete proposed in Option D with Salado mass concrete. EPA requires the use of Salado mass concrete for construction of the concrete barrier component of the panel closure due to the potential for degradation and decomposition of fresh water concrete. The degradation of the freshwater concrete barrier component could occur because of infiltration of brine into the block of concrete or along the interface between the salt and the concrete. These processes could potentially reduce the strength of the concrete and potentially increase the permeability of the concrete.

Although EPA's sensitivity analysis indicates that the panel seal permeability is not a sensitive parameter; see EPA Technical Support Document for § 194.23: Sensitivity Analysis [Docket: A-93-02, Item V-B-13] also see Technical Support Document for 194.23: Parameter Justification Report, Section 5.4, [Docket: A-93-02; Item V-B-14][6], especially with the disturbed rock zone at the same or higher permeability, the Agency believes it is important to ensure that the proposed design on which compliance was based is actually implemented at the site. Therefore, EPA is requiring that DOE implement panel closure seal design Option D, with Salado mass concrete replacing fresh water concrete. The waste storage panels within WIPP must be sealed with a strong concrete barrier engineered to contain hazardous gases. The panel seals will also impede the transport of radioactive materials.

In response to Comment 3.HH.9, the panel closures will be constructed using currently available, widely used, tested and "proven" technology. Mixing and transportation of concrete, using special measures to prevent segregation of fine and coarse particles (as required in the Panel Closure System construction specifications), and placement in confined spaces by pumping, is accomplished every day in this country and throughout the world. Millions of cubic yards of concrete have been successfully emplaced in bridge and building foundations, dams, and in water supply, subway and highway tunnels, using the same methods planned for emplacement in the panel closures. The steel forms in which the concrete will be confined are somewhat unusual in shape, but the methods of construction are fairly simple and standardized. The Salado mass concrete mix is specially formulated for use in the WIPP, but it has been extensively tested to determine its properties (e.g., strength and resistance to chloride degradation) as explained in "Variability in Properties of Salado Mass Concrete", SAND93-1013. [Docket: A-93-02, Item II-G-1, Ref. No. 662]

The seven rooms in each panel (mentioned in Comment 898) will not be "sealed." Only a lightweight synthetic tarp or brattice cloth will be placed across the entry and exit drifts after each room is filled. This will reduce the flow of ventilation air into and out of the filled rooms, which will help to reduce the levels of volatile organic compounds in the airflow downstream from each panel. In the event of a roof fall in a waste-filled room, while the panel entries are still open (a very unlikely but possible event), the brattice cloth room closures will substantially reduce, if not completely eliminate, any added release of waste constituents into the occupied portions of the repository, or above ground. The room closures are not required to be airtight. They are only temporary (maximum required life is about 2 years), and are not critically important for safe operation or compliance with regulations. Construction of the room closures will require only lightweight bolts, tarps, battens, drills, and a few other tools.

<u>Shaft seals</u>

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6 Panel closure permeability values were varied in a range from 10,000 times less, then up to 100 times greater, than the constant value used by DOE in the PA model supporting the CCA. The DRZ permeability value is based on results from tests performed in holes drilled into the repository walls, roof and floor.

(Comments 3.HH.2, 3.HH.3, 3.HH.4, 3.HH.5, 3.HH.6, 3.HH.7, 3.HH.8, 3.HH.9, 3.HH.10) DOE described the seals to be used in each of the four shafts in CCA Chapter 3.3.1. [pp. 3-15 to 3-27] Appendix SEAL included the design plans and the material and construction specifications for the seals. The purpose of the shaft seal system is to limit fluid flow within the shafts after the WIPP is decommissioned and to ensure that the shafts will not become pathways for radionuclide release. The shaft seal system has 13 elements that fill the shaft with engineered materials possessing high density and low permeability, including concrete, asphalt, clay, compacted salt, cementitious grout, and earthen fill. The compacted salt column component of the system within the Salado is intended to serve as the primary long-term barrier by limiting fluid transport along the shaft during the 10,000-year regulatory period. The other components of the shaft seal within the Salado are intended to prevent migration of radionuclides in the short term and protect the compacted salt column until it becomes effective as a long-term barrier. Components of the seal system within the Rustler are intended to limit the commingling of ground water between the water bearing members. The seal system through and overlying the Rustler will consist of compacted earthen fill. [Chapter 3.3.1 and Appendix SEAL]

The shaft seal design is based in part on extensive research performed at the WIPP and elsewhere. The research is summarized in the CCA [Appendix SEAL, Docket: A-93-02, II-G-1], and described in detail in documents referenced in the CCA. [Docket: A-93-02, Item II-G-1, Ref. #49, #85, #280, #574] For example, the behavior of the mined openings at the WIPP and properties of reconsolidated crushed salt under pressure have been investigated extensively at the WIPP and at contract laboratories under the management of Sandia National Laboratories. Examples of Sandia National Laboratories' conclusions pertinent to seal design include the expected final degree of reconsolidation of the salt column (approximately 96% or more of the density of undisturbed Salado salt), the time required to reach that density in most of the 500-feet long compacted salt column (about 100 years after installation), the optimum moisture content for the salt (1.5%) to achieve the maximum constructed density with a reasonable amount of compaction, and the permeability of the reconsolidated salt column (within an order of magnitude of the permeability of the undisturbed Salado Formation). Other recent DOE research [Docket: A-93-02, Item II-G-1, Ref. #662] investigated the properties of salt-saturated concrete, which may provide somewhat enhanced long-term performance (e.g., resistance to chloride degradation) compared to concrete made with fresh water. Although the advantages of using the special salt-saturated mix (Salado Mass Concrete, or "SMC") may be small, EPA has required DOE to use SMC in the panel closures (where freshwater concrete was proposed) as well as the concrete segments of the shaft seals within the Salado.

The other components of the shaft seals (asphalt and bentonite clay) were included to ensure that the compacted salt columns will be protected against infiltration of ground water from the Rustler Formation during (at least) the first 100 years after construction is completed, and to provide additional large barriers with physical and chemical properties distinctly different from both salt and concrete.

The technology planned for use in constructing shaft seals has been thoroughly tried, tested and proven in the real world. The construction equipment and procedures necessary to emplace the seal materials are in large part the same as those used to excavate the WIPP, used in reverse.

Most of the seal materials will be hauled down the shafts in buckets or on cargo decks, or will be emplaced via slick lines (pipes). Except for salt, the shaft seal component materials are commonly used in construction. Salt has been extensively tested to determine its properties and behavior in the conditions which will exist in the shafts after closure. Compaction is the only special process or procedure which will be performed on the salt after placement in the shafts. Large-scale "dynamic" compaction is commonly used as a soil improvement procedure. It is used throughout the world to densify and consolidate soils and similar materials in order to provide improved foundation conditions, or to reduce erosion or other problems. Sandia National Laboratories performed dynamic compaction testing of WIPP salt to verify the expected characteristics of the material when placed in the shafts. [Docket: A-93-02, Item II-G-1, Ref. #85 and #280]

DOE has provided a final design for the shaft seals which could be constructed with little or no modification. However, EPA recognizes the fact that many changes will occur in knowledge of construction materials, and in construction methods and equipment, during the 35 years before the WIPP is expected to be closed. The panel closure and shaft seal plans are expected to be periodically reviewed and revised to take full advantage of new knowledge or construction equipment in the future. Acknowledgment of this circumstance does not mean that the existing plans are inadequate, or that major changes in the design are anticipated. Periodic review of the WIPP authorization(s) is required by the various statutes and regulations applicable to the WIPP, including EPA review of recertification applications every five years, and state review of the RCRA permit at least every 10 years. Panel closure and shaft seal design changes may be proposed and perhaps approved by EPA several times before the end of the WIPP disposal operations phase. Changes in the designs will be required to go through standard public notice and comment procedures before approval by EPA. [40 CFR § 194.67]

(Comments 3.HH.7, 3.HH.8) As stated in issue FF of the comments to the proposed rule [CARD 14], "DOE has performed and referenced numerous tests and experiments [Appendices SEAL, PCS, DEL, and MASS] to establish the material characteristics of importance to containment of waste at the WIPP. The characteristic of primary importance is the material's permeability. The permeability of concrete, asphalt, and bentonite clay was well documented, and DOE performed numerous experiments to demonstrate the applicability of these characteristics to the WIPP's site specific conditions (high brine concentration). DOE has documented many laboratory and in situ tests of the permeability of compacted crushed salt including a large-scale, "thumper" test to demonstrate the feasibility of implementing such a seal measure."

(Comment 3.HH.11) The statement that the WIPP shafts must be sealed "perfectly" does not recognize the testing and analyses performed to estimate performance of the shaft seal materials, and the overall effects of natural processes (such as ground water flow and salt creep) on the repository. There is a high degree of confidence that the seal materials will behave in a manner similar to the behavior observed in actual field and laboratory testing performed specifically to provide the basis for such predictions. The overall design strategy accounts for the fact that the compacted salt (the largest and "main" long-term seal material) will continue to consolidate under the pressure of overlying seal materials and the inward creep of the Salado Formation, for more than 100 years after construction of the seals. The bentonite, asphalt and concrete components of the seals will also be confined under the same extreme (lithostatic) pressures during this time. Hydrostatic (ground water) pressure at the top of the Salado will be less than half the lithostatic pressure, indicating little potential for intrusion through the low permeability seal materials, even if the extreme swelling properties of bentonite were not considered. Further, EPA does not believe karst conditions warranting unique shaft seal designs are present in the shaft area.

(Comment 3.HH.13) Dissolution of salt (halite) in the WIPP shafts would require a source of water that is not saturated with salt, and a sink, i.e., some location for the water to flow to after it has dissolved the salt in the shafts. Since all of the ground water from the top of the Salado downward is saturated with salt (i.e., it is "brine"), the unsaturated water would have to come down the shaft from the Rustler Formation. In order to reach the salt component of the shaft seal, that water would have to pass through or around a 20 foot long concrete plug, 140 feet of asphalt (emplaced as hot flowing liquid), a combined concrete-asphalt waterstop (dug into the surrounding Salado a distance of at least one shaft radius), a bentonite clay column more than 330 feet high, and another concrete-asphalt waterstop. Then, after flowing through the 550 feet compacted salt column, the saturated water would have to flow through or around another concrete-asphalt waterstop, another 100 feet of bentonite clay, and the shaft station concrete plug. Upon completion of the shaft seals, each of these solid materials, and the surrounding Salado Formation, will be under lithostatic pressure, which will be more than twice the pressure which would be exerted by any water flowing down from the Rustler Formation, at any given elevation. [Appendix SEAL, Section 8.3, pp. 63-69]

In addition to the well-known and predictable slow creep or solid flow of the salt under unbalanced pressure, which will result in further post-construction consolidation and reduction in the permeabilities of both the disturbed rock zone and the seal materials, the asphalt and clay components will provide immediately effective barriers to water flow. For example, if water was somehow able to flow past the first Salado concrete plug, the entire asphalt plug (140 feet), and the upper concrete-asphalt waterstop, it would encounter the large volume of bentonite clay. The clay will be emplaced with a moisture content about 20% below saturation. [CCA Appendix SEAL, Section 8.3] Any water moving down into the clay will be rapidly absorbed, and the clay will expand into the water transport path. Hydrated or saturated bentonite has extremely low permeability, and will expand by 10 to 15% or more of its original (unsaturated) volume. These properties have resulted in the use of bentonite as one of the components for lining many hazardous waste landfills and surface impoundments. The CCA mathematical analyses and the computer model which predicts flow of less than 5 cubic meters of water down each shaft [CCA Appendix SEAL, Section 8.3] during the first 200 years after closure of the WIPP do not include any "credit" for the effects of bentonite swelling and capture of water that might reach the clay column. The calculations also do not take credit for absorption of water into the dry halite in the shaft walls, and are therefore considered conservative.

This (5 m^3) brine inflow is very small in comparison to the volumes of the shaft materials (i.e., less than 0.1 % of the salt column which will occupy about 5,100 cubic meters in the Air Intake Shaft). Even if a hundred times this volume of water were to pass through the salt column, and it contained no salt when it reached the top of the salt column (an impossibility), and it was somehow able to escape past the underlying clay column, only a small amount of the salt column would be removed. (The maximum amount of salt that could be removed, given the above unrealistic assumptions, is that required to saturate the water, about 374,000 mg/l. [CCA Chapter 2, Table 2-5] A flow of 500 m^3 of water could carry about 187 metric tons of salt, which is about 94 cubic meters, or less than 2% of the initial salt column volume.) Since the amount of water flow from the Rustler (if any) will decrease over time, due to the ongoing inward creep of the Salado Formation, the salt column would still be consolidated after such a dissolution episode. In fact, the entry of water into the DRZ of the shafts would increase the rate of creep closure toward the shafts, due to softening of the halite. EPA concludes that dissolution of the salt seal is therefore not a concern.

Issue II: The big steel doors that they have designed to seal off the rooms after they have placed the waste would not work.

1. In my first conversation with the Admiral ten years ago, I mentioned to him that the big steel doors that they had designed to seal off the rooms after they had placed the waste would not work. (733)

Response to Comment 3.II.1:

EPA assumes that the commenter is referring to the barricades to be constructed at each end of a full waste disposal room (within a waste disposal panel), during the operational phase (not the panel seals). The brattice cloth barricades are not required nor modeled in Performance Assessment scenarios and there are no specific performance or design standards in the compliance criteria which the short-term barricades are required to meet.

Issue JJ: Precipitation values in the CCA are too low.

1. Precipitation values in the CCA are too low. (20)

Response to Comment 3.JJ.1:

EPA does not believe that precipitation values included in the CCA are too low. DOE provided information regarding precipitation in the vicinity of the WIPP in CCA Chapter 2.5.1 [pp. 2-176 to 2-178] and Appendix CLI. After studying multiple lines of physical and biological evidence, DOE concluded the following regarding precipitation in the WIPP region:

- ♦ Maximum precipitation coincided with the maximum advance of the North American ice sheet (22,000 to 18,000 years ago) and minimum precipitation occurred after the ice sheet had retreated to its present limits.

- ♦ Past maximum long-term average precipitation was roughly twice the present level, and past minimum precipitation may have been 90 percent of the present level.

- Short-term fluctuations in precipitation have occurred during the present relatively dry, interglacial period (from 18,000 years ago), though the long-term average precipitation has not exceeded upper limits of the glacial maximum (22,000 to 18,000 years ago).

From a review of the CCA, Appendix CLI and related supporting references, EPA believes DOE provided adequate evidence that demonstrated that the maximum precipitation in the WIPP area is associated with advances of ice sheets and that maximum past precipitation was about twice of current levels. In the performance assessment, DOE assumed that the range of precipitation levels in the future would be no less than current levels with a precipitation maximum up to 225 percent, about that of past known maximums. In addition the PA assumed a function of potential future climates that ranged from low to high precipitation levels. While it is not possible to predict future climates with any certainty, DOE used information on the past to reasonably project potential precipitation amounts into the future. EPA believes that the precipitation values in the performance assessment to estimate future climates (i.e., precipitation amounts) are adequate because they attempt to incorporate the known information about past climate associated precipitation levels.

EPA also determined that the information provided regarding records of recent annual and monthly precipitation averages, were adequately detailed. For more information, refer to EPA Technical Support Document for § 194.14: Content of Compliance Certification Application, § 194.14(I). [Docket: A-93-02, Item V-B-3]

Issue KK: WIPP exists in a known oil and gas district.

1. The WIPP lives or exists in a known oil and gas district. There are 120 oil and gas wells right now within two miles of the WIPP site boundary. The Department of Energy cannot control this site forever. (307)

Response to Comment 3.KK.1:

EPA agrees that the WIPP Site is located in a known oil and gas district and that DOE cannot be expected to control the site forever. However, both of these considerations were included in EPA's requirements for DOE's performance assessment of the WIPP. The principal impact on WIPP resulting from the likely presence of oil and gas resources beneath the site will be the possible penetration of waste panels by exploration boreholes. DOE was required to estimate the rate at which exploration boreholes would be drilled and the probability that such boreholes would penetrate the repository. DOE was required to assume that its active institutional control of the WIPP would not extend beyond 100 years. DOE was also required to predict the radionuclide releases that would result from borehole penetrations after 100 years, and include those in the overall releases that might occur from the site. DOE was then required to show that those releases are less than the maximum allowable releases that would provide adequate protection to public health. The concerns identified in this comment have therefore been incorporated by EPA into the rule and by DOE into the WIPP performance assessment.

Issue LL: What's the likelihood of leakage from the storage facility up through holes formed by oil and gas drilling?

1. What's wrong with WIPP, that's what I came to say here. It's full of holes, literally and figuratively. There been a steady stream of oil and gas drillers that have been located next to the site there. What's the likelihood of leakage from the storage facility up through these holes, that is a question I have. (513)

Response to Comment 3.LL.1:

EPA recognized the importance of oil and gas drilling to repository performance, and required intrusion scenarios be included in performance assessment. Also, as part of its features, events and processes evaluation, DOE examined the possibility that an improperly abandoned borehole through or near the repository could provide a conduit for contaminant migration upward. DOE concluded that the probability of a yet-to-be discovered borehole within the WIPP site boundary was very low.

DOE concluded [Chapter 6.4.7.2 and Appendix MASS 16-1] that all oil and gas related boreholes in the WIPP area were plugged, or scheduled to be plugged, according to applicable regulations. DOE's assumption was based on well records for intrusions on Federal lands, wherein NMOCD data showed all wells to be plugged or scheduled to be plugged per regulatory requirements. DOE also indicated that 100 percent of wells drilled and then abandoned since 1988 were, or are, in the process of being plugged per applicable standards. DOE also evaluated the borehole permeability variations that may occur, and estimated that the plug system was expected to have an initial permeability of 5×10^{-17} m^2. DOE assumed casing would corrode due to the saline ground water environment [Appendix DEL, Attachment 7, Appendix B] and concrete plugs would degrade when sufficient water entered the plug to cause matrix degradation. [Appendix DEL, Attachment 7, Appendix C] DOE also assumed that shallower casing and cement plugs will degrade in about 200 years, allowing for more potential fluid flow earlier in the regulatory period in shallower horizons when compared to deeper casing, which was assumed to fail approximately 5000 years after installation. DOE assumed that the "corroded casing and degraded plug will fill the hole with material with a permeability about one order of magnitude lower [than when undegraded]." [Appendix DEL, Attachment 7, p. 19]

EPA evaluated the effects that natural degradation of long-term borehole plugs would have on the plug system and the potential for increased transmissivity of abandoned well plugs due to such degradation. EPA found that DOE's assumed borehole plug permeabilities were partially incorrect. [CARD 33, section 33.G.5, Docket: A-93-02, Item II-B-01] Although DOE's permeabilities assigned for the various plug configurations were based on plausible data, EPA believed that DOE made certain degradation assumptions that resulted in a low-end permeability of the long-term borehole plug parameter that was too high. In other words, DOE assumed that plugs may be more permeable than may be the case. Lower values are more conservative because they allow for greater gas pressurization of the WIPP and a potential increase in releases due to mechanisms such as spallings. [Technical Support Document for § 194.23: Parameter Justification Report, Section 5.17; Docket: A-93-02, Item V-B-14]

EPA began by investigating the permeability of borehole materials and drilling fluids used in the petroleum industry. Literature values for the permeability of the concrete used in borehole plugging applications can range from 9×10^{-21} to 1×10^{-16} m^2 (1×10^{-5} to 0.1 millidarcy (md)); these values are also cited in some of the publications referenced in the CCA. EPA also investigated the permeabilities of drilling muds. Filter cake and compacted clay-based drilling muds can have permeabilities of less than 9.9×10^{-22} m^2 (1×10^{-6} md) based on field data for 11 ppg mud. [Technical Support Document for § 194.23: Parameter Justification Report, Section 5.17; Docket: A-93-02, Item V-B-14]

EPA concluded that drilling mud circulated in Delaware Basin boreholes may not have the degree of clay-based solids loading typically experienced elsewhere, as discussed in CCA Vol. X, Appendix MASS 16-3, Appendix C; however, natural cuttings could contribute to lower borehole permeability than that postulated by DOE. Lower initial permeabilities, more effective plug segments, mixed layers between plug components that would take time to degrade, and lower fluid velocities than DOE assumed in its calculations could significantly retard plug degradation and could maintain the effective seal of the plug sequences for hundreds or thousands of years beyond that assumed by DOE in CCA Appendix MASS, Attachment 16.

DOE provided a variety of plausible mechanisms to increase plug permeability, and EPA believes that this high range of permeability may be attained. However, EPA also believes that there is a probability that the low end of the range of borehole permeabilities (effective over several hundred vertical feet of borehole) would be lower than the low end of the range estimated by DOE. Since the effective permeability for fluid movement through any given borehole will actually be controlled by the permeabilities of all zones through which the fluids must pass, the effective average permeability could be dominated by small sections of remaining competent plug or other low permeability material. If complete degradation does not occur throughout a well, or if natural materials and mud provide additional layers with sealing properties, it is possible that the effective average permeability over several hundred feet of abandoned borehole could remain in the range of 9×10^{-21} to 1×10^{-16} m^2 (1×10^{-5} to 0.1 md) over a period of hundreds, if not thousands, of years.

EPA concluded that the borehole permeabilities assigned in the CCA [Vol. X, Appendix MASS, Appendix 16] were consistent with the broad range of available permeability data, but did not adequately incorporate the total range of permeability conditions that could exist in boreholes. Permeabilities assigned by DOE may therefore overestimate the degree to which plugs would lose effectiveness. EPA concluded that an alternative case could be made in which many of the plugs would retain a larger degree of effectiveness. As such, a lower maximum permeability value of *approximately* 1×10^{-17} m^2 (1×10^{-2} md) is quite possible (particularly for long-term conditions) and may have an impact on performance assessment results. As a result, EPA included both long- and short-term plug permeability changes in the PAVT. EPA required that performance assessment simulations be conducted with lower minimum permeabilities (an undegraded concrete plug minimum of 1×10^{-19} m^2 instead of the constant value of 5×10^{-17} m^2 used in the CCA, and a degraded borehole filling minimum of 5×10^{-17} m^2 instead of the minimum value of 1×10^{-14} m^2 used in the CCA) to account for possible cases in which complete degradation does not occur throughout a well, or where natural materials and mud provide additional layers with sealing properties. See § 194.23(a) in CARD 23 -- Models and Computer Codes for more information regarding the permeability values assigned by EPA in the PAVT. [Docket: A-93-02, Item V-B-2] Results of the PAVT indicate that a lower borehole permeability does allow greater pressure build-up in the repository and, hence, greater release potential from mechanisms such as spallings. However, releases predicted by the PAVT were still well below the EPA release limits. For information on EPA's evaluation of the PAVT, see Docket: A-93-02, Item V-B-05.

Issue MM: Culebra transmissivities are greater than previously believed

1. Since the submission of its original paper [Potential Flow Paths from the WIPP Site to the Accessible Environment], CARD has discovered a more complete transmissivity database for the Culebra dolomite (LaVenue et al., 1988, SAND 88-7002, Table C.1; Beauheim, 1989, SAND89-0536, Table 6-1). When CARD submitted its original paper, the Culebra transmissivity at H-3 (19 ft^2/day) was thought to be anomalously high. Now we know that Culebra transmissivities elsewhere in the recharge area are comparable (20.0 ft^2/day at H-1; 16 ft^2/day at H-2; 22.0 ft^2/day at ERDA-9; and 28.0 ft^2/day at the WIPP exhaust shaft). These transmissivities are more than an order of magnitude (more than ten times) greater than previously believed, implying a faster rate of recharge and lateral flow. (854)

Response to Comment 3.MM.1:

EPA recognizes the large variability in transmissivity for the Culebra as well as the higher values cited in this comment. Variability and uncertainty in the spatial distribution of transmissivity in the Culebra are addressed in the WIPP performance assessment calculations through the use of Monte Carlo techniques. A large set of transmissivity fields (100) were developed with each transmissivity field being a statistical representation of the natural variation in transmissivity that uses measured data according to certain criteria. The references cited by the commenter were incorporated into development of the transmissivity fields. Monte Carlo simulations using a large number of equally-likely transmissivity fields is a statistically valid method of characterizing the uncertainty associated with transmissivity in the Culebra. [Appendix TFIELD, Chapter 6.4.6.2, pp. 6-131]

As a point of clarification, the rate of recharge is not necessarily directly related to the localized transmissivity of the Culebra. Recharge occurring as a result of infiltration of precipitation or surface waters is more dependent on factors such as the vertical hydraulic conductivity of geologic units that overlay the Culebra and the amount of infiltration that is available. The rate of recharge occurring to the Culebra in the vicinity of WIPP as a result of lateral ground water flow is largely dependent on the transmissivity of the Culebra hydraulically upgradient of the WIPP.

Issue NN: H-19 results remain unpublished.

1. It should be noted that H-19, the latest WIPP hydropad, consisting of an array of seven test wells, is located between H-3 and DOE-1, within the zone of high transmissivity. Multi-well

pumping tests and tracer tests have been performed at H-19, but the results remain unpublished. EPA should not be content without full disclosure of these most recent drillholes and tracer tests. (856)

Response to Comment 3.NN.1:

Results of the H-19 multi-well pumping tests and tracer tests have been fully disclosed and published and presented under several venues. Discussion of the tracer test results as well as the rationale for the tests were presented in the OECD Proceedings-Conference of Radioactive Waste in Cologne, Germany August 1996. [Docket: A-93-02, V-B-1, WPO #43426 and WPO#44456] Transmissivity determinations from hydraulic testing of H-19b2 are found in WPO38401. In addition, results of the H-11 and H19 tracer tests are summarized in the Conceptual Model for Transport Processes in the Culebra Dolomite Member, Rustler Formation. [Sandia National Laboratories, Holt, R.M., 1997. Conceptual Model for Transport Processes in the Culebra Dolomite Member, Rustler Formation*.* SAND 97-0194, see Docket: A-93-02, Item V-B-1] The results of the tracer tests as well as hydraulic tests have led to refinement of the conceptual model for transport in the Culebra. Results of the hydraulic tests were used in developing the transmissivity fields used in WIPP for the PAVT. EPA concludes that data concerning H-19 have been presented and are available for review.

Issue OO: Culebra and Magenta hydraulic heads

1. CARD stated in its original paper that hydraulic heads in the Culebra and Magenta are equal at WIPP-25 in Nash Draw and at H-6 within the northwestern corner of the WIPP site. CARD has since discovered that the Culebra head at H-18 (3059 feet) is also higher than at H-6; again, hydraulic heads in the Culebra and Magenta may be equal, but the data are not available. DOE needs to perform the necessary testing to determine where the Culebra and Magenta lose their hydraulic isolation from each other. (857)

Response to Comment 3.OO.1:

Statements regarding the relationship of water elevations in various wells can be misleading because the water elevations change over time and because the water level elevations are affected by the density of the ground water. The hydraulic heads in the Culebra and Magenta at WIPP-25 in Nash Draw and H-6 in the northwest corner of WIPP were not equal based on data from 1982. [Appendix HYDRO, pp. 55-69] (Note: Hydraulic heads are measured in length, in this case, feet. In the case of brines a density correction is typically used in order to compare with freshwater; this correction produces what is known as the equivalent freshwater head.) The Magenta had 4 foot higher freshwater equivalent head than the Culebra at WIPP-25. At H-6 the Culebra freshwater equivalent head was 2 foot higher than in the Magenta. EPA acknowledges that these differences are less than the head difference between the Magenta and Culebra that is more typical of WIPP -- up to tens of feet as shown in CCA. [Figure 2-31 and 2-32] EPA points out that the flow direction in the Magenta and Culebra differ. [Figure 2-31 and 2-32] The potentiometric surface of the Culebra decreases from north to south. The intersection of the highest hydraulic head value for the Culebra with the lowest hydraulic head value for the

Magenta is in the northwest corner of WIPP, but there is still an observed, measurable head difference between the Magenta and Culebra in this location. Furthermore, there are large differences in water chemistry between the Magenta and Culebra at H-6 [Table 8 Appendix HYDRO] indicating hydraulic isolation between these hydrologic units in this area. At WIPP-25, water quality between the Magenta and Culebra is similar. The similarity in hydraulic head and water quality may indicate some very localized hydraulic connection exists between these units, but this is consistent with geohydrologic conceptual models that indicate Nash Draw was formed by solution-subsidence and collapse followed by extensive erosion resulting in a zone of dissolution. However, the inferred flow direction (based on potentiometric surface maps) for the Culebra is to the south across WIPP and therefore the degree of hydraulic connection between the Magenta and Culebra in the northern reaches of Nash Draw has little if any bearing on potential transport of radionuclides from WIPP, since releases to the Culebra would be transported southward.

Issue PP: Geophysical logs for H-4, H-5, and H-6 were never published.

1. At the public hearings in February 1997, CARD noted that the geophysical logs for H-4, H-5 and H-6 were never published; only brief lithologic descriptions were provided (Mercer and ORR, 1979). CARD has since discovered that only 2.3 feet of core was recovered at H-6b (Jones et al., 1992, SAND92-1579, Figure 9-2). It is described as "dense dolomite with minor vugs and some vertical fractures." Altogether, 90% of the core was lost, indicative of conditions of dissolution. The release of the geophysical logs for H-4, H-5 and H-6 is required. (858)

Response to Comment 3.PP.1:

EPA went to the Sandia Records Center to review geophysical logs and found that three borings were installed at each of the hydropads in question (H4, H5, H6), however, only one boring at each hydropad was logged geophysically. The geophysical logs for borings H4c, H5c, and H6c are in the Sandia Records Center and are referenced in Seward, 1982. [Docket: A-93-02, V-B-1, SAND-82-0080, Form H4a,b, and c; Form H5a, b, and c; Form H6a, b, and c] Generalized lithologic descriptions of the stratigraphy and hydrology at each hydropad is presented in Jones. [1992, Figure 9.2] Boring H6b, cited by the commenters, was not logged. Dennehy [1982] in Jones [1992, Docket: A-93-02, Item II-G-1, Ref. #343, in Figure 9.2] attributes the core loss in H6b to fracturing within the Culebra. EPA does not believe that all fracturing within the Culebra is attributable to dissolution and karst development as inferred by the commenter. Core loss is a common occurrence in the drilling of all rock strata and can be associated with many causes, including the type of drilling technology used (i.e., air drilling), presence of fractures, and the occurrence of soft or incompetent rock. EPA believes that it is incorrect to interpret all zones of lost core as zones of high permeability caused by dissolution.

Issue QQ: A variable-aperture channel model could fit observed hydrologic data.

1. In Jones et al., (1992, pp.3-9, 3-10, 12-19), DOE admits that a variable-aperture channel model, with the bulk of the flow occurring in channels, "could fit the observed data equally as

well." Yet DOE adheres to its "stochastic" model, treating the heterogeneous transmissivities" in the Culebra as "random variables" without geographic orientation. Given the observed data, the conservative approach would be: (1) to acknowledge that paths of anomalously high transmissivity, being interconnected paths of least resistance, are representative of actual site-scale ground water flow paths and to assess the suitability of the WIPP site according to these data; and (2) to convert WIPP-33 and WIPP-14 into hydrologic test wells in order to measure Rustler transmissivity under actual karst conditions in the immediate vicinity of the WIPP site. (863)

Response to Comment 3.QQ.1:

EPA points out that the reference to Jones et al., 1992 [Docket: A-93-02, II-G-1, Ref. #343] cited by the commenter is misquoted to eliminate the proper context of the statement. The full statement on p. 12-19 of Jones et al., 1992 [Docket: A- 93-02, II-G-1, Ref. No. 343] is that "Alternative conceptualizations for transport through the Culebra that could fit the observed data equally as well as a double-porosity conceptualization may be possible." The discussion prior to that statement indicates that the double porosity conceptualization resulted in good agreement between observed and simulated breakthrough curves for tracer tests at the H-3, H-6 and H-11 hydropads. After the referenced statement, Jones et al., 1992 [*ibid.*] continues, "differentiating realistic alternative transport models from unrealistic models can probably not be performed with the existing tracer-test data. . . A new series of tracer tests has been proposed that incorporates a large number of travel paths, transport under a variety of flow rates and transport scales that vary by an order of magnitude. This test series will provide the data necessary to rigorously test the viability of the double porosity model and whether or not alternative transport conceptualizations are realistic for the Culebra dolomite at the WIPP site." Jones et al was referring to the H-19 tracer tests. Results of these tests have been incorporated into the conceptual model for Culebra transport and support the notion of double porosity for zones of higher transmissivity whereas a single porosity model is more appropriate for zones of lower conductivity. [Docket: A-93-02, V-B-1, SAND98-0049] Furthermore, results of the tracer tests indicate that significant matrix diffusion occurs within the Culebra. [Docket: A-93-02, V-B-1, WPO 44456, pp. 157-179]

EPA has reviewed the PA and determined that DOE's use of stochastic modeling to represent the variability and uncertainty in the spatial distribution of transmissivity in the Culebra through the use of Monte Carlo techniques is adequate for modeling. [CARD 23, Section 4.1, Docket: A-93-02, Item V-B-2] The methodology employed does not treat transmissivity data as "random variables without geographic orientation" but rather uses available transmissivity data as a limiting constraint. A large set of transmissivity fields were developed with each transmissivity field being a statistical representation of the natural variation in transmissivity that uses measured data according to certain constraints.

Issue RR: Any data can be mapped with smooth contour lines.

1. DOE contends that "the measured head data can be contoured as continuous smooth surfaces and so argue against karstic flow." This statement is misleading. Any data can be mapped with smooth contour lines if the data is used selectively. (864)

Response to Comment 3.RR.1:

EPA did not rely on contoured measured head data to conclude that subsurface karst features affect ground water flow in Nash Draw, but not at the WIPP site itself. Instead, the conclusion is based on the results of hydrologic testing and geologic data. DOE performed numerous aquifer tests in the Rustler Formation (e.g., hydropads H-3, H-11, and H-19), as well as tracer tests at six locations (H-2, H-3, H-4, H-6, H-11 and H-19 hydropads). [CCA Chapter 2.21.4.1.2; Appendix MASS 15] DOE's data indicate that the Rustler is a fractured dolomite with nonuniform properties both horizontally and vertically, and "hydrologic connections" are noted between boreholes, which is consistent with this interpretation. However, no data acquired to date indicate that there is cavernous flow at the WIPP site.

DOE also conducted hydrologic testing in a well from a karst area (e.g., well H-7). Well H-7 is located in Nash Draw, a large karst feature west of the WIPP. The Culebra transmissivities from Nash Draw were much greater than those at the WIPP site. The transmissivity ($1x10^3$ square feet per day or $1x10^{-3}$ square meters per second) of the Culebra in Nash Draw is 100 times or more higher than in wells on the WIPP site, indicating that karst processes have not affected Culebra ground water flow at the WIPP site as they have in Nash Draw. The hydrologic test results confirm that transmissivities in the Culebra vary significantly from east to west in the WIPP area, and this was modeled by DOE in its PA calculations. See Appendix TFIELD for a discussion on how DOE incorporated the transmissivity data into the PA calculations. EPA concludes that sufficient hydrologic testing has been performed to indicate that subsurface karst features affect flow in Nash Draw but not at the WIPP site itself, and that these results have been integrated into the transmissivities modeled in the performance assessment.

Issue SS: Rise in water levels in the Magenta and Culebra can be correlated with short-term trends in precipitation.

1. DOE proclaims that "head changes in boreholes indicative of rapid recharge at the WIPP site during times of heavy rainfall have not been observed." CARD offers an explanation. During this four-year period 68.55 inches of rain (17.14 inches per year) was recorded in Carlsbad, compared to an average of 10.85 inches per year during the preceding 25 years. While the rise in Magenta and Culebra water levels cannot be correlated with individual rainstorms, it can be correlated with short term trends in precipitation. (865)

Response to Comment 3.SS.1:

EPA believes this comment means either that: 1) the commenter disagreed with the DOE statement that head changes in boreholes indicative of rapid recharge at the WIPP site during times of heavy rainfall have not been observed; or 2) that the commenter believes that the water level rises in the Culebra that have been observed in the WIPP region are explained by recharge from precipitation, rather than DOE's explanation for water level rises provided in CCA Chapter 2.2.1.4.1.2. [p. 2-124]

EPA concurs with DOE's statement that head changes in boreholes indicative of rapid recharge at the WIPP site during times of heavy rainfall have not been observed. As noted in CCA Chapter 2.2.1.4.1.2 [p. 2-124], ground water levels in the Culebra in the WIPP region have been measured continuously for several decades. There have been no data collected that would be indicative of rapid water level rises due to rapid recharge due to infiltration of precipitation in a karst system.

EPA concurred with DOE's explanation that some anomalous water level rise in the Culebra can be attributed to recovery of Culebra heads from drainage in the WIPP shafts after installation, and/or effluent discharge from potash mines. [CARD 14, sections 14.B.4 and 14.B.5, Docket: A-93-02, Item V-B-2] DOE has incorporated the potential for rises in the Culebra water level under a range of different future states in which the climate may be wetter into the PA modeling. As described in CCA Chapter 6.4.9 [p. 6-166], a Climate Index parameter is used to vary the specific discharge in each grid block of the SECOFL2D model. The Climate Index parameter is a sampled parameter in the performance assessment, with a bimodal distribution ranging from 1.00 to 1.25 and 1.5 to 2.25. The variation of the Culebra water levels within the PA modeling did not result in releases of radionuclides that exceeded the EPA standards.

EPA acknowledges that DOE has not provided an explanation for the water-level rises in the Culebra in the vicinity of the H-9 hydropad, as described in CCA Chapter 2.2.1.4.1.2. [p. 2-124] Although the water level changes have not been explained, EPA believes that the magnitude of the water-level rises are already accounted for in the water level variations that have been incorporated into the PA modeling. This minimizes the need to establish the cause of the anomalous water level changes. In addition, the unexplained water-level rise occurred in the vicinity of a hydropad that is located approximately 6.5 miles (10.46 kilometers) south of the southern boundary of the Land Withdrawal Act boundary, which is far from the maximum downgradient extent of the modeled 10,000 year ground water flow. As a result, EPA believes that the water level rises will not impact the results of the PA. In addition, actinides are not expected to travel very far during the regulatory time period due to retardation. DOE demonstrated that actinides will be retarded and do not contribute much to releases [CCDF graphics in Chapter 6.5 of the CCA] at the boundary and would not reach the location in which the unexplained water level rises have occurred.

Issue TT: Rustler dissolution

1. In order to deny that subsurface dissolution has ever occurred in the Rustler Formation, Powers and Holt attribute all fracturing and brecciation in the Rustler to dissolution at the top of the underlying Salado Formation. Powers and Holt have confused the cause with the effect. Dissolution proceeds from the top down, due to infiltrating rainwater. Dissolution at the top of the Salado cannot occur without dissolution of the Rustler, and the more fractured and brecciated the Rustler, the more likely that dissolution will affect the top of the Salado. (867)

2. The EEG has shown (Chaturvedi and Channell, 1985; Lowenstein, 1987) that the pattern of occurrence of salt in the Rustler Formation can be more rationally explained by the hypothesis of

post-dissolution salt removal as first proposed by Snyder (1985), rather than the Holt and Powers (1988) and Powers and Holt (1990) hypothesis of facies change. (1229)

Response to Comments 3.TT.1 and 3.TT.2:

(Comment 3.TT.1) DOE proposed that three principal dissolution mechanisms may occur in the Delaware Basin: lateral, deep and shallow. [Docket: A-93-02, Item V-B-2, CARD 14, sections 14.B.4 and 14.B.5] Deep dissolution refers to that at the base of or within the salt section; lateral dissolution occurs within supra-Salado units (progressing eastward from Nash Draw); and shallow dissolution would occur from surface-down infiltration of undersaturated water. Contrary to the commenter's assertion, lateral, strata-bound dissolution can occur without shallow dissolution from above if undersaturated water is somehow introduced into a strata. Fracturing of the Rustler can be associated, at least in part, to halite loss in the Rustler (which is presumably due to syn or post depositional lateral interformational halite dissolution, and is not necessarily associated with overlying shallow (i.e. surface down) dissolution). This is evidenced by brecciated units that are bounded, top and bottom, by unbrecciated units (e.g. at the base of the Rustler in the WIPP Air Intake Shaft), or by dissolution of units and subsequent collapse of overlying units. DOE concluded, and EPA agreed, that fracturing of the Rustler can and does impact vertical infiltration, and Culebra water chemistry in the area of greater vertical transmissivity exhibits lower total dissolved solids concentration that other less permeable areas (refer to response to Comment 17 which deals with conceptual models, and Figure 2-40 of the CCA). This does not mean, however, that vertical infiltration is currently occurring in this area (hydrogeochemical Facies B area) sufficient to dissolve the Salado Formation.

In response to Comment 3.TT.2, EPA notes that DOE has asserted that many brecciated units present in the Rustler Formation can be attributed to syn and immediate post depositional processes, such as slumping of sedimentary strata, and need not be attributed to dissolution. For those brecciated Rustler units that are stratabound (i.e., non-fractured units above and below the brecciated zone), the age of brecciation is older than 200 million years. EPA has examined geologic data available through geologic borehole logs and associated records, available core data, and geologic interpretive reports [Appendix FAC, Docket: A-93-02, II-G-1] and concludes that these syn and post depositional processes could account for some of the observed sedimentary fabrics. However, EPA also concludes that any number of other processes could account for some of the observed sedimentologic features, including dissolution of interbedded halite and other soluble units. DOE also indicates, in Appendix FAC, Section 8, pp. 8-1 through 1-18 that any number of sedimentary processes can occur, and DOE acknowledges that there are indeed examples of significant rock unit collapse and brecciation due to post-deposition dissolution (WIPP-13 and WIPP-33). It is clear that the depositional and post depositional history of rock units in the Rustler is complex, and a variety of plausible explanations for observed fabrics can be present.

Issue UU: Salado dissolution

1. DOE, citing Powers and Holt (1995), says that "there is no indication that the Salado at the WIPP site has been thinned by dissolution," and that "evidence for a dissolution residue at the

top of the Salado is limited to the west of the WIPP site." Yet at least seven boreholes [P-12, P-14, WIPP-33, H-3, H-6, P-6 and P-13] east of Livingston Ridge encountered dissolution residue at the top of the Salado. (869)

Response to Comment 3.UU.1:

EPA assumes that this comment was made in reference to shallow and lateral dissolution at the top of the Salado, not thinning of the Salado due to deep dissolution. EPA also questioned DOE's interpretation that syndepositional and immediate post depositional processes are the origin of some Rustler stratigraphic characteristics. [Docket: A-93-02, V-B-2, CARD 14, p. 14-23] EPA examined well data in the WIPP area that exhibit dissolution features (e.g., WIPP-33), and believed DOE's broad conclusion that depositional or immediately post-depositional processes cause the observed fabrics is too limited. However, EPA also concluded that there is no evidence that dissolution (which could create observed residues) is occurring or will occur at such a rate as to compromise the containment capabilities of the WIPP during the 10,000 year regulatory time frame. [*ibid.*, p. 14-24]

Issue VV: No measurement of infiltration rate at WIPP

1. DOE has never even attempted to measure infiltration rates at the WIPP site, reliance on a chloride mass balance method is no substitute for measured data. (872)

Response to Comment 3.VV.1:

EPA believes that the question posed in the comment is made in reference to the use of a 0.2 to 2 mm infiltration in the ground water basin model [Docket: A-93-02, II-G-1, CCA Ref #147], wherein a reference to the chloride mass balance study of Campell, 1996 [Docket: A-93-02, Item V-B-1] is also made. EPA points out that the infiltration values used in Corbet and Knupp were somewhat artificial values derived by calculating the necessary recharge that would result in a Culebra water level rise to ground surface, which is the modeled maximum Culebra response to climate change. It is not meant to necessarily indicate the quantity of surface infiltration present at WIPP. EPA agrees that site-specific infiltration testing that would be directly useful in determining surface water infiltration through sand, caliche, and rock unit horizons above the Salado are not available. However, infiltration data of this nature would require the analysis of vertical surface water flow through hundreds of feet of material (assuming that the commenter is concerned that infiltration information regarding the Rustler be acquired). EPA believes that available hydrologic information is sufficient to understand ground water flow in the Rustler Formation without acquiring additional infiltration data.

Issue WW: Water within the WIPP shafts

1. DOE stated that the Dewey Lake Redbeds have not produced water within the WIPP shafts or in boreholes in the immediate vicinity of the waste panels, and that the Dewey Lake exhibits no flow at the WIPP site. These statements are false and here is why. The Dewey Lake Redbeds have produced water in the WIPP exhaust shaft at approximately 100 feet below the surface

which EEG says can be traced to recharge. The Dewey Lake produced water in the air intake shaft as well. The Dewey Lake Redbeds have produced water in four test wells in the immediate vicinity of the waste panels H-1, H-2, H-3 and WQSP-6. (605)

2. DOE still claims that the Dewey Lake Redbeds have "not produced water within the WIPP shafts or in boreholes in the immediate vicinity of the panels." (CCA, p. 2-131). To the contrary, EEG has reported that the Dewey Lake Redbeds produce water in the WIPP exhaust shaft at a depth of approximately 100 feet below the land (CCA Docket, A-93-02, Item # II-E-36). The Dewey Lake produced water in the WIPP air intake shaft as well (EEG-61, 1996, p. 2-6). The Dewey Lake has also produced water in test wells H-1, H-2, H-3 and WQSP-6, all in the immediate vicinity of the waste panels. (879)

3. The hydrology of the Dewey Lake Redbeds (DLR) and the overlying Santa Rosa Formation has not been adequately considered in the CCA. The CCA rejected consideration of transport through the DLR on the basis of the DOE assumption that "chemical retardation occurring in the Dewey Lake will prevent release within 10,000 years of any actinides that might enter it."(1225)

4. The DOE has conducted hydrological tests in the Dewey Lake Redbeds and the Santa Rosa Formation in 1997 after the submission of the CCA to investigate the source of water leaking in the WIPP exhaust shaft. The results of these tests and the surprising encounter of water in the DLR in the borehole WQSP 6 and 6a at the site indicates that more surprises may be in store with respect to the hydrology of this Formation. (1228)

<u>Response to Comments 3.WW.1 through 3.WW.4:</u>

EPA and DOE recognize that there is water present in the Dewey Lake and Santa Rosa. DOE concluded that, based upon the definition of USDW presented in 40 CFR § 191.22, four formations could potentially be USDWs in the WIPP area: the Culebra, Magenta, Dewey Lake, and Santa Rosa (the Capitan Aquifer was also identified as a potential USDW but is not present at the WIPP). [CCA Chapter 8.2] As such, DOE acknowledges the water-bearing capabilities of the Dewey Lake, and the Santa Rosa and has considered this possibility in performance assessment evaluations. Currently, the Dewey Lake Redbeds Formation has a water table with a hydraulic head that has been estimated by DOE to be at an elevation of about 940 to 980 meters above sea level [CCA Chapter 2.2.1.4.2.1, p. 2-131], but water can only be produced at scattered sites; many wells in the Dewey Lake cannot produce water. DOE indicates that the Santa Rosa is present over the eastern half of the WIPP site and may have a saturated thickness of limited extent. [CCA Chapter 2.2.1.4.2.2, p. 2-132]

EPA recognizes that the Dewey Lake contains a productive zone of saturation, probably under water table conditions, in the southwestern to south-central portion of the WIPP site. [Chapter 2.2.1.4.2.1, p. 2-131] The productive zone is approximately 180 to 265 feet (55 to 81 meters) below ground surface and appears to derive much of its transmissivity from open fractures. The Dewey Lake is not an aquifer (by definition) in most areas near the WIPP site, but this does not mean that water cannot be present in the unit. DOE indicated, in CCA Chapter 2.2.1.4.2.1, [p. 2-131] that the Dewey Lake is the uppermost important layer in the hydrological model and that changes in the water table in the Dewey Lake in the future, due to wetter conditions, were included in the conceptual model. DOE interpreted ground water flow to be to the southwest at about 70 feet per mile (13 meters per kilometer). DOE estimated the saturated hydraulic conductivity of the Dewey Lake to be $3x10^{-3}$ feet per day (10^{-8} meters per second) and even assumed that the Dewey Lake is a USDW in their bounding analysis in the compliance assessment. EPA has evaluated data pertaining to the Dewey Lake and concurs with DOE's assessment that this unit is water-bearing in the WIPP region. EPA has participated in WIPP site visits to observe shaft features [Docket A-93-02, Item V-B-3, Attachment 1], and notes that ground water inflow to the shafts primarily from the Salado Formation is evident. In addition, ground water in the Dewey Lake is monitored in well WQSP-6a, which is within the WIPP site.

EPA acknowledges that the CCA provided limited information regarding the hydrology of the Dewey Lake and that DOE could have provided additional information regarding the sorptive characteristics of the Dewey Lake. However, EPA concluded that the EPA Mandated Performance Assessment Verification Test [pp. 1-3, Docket: A-93-02, Item II-G-28] results indicated that little or no ground water flow would occur from the repository to the Dewey Lake, thus removing the Dewey Lake as a potential pathway. In addition, DOE did include the Dewey Lake as a potential underground source of drinking water for the undisturbed scenario in CCA Chapter 8. [Chapter 8.2.2, p. 8-14]

Issue XX: Rustler recharge

1. DOE's model (as adopted by EPA) holds that recharge would "pass slowly through the overlying strata before reaching the portion of the Culebra within the boundaries of the WIPP site." (CARD 23 at 125). Such conclusion is invalid in the face of data such as that presented by Prof. Fred Phillips at the EPA technical meeting in Washington, D.C. (Feb. 16, 1995) (appended hereto), showing both the extremes of recent climate variation and the recent nature of Rustler recharge. (985)

2. DOE has incorporated whatever assumptions were necessary to show compliance (e.g., DOE's assumed recharge rate of 0.2 to 2.0 mm/yr, which gives a ground water travel time of thousands of years). Phillips and Snow (1998) have shown, by means of a regional water balance analysis, that the recharge rate approaches 20 mm/yr. Only by ignoring the large amount of water in Laguna Grande de la Sal can DOE justify its assumed recharge rates and travel times. (1183)

Response to Comments 3.XX.1 and 3.XX.2:

In Comment 3.XX.1, the commenter believes Phillip's assertion that isotopic data show a recharges process is active at the WIPP that allows no evaporation of infiltrating water. [Docket: A-93-02, IV-G-38] EPA agrees that isotopic data can be interpreted differently. Chapman [EEG-35, Docket: A-93-02, Item II-G-1, Ref. #118] states, on p. 64 "there is currently no basis for concluding that the Rustler aquifers are not receiving significant amounts of modern meteoric recharge", although she also admits [p. 63 and p. 39] " it is difficult to infer a recent meteoric origin for these [eastern, i.e. WIPP site] samples", based solely on the isotopic information.

DOE has interpreted the data to mean that ground water can be over 10,000 years in age, but also states that [Appendix CLI of the CCA, p. 21], "Questions about recharge to the Rustler Formation and the true age of WIPP-area ground water remain unanswered. In the absence of definitive data, this report makes no assumptions about ground water age." Because the isotopic data can be interpreted differently, EPA examined the entire spectrum of data that could be used to assess infiltration rates, including DOE's ground water basin model, carbon-14 data, and tritium data. EPA concluded that the ground water basin model provides a plausible description of ground water conditions in the Culebra. EPA also points out that recent carbon-14 data indicate that a minimum age of 13,000 years is appropriate for Culebra waters. [Phillips, 1987, Docket: A-93-02, Item V-B-1] Further, geochemical facies in the WIPP are explained by differential recharge and long residence time. [Docket: A-93-02, Item II-I-31] Further, EPA has found no evidence to indicate that rapid, karst-related infiltration occurs at the WIPP. For example, EPA Office of Solid Waste performed a field investigation during which no evidence of direct surface infiltration was observed. [Department of Energy Waste Isolation Pilot Plant; Notice of Final No-Migration Determination, 55 FR 47714, November 14, 1990] In addition, DOE performed numerous aquifer tests in the Rustler Formation (e.g. hydropads H-3, H-11, and H-19), as well as tracer tests at six locations (H-2, H-3, H-4, H-6, H-11 and H-19 hydropads). [Docket: A-93-01, Item II-G-1, Chapter 2.2.1.4.1.2; Appendix MASS 15] DOE's data do indicate that the Rustler is a fractured dolomite (which is accounted for in PA modeling), but no data acquired to date indicate that there is pervasive, cavernous, karst porosity that would allow for rapid, near-instantaneous infiltration of rainwater to the Rustler Formation.

In response to Comment 3.XX.2, EPA points out that Phillips and Snow [1998, Docket: A-93-02, Item V-B-1] estimated the infiltration rate based upon their calculated water balance in Laguna Grande de la Sal, assuming that all water within Laguna Grande is sourced from infiltration of ground water through karst features that subsequently discharge Rustler ground water into the lake. [p.19] EPA does not believe that there is any evidence to suggest that all water entering Laguna Grande de la Sal is from ground water discharge from the Rustler alone. In the CCA's description of ground water flow in units above the Salado provided in Section 2.2.1.4 [p. 2-114], DOE acknowledged that Nash Draw and the Pecos River are areas where discharge of ground water to ground surface occurs, and specifically references Surprise Springs and the saline lakes in Nash Draw. Surprise Springs discharges into Laguna Grande de la Sal. In the discussion of the Culebra hydrology provided in Section 2.2.1.4.1.2 [p. 2-120] of the CCA, DOE also indicated that flow in the Culebra is dominantly lateral and southward except in discharge areas along the west or south boundaries of the ground water basin. Based on information provided in Appendix HYDRO [pp. 47 to 55; Docket A-93-02, Item G-II-1], regarding the"brine aquifer," which occurs within the Rustler-Salado Contact Zone residuum west of the WIPP area in Nash Draw, DOE also stated that the sources of water in Laguna Grande de la Sal were precipitation, surface drainage, ground water inflow from upper units above the brine aquifer and possibly inflow from mining activities that take place further north in Nash Draw. DOE further indicated that discharge of ground water into Laguna Grande de la Sal is by flow of seeps and springs, particularly along the northern end of the lake, and Surprise Springs is specifically identified by DOE as a potential ground water discharge point. However, in Appendix HYDRO [p. 49], DOE indicated that because sodium and chloride concentrations in samples from Surprise Spring and samples of Culebra and Rustler-Salado contact residuum water collected from test-hole WIPP-29 (located near Surprise Spring) are different, the Culebra and the Rustler-Salado contact residuum are not the source of water in Surprise Springs. Appendix HYDRO [pp. 53 and 61] also indicated that the discharge point for the ground water within the Culebra and the Rustler-Salado contact residuum is located south of Laguna Grande de la Sal, near Malaga Bend. In summary, DOE acknowledged within the CCA that sources of water in Laguna Grande de la Sal included discharge of ground water from the units above the Salado, although DOE does not necessarily agree that the Culebra is the sole source of this discharge.

EPA evaluated information presented by DOE and stakeholders concerning the origin of ground water in Laguna Grande de la Sal and extended inferences regarding infiltration rate. EPA believes that the presence of springs and seeps along the northern end of Laguna Grande de la Sal is not by itself an indication of the presence of karst topography or channelized flow through an aquifer, which is required to attribute all sources of water within Laguna Grande de la Sal to infiltration, as calculated by Phillips and Snow [Docket: A-92-03, II-G-63]. Based on WIPP field observations and site-specific hydrologic information, EPA also concludes that there is no indication that cavernous or other karst-related flow is present at the WIPP as espoused by Phillips and Snow. As such, Phillip and Snow's calculation of infiltration rate based upon a complete karst channel source of water to Laguna Grande de la Sal is a simplistic approach that does not recognize the factual information pertaining to surface water and ground water hydrology present in the WIPP area.

Issue YY: EPA has not provided data that only the Culebra dolomite has the capability to transmit significant amounts of radionuclides.

1. EPA states that only the Culebra dolomite has the capability to transmit significant amounts of radionuclides (at 58799). EPA has not provided experimental and modeling data to support that conclusion. Because data exists that large amounts of brine can move through fractured marker beds, EPA must assume that is true at the WIPP site and use modeling that uses such data. (1146)

Response to Comment 3.YY.1:

DOE provided adequate information regarding the hydrogeologic characteristics of the geologic units in the disposal system in Chapter 2.2.1 [pp. 2-97 to 2-145], Appendix FAC, Sections 7 and 8 [pp. 7-1 to 8-18], Appendix GCR, Section 6 [pp. 6-1 to 6-62], and HYDRO. [pp. 22 to 75] For each of the geologic units in the vicinity of the WIPP disposal system, DOE provided information regarding hydraulic conductivity, storage coefficients, transmissivity, permeability, thickness, matrix and fracture characteristics, and hydraulic gradients in a summary table provided to EPA in a letter dated February 14, 1997. [Docket: A-93-02, Item II-I-08] This summary table was included as Figure IV-10 of the Technical Support Document for § 194.14: Content of Compliance Certification Application. [Docket: A-93-01, Item V-B-03] The CCA also provides detailed ground water hydrology information for geologic units that could be expected to transmit radionuclides to the accessible environment.

DOE determined that the Castile, Salado, Rustler and Dewey Lake hydrological systems are the most important to disposal system performance and modeling. [Chapter 2.2.1, p. 2-97] The Castile provides a hydrologic barrier between the Bell Canyon and Salado and contains high-permeability zones with pressurized brine. DOE considered the Salado to be the most significant hydrologic barrier between the repository and more transmissive beds. At the WIPP site, the Rustler Formation contains two transmissive members: the Culebra and the Magenta. DOE stated that the Dewey Lake is not an extensive aquifer at the WIPP site, though DOE reports ground water movement in a fractured zone of the Dewey Lake off-site of the WIPP.

DOE indicated that the low permeability Salado has limited water (in the form of brine) available to dissolve the halite or to transport radionuclides. If fluid is available to move through the Salado and potentially transport radionuclides, DOE contended that the major pathway for flow and transport is believed to be the more permeable anhydrite interbeds. While more permeable than the halite, the Salado anhydrite interbeds are still very impermeable ($\sim 10^{-19}$ m^2 permeability for the anhydrite versus $\sim 10^{-21}$ m^2 permeability of the halite) to fluid flow.

DOE included a complete analysis of ground water flow in fractured marker beds, and also assessed the possibility of contaminant transport in supra-Salado beds other than the Culebra. EPA agrees that the PA for the disturbed scenario includes contaminant transport only in the Culebra. However, based on the hydrogeologic information for the various hydrogeologic units at the WIPP that was included in Figure IV-10 of the Technical Support Document for § 194.14: Content of Compliance Certification Application [Docket: A-93-01, Item V-B-03], EPA believes that the Culebra has the highest permeability and transmissivity of all of the hydrogeologic units. EPA believes that contaminant transport in the Culebra would be more rapid than in other geologic units and analysis of this unit as a conservative indicator of compliance is appropriate. In addition, EPA points out that DOE did consider both contaminant transport in supra-Salado units and marker beds under undisturbed conditions. [Docket: A-93-02, Item II-G-1, Chapter 8, p. 8-4 to 8-10 and 8-15 to 8-17] Results of these analyses indicate that calculated maximum potential dose to an individual would be about one-thirtieth of the individual protection standard, and the maximum concentration in the USDW would be less than half of the EPA ground water protection limits. Also, the maximum dose to a receptor who drinks from the USDW is an order of magnitude less than the standards. EPA concludes that DOE has appropriately assessed contaminant transport in supra-Salado units, and DOE has also assessed the potential for contaminant transport in marker beds.

Issue ZZ: Presence of karst voids DOE's predicted dose.

1. DOE assumes that any radionuclides that enter an intrusion borehole would reach the land surface, bypassing the karstic Rustler aquifer. Even if the hole is not cased during drilling, the predicted dose is not fatal to the rancher or the cow. If the karst model of Phillips and Snow (1998) is essentially correct, than this statement by DOE is wholly invalid. (1184)

Response to Comment 3.ZZ.1:

DOE has evaluated brine release to ground surface and through radionuclide-bearing brine flow in the Culebra. DOE's PA analysis [Chapter 6.5.3, Docket: A-93-02, Item II-G-1] shows that the cumulative effect of brine releases through these pathways is well below the EPA release limits. In addition, DOE modeled the effect of waste/formation material that is brought to the land surface during drilling; i.e., cavings, cuttings, and spallings. As with direct brine releases, cuttings, cavings, and spallings release did not result in radionuclide releases above the EPA release limits. [Docket: A-93-02, Item II-G-1, Figure 6-41] The EPA-mandated PAVT, which was performed using parameters modified by EPA, also shows no EPA limit exceedences. [Docket: A-93-02, Item II-G-28] EPA examined hydrology and geologic site characteristics, and concluded that although dissolution features are present (i.e., WIPP-33), these features are not pervasive and are not associated with any identified preferential ground water flow paths or anomalies, a view that is also shared by the EEG. [Docket A-93-02, V-B-2, CARD 14, Section 14.B.5, p. 14-24; and Docket: A-93-02, Item II-D-102] EPA concluded that a karst model (which would significantly increase ground water flow velocity through karst solution channels and other features) is not an appropriate representation of site conditions during the 10,000 year regulatory time period.

Issue AAA: Fracture distribution and corresponding Culebra transmissivity

1. [There is a] problem with using Terry Sewards' work to conclude that corrensite clay lined fractures in the Culebra may provide retardation for radionuclide migration through the Culebra. The argument is based on a sample from a "black shale layer" obtained from the lower part of the Rustler Formation, below the Culebra, because not much clay could be sampled from the Culebra fracture coatings! And yet, this information is used to argue that "significant radionuclide retardation in fractures in the Culebra" could be present.

Any reference to the existence of corrensite or other clay minerals lining the fractures in the Culebra Dolomite member of the Rustler Formation at the WIPP site should be deleted from the project documents because there is no basis for this assumption. (1235)

Response to Comment 3.AAA.1:

DOE did not assume the presence of corrensite in performance assessment modeling, nor is it emphasized in the text of the CCA. As stated in Chapter 2.1.3.5.2, the Culebra conceptual model takes no credit for the presence of clays in bulk rock and on fracture surfaces. Whether clays are mentioned in "the project documents" has no bearing on EPA's certification decision.

Issue BBB: Rustler/Salado contact ground water zone

1. The EPA has accepted the CCA contention that the Rustler/Salado contact ground water zone does not underlie the WIPP site (CARD 14-21; TSD V-B-3, pp. 87-88). As pointed out by Chaturvedi and Channell (1985) and Neill et al. (1996, p.2-3), this assumption is not correct. Most of the WIPP boreholes have found brine in the Rustler/Salado contact zone (see Mercer and Orr, 1979; pages 10, 46, 63, 77, 98, 104, and 113) within the WIPP site. In fact, according

to Mercer and Orr (1979, p. 120), in at least one borehole (P-18), the water-level recovery rate after pumping from this aquifer was much faster than the Culebra recovery rate. (1237)

Response to Comment 3.BBB.1:

Contrary to the first sentence of the comment, EPA has not accepted the CCA contention that the Rustler/Salado contact ground water zone does not underlie the WIPP site. The commenter has referenced statements from the DOE Methodology and Conclusions section of CARD 14, Section 14.B.4, p. 14-21 [Docket: A-93-02, Item V-B-2] and the Technical Support Document for § 194.14 [Docket: A-93-02, Item V-B-3], rather than the EPA Compliance Review section of CARD 14. [Docket: A-93-02, Item V-B-2, Section 14.B.5, p. 14-29] The EPA Compliance Review section [p. 14-29] indicates that EPA's initial review of the CCA found the discussion of the Rustler/Salado contact to be confusing, particularly with respect to the possibility of the continued development of and characteristics of a dissolution front along this contact, and the impact that continued dissolution within the brine aquifer residuum would have on the overlying units of the Rustler. DOE discussed the rate and extent of dissolution processes further in supplemental information provided in a letter dated June 13, 1997. [Docket: A-93-02, Item II-H-44] Based upon this information, EPA concluded [CARD 14, Docket: A-93-02, Item V-B-2, Section 14.B.5, p. 14-29] that while dissolution may occur along the Rustler/Salado Contact (which requires water to be present to a limited extent), it would not impact the WIPP's containment capabilities during the regulatory time period because it would not travel rapidly enough to dissolve the Salado or adversely disrupt the Rustler Formation.

In addition, based on the hydrogeologic information for the various hydrogeologic units at the WIPP that was included in Figure IV-10 of the Technical Support Document for § 194.14: Content of Compliance Certification Application [Docket: A-93-01, Item V-B-03], the transmissivity of the Culebra (10^{-3} m^2/s to 10^{-9} m^2/s) is higher than the transmissivity of the Rustler/Salado Contact Zone (3.2×10^{-11} m^2/s to 5.4×10^{-8} m^2/s). Therefore, even if the dissolution front were to continue to develop, EPA believes that contaminant transport in the Culebra would be more rapid than in other geologic units and analysis of this unit as a conservative indicator of compliance is appropriate.

Issue CCC: Poor Rustler Formation core recovery at WIPP

1. I also correlated all of the bore hole data from all the WIPP bore holes and discovered that there were zones both above the Magenta dolomite and below the Culebra dolomite in members of the Rustler formation that were thought not to be a problem, not to be part of the ground water flow system. These zones were characterized by consistent inability to recover a core sample from the drill hole because the rocks were so unconsolidated. Sometimes there were complete washouts where the drilling fluid was lost as it flowed into those cavernous zones, and as you see, they snake entirely across the WIPP site, including most of the drill holes I have already shown you. So that opens one more question about shallow ground water hydrology. If there are cavernous zones snaking across the WIPP site, penetrating the WIPP shafts and connecting

to Nash Draw, are these ancient features left over from the ice ages or do they carry water today? (300)

2. DOE has failed to adopt vastly-improved technology of core recovery available for at least 20 years, or of directional drilling technology available for at least 10 years. Inspection of WIPP Project cores pre-dating 1995 (i.e., most of the data-base) reveals so much rubble and so many missing core intervals as to guarantee that fractured and dissolved features, if present, could not be described. (851)

3. CARD's original paper correlates and presents borehole data showing washouts and consistent loss of core in two distinct horizons of Rustler mudstone: in the Forty-Niner member about 20 feet above the Magenta, and in the lower unnamed member immediately beneath the Culebra. DOE denies that these are evidence for caverns, citing DOE's own poor coring techniques, and DOE denies that these are dissolution residues, thereby challenging the validity of DOE's own lithologic logs. CARD has since discovered the caliper log for the WIPP exploratory shaft, which records washouts in nearly the same stratigraphic horizons. (852)

4. CARD noted at the public hearings in February 1997 that lithologic descriptions for H-1, H-2 and H-3 were never published. CARD has since discovered drawings and brief descriptions of Culebra core samples at H-2b, H-2b2, H-3b2 and H-3b3 (Jones et al., 1992, (SAND92-1579, Figures 6-2, 6-3, 7-2 and 7-3). At H-2b and H-2b2 the cores were massive or vesicular with some fractures, most of them filled with gypsum. But at H-3b2 the Culebra is "totally fragmented." At H-3b3 the whole Culebra interval was "broken into pieces" less than 1 foot in length; where pieces were preserved, the core was very porous; some fractures were open, some were filled with gypsum; 14.5 feet of Culebra core was lost, and another 4.0 feet of core was lost in the black clay beneath the Culebra. This is entirely consistent with a cavernous ground water flow path through the Culebra dolomite and the claystone of the lower unnamed member. (855)

5. In the Culebra and lower unnamed members, taken together, there was 33.9 feet of lost core in a 39.0 foot interval at H-6. Core recovery was only 13%, and this consists mostly of surrounded dolomite fragments or dissolution residue with a mud matrix, all of which are indications of moving ground water. This 39-foot cavernous zone is direct evidence of karst at the WIPP site. (1323)

Response to Comments 3.CCC.1 through 3.CCC.5:

(Comments 3.CCC.1, 3.CCC.2, 3.CCC.3 and 3.CCC.4) "Washout" zones (Comment 3.CCC.3) are developed when the rock strength of strata differs from that of surrounding units, allowing the weaker material to be more readily removed via drilling fluid circulation. The presence of a caliper response is in no way definitive "proof" of caverns, but instead indicates lithologic/rock strength differs between adjacent strata. Core recovery is related to rock strength, and does not necessarily have an association with local hydrologic conditions. In the case of WIPP, cores that were attempted through fractured material, including the Culebra, exhibited poor recoveries. In response to Comments 3.CCC.4 and 3.CCC.5, EPA agrees that fractured Rustler is present at H-3. However, EPA does not believe that the presence of fractured material in the Rustler indicates that karst processes are active. In fact, the development of fractures can occur for various reasons unrelated to dissolution (i.e., geologic unloading). DOE has long recognized the presence of fractures within the Culebra, and has included this dual porosity system in performance assessment modeling. [Docket: A-93-02, Item II-G-1, Chapter 6.4.6.2]

Issue DDD: Bacteria at WIPP

1. Bacteria have recently been found at great depths in ground water at WIPP. This raises the question as to whether the bacteria could absorb some wastes and then transport them to outside locations. What biological consequences could there be? The bacteria can apparently survive small doses of plutonium. There is no way to confine bacteria and there is no accounting for their tastes. (826)

Response to Comment 3.DDD.1:

DOE included the possibility of microbial colloids in its PA analysis. [Appendix SOTERM, Section 6.3.4.1 and 6.3.4.2] DOE conducted bioaccumulation tests and toxicity experiments to assess microbial impact, and concluded that microbial colloids should be accounted for in PA. As such, DOE applied proportionality values to the calculated actinide solubilities to account for potential increase in actinide concentration due to the presence of microbes. EPA agreed with DOE's approach to modify actinide solubility in this manner, and concluded that DOE accounted for the presence of microbes in PA. EPA's review of this topic is presented in EPA's evaluation of DOE's actinide source term. [Docket: A-93-02, Item V-B-17, section 8]

Issue EEE: Karst related channels extend into the Land Withdrawal Area.

1. The variable removal of strata gives rise to the differential displacements of the overburden, producing by their irregular recurrence a pattern of randomly-oriented steep-dipping subsidence fractures superimposed upon the tectonic pattern, northeast and northwest oriented. Because the processes have reached conclusion at Culebra Bluffs, with no more salt to be removed, there must be, in the transition zones extending eastward across Nash Draw and the LWA towards the line of no salt dissolution, a region of active channels that typifies an evaporate karst. Though undetected east of the WIPP-33 chain of sinkholes, open channels probably extend east from the discharge area in Nash Draw, across Livingston Ridge and into the LWA, as surface morphology suggests (Phillips, 1987 and March, 1997). They may be oriented preferentially parallel to the northwesterly and southwesterly fractures, with dissolution controlled by the paleo-gradient and its variations over the span of time of formation. Their traces as conduits could be intersected by a gently-dipping hydrofracture propagating upwards from the repository through the remaining thickness of Salado salt. (845)

2. It is by no means evident that all Rustler conduits were initiated along fractures formed in response to Salado salt dissolution. Dissolution channels may also have been directly caused by dissolution of salt beds in the Rustler, or by fractures developed as a result of differential subsidence as Rustler or Salado salt was removed. The clay horizons in the Rustler were probably residuals from dissolution of those Rustler salt beds. The solution channels may extend

eastward into the WIPP site, because they are related to Rustler, not necessarily Salado salt dissolution. (849)

3. Phillips (1987, Chapter IV) demonstrated through structure contour maps based upon 347 augur holes that WIPP-33 is one of a chain of four sinkholes, all of which are evident in the air photos. DOE considers this chain of sinkholes to be a "prong of dissolution" that extends eastward "as far as WIPP-33." If DOE would examine its own air photos, DOE would discover that the sinkhole drilled as WIPP-33 is the westernmost in this "line of sinkholes described by CARD." In fact, by confirming that these are sinkholes, DOE inadvertently admits that proven karst features extend 2000 feet east of the WIPP-33 borehole, to within 1000 feet of the current WIPP site boundary. (868)

Response to Comments 3.EEE.1 through 3.EEE.3:

EPA believes it important to clarify what is meant by "karst", and the importance of timing relative to karst development. Karst is defined, in Bates and Jackson, 1980 [Docket: A-93-02, Item II-G-1, Ref. #37, p. 280] as "a type of topography formed over limestone, dolomite, or gypsum by dissolution that is characterized by sinkholes, caves, and underground caverns." This topographic modification can happen at any point in geologic time, and "karst" features can then be covered by sediments that lithify to rocks. Also, these *paleo*karst features can continue to change as the rock column undergoes consolidation, lithification, or other geologic modifications through time. If a modern karst system is currently developing at WIPP, all rocks from ground surface downward would be impacted by the dissolution process, whether it be from dissolution of soluble intervals or from collapse of non-soluble rocks due to removal of soluble material. Paleokarst or other paleodissolution features, if present, would be stratabound.

Numerous geologic investigations have been conducted in the vicinity and across the WIPP site to assess the occurrence of dissolution (karst) including, for example, Anderson, 1978 [Docket: A-93-02, Item II-G-1, Ref. #12], Bachman, 1976 and 1987 [Docket: A-93-02, Item II-G-1, Refs. #22 and #27, respectively], and Borns et al, 1983. [Docket: A-93-02, Item II-G-1, Ref. #79] Detailed geologic analysis of subsurface strata to assess the presence of dissolution-related features has been conducted. [Holt and Powers, 1988, Docket: A-93-02, Item II-G-1, Appendix FAC] The presence of active karst features at the WIPP site has also been investigated by EPA. EPA conducted a field investigation during the summer of 1990 to assess the occurrence of karst features as part of its WIPP Test Phase No Migration Variance determination. EPA traveled to the WIPP site and inspected geomorphologic features that the commenters believed were evidence of dissolution and karst development. For example, EPA observed a topographic depression claimed to be evidence of karst because the Mescalero Caliche was removed. Detailed examination of the feature, however, revealed mechanical disruption of the land surface, and potential removal of the material for use as road bed (not via dissolution). As a result of that field investigation and detailed examination of site geologic and hydrologic information, including core data and hydrologic (i.e., water level) information, EPA concluded that "karst is not now an issue at the WIPP, and is unlikely to become one for many thousands of years, if ever." [Department of Energy Waste Isolation Pilot Plant; Notice of Final No-Migration Determination, 55 FR 47714, November 14, 1990]

DOE has asserted [Appendix FAC, p. iii-v] that many brecciated units present in the Rustler Formation can be attributed to syndepositional (i.e., accompanying deposition of the sediment) and immediate post depositional processes, such as slumping of sedimentary strata, as well dissolution that occurred immediately post depositionally. DOE does not believe that salt/soluble bed distribution need be attributed to more recent dissolution. EPA has examined geologic and/or hydrologic data for H1, H3, H6, and WIPP wells 13, 18, 19, 21, 22, 23, and 25, available through geologic borehole logs and associated records, available core data, and geologic interpretive reports [Appendix FAC, Docket: A-93-02, Item II-G-1] and concludes that the syndepositional and post depositional processes (including dissolution soon after deposition) could account for some of the observed sedimentary fabrics. For example, the exhaust shaft includes a brecciated zone that could have been formed due to post depositional slumping and/or dissolution, but this unit is immediately covered by undistrupted strata. [Docket: A-93-02, Item II-G-1, Ref. #309, Figure 11] The contact between this brecciated zone and underlying/overlying units is gradational (indicating that no large time or sedimentologic "breaks" between depositional and brecciation events is apparent), supporting the conclusion that the brecciated feature formed at the same time (or immediately after) the rock units immediately surrounding the brecciated zone were deposited. EPA does not agree with DOE's assertion that the distribution of salt in the Rustler is solely a depositional feature because Rustler transmissivity (which is related to fracture occurrence in the Rustler, [Figure 2-30, Docket: A-93-02, Item II-G-01] generally corresponds to the occurrence of salt in the Rustler. [Figure 13, Appendix HYDRO, Docket: A-93-02, Item II-G-1] This implies that some post-Rustler dissolution has occurred which impacts the fracturing in Rustler rocks. However, the sum evidence observed by EPA and described above indicate that a complex history of deposition and dissolution has occurred in the WIPP area, but many Rustler features (e.g., the breccia zone in the exhaust shaft, or at WIPP-18, where anhydrite/clay-rich strata may be halite dissolution residues) were formed during unit deposition or immediately post depositionally over 200 million years ago.

(Comments 3.EEE.1 and 3.EEE.2) In response to Comment 3.EEE.1, EPA points out that DOE has long recognized a complex history of site loading and unloading that resulted in "variable removal of strata" and the potential development of fractures. [Docket: A-93-02, Item II-G-1, Chapter 2.1.5.2] DOE also believes that the presence of salt in the Culebra is attributable to syn or near post-depositional processes, but EPA concluded that a more complex set of processes contributed to both halite and fracture distribution. EPA agrees with Comment 3.EEE.2 that fracture formation is likely a result of Rustler halite dissolution and subsequent overlying unit fracturing loading/unloading, as well as the syn and post depositional processes espoused by DOE. Some of the clay horizons within the Rustler could well be the result of dissolutional processes that occurred possibly over many thousands of years after the beds were deposited. EPA also agrees that limited lateral dissolution at the Rustler/Salado contact and within Rustler halites could be ongoing, but the process is very slow and will not impact the containment capabilities of the WIPP disposal system. [Docket: A-93-02, Item V-B-02, CARD 14, p.14-24] In reference to Comment 3.EEE.1, which infers that fractures are propagating upward from the repository to ground surface, EPA believes that there is no geologic evidence whatsoever which indicates that the DRZ extends beyond the immediate vicinity of the WIPP. The elastic properties of salt units preclude the continuous "opening" of fractures from the repository to ground surface, and there is no indication that open vertical fractures transect the repository horizon.

(Comment 3.EEE.3) The commenter alleges that Phillips has "demonstrated" that a "chain" of four sinkholes exists which includes WIPP-33 (Docket: A-93-02, V-B-1, WPO # 26144). It is not possible to demonstrate the presence or nature of geologic features on the basis of structural contouring or air photo interpretation in the absence of other supporting data, since these processes, used by Phillips, are entirely interpretive. EPA agrees that there is evidence of paleodissolution at WIPP-33. However, the presence of the Mescalero Caliche over this feature implies that it is ancient and that recharge has been insufficient to remove the caliche by dissolution. The presence of paleodissolution features does not impact the result of hydrologic testing, flow modeling and performance assessment. Testing of the rock in the region noted by the commenter was part of the WIPP-13 multipad pumping test [Beauheim, 1987, Docket: A-93-02, V-B-1] and the hydrological properties of the region are well documented. Site hydrologic test data do not support the presence of karst. The Conceptual Models Peer Review Panel [July 1996] has accepted the numerical flow model of the site for purposes of the site performance assessment, in that the conceptual model was sufficiently rigorous to model site performance without integration of karst features.

Issue FFF: Water table and karst

1. The CCA uses the assumption that climate change may raise the water table to the surface, a condition impossible in karst terrain. A rise in the water table can multiply karst system discharges many-fold, because small rises saturate larger channel cross-sections and increase low gradients several-fold. The Mescalero Caliche implies a persistent water table below the caliche, even during glacial maxima. The horizon would be a good candidate for modeling the highest water table. Even for modern conditions of precipitation, the water table has remained undefined for lack of diligent field measurement. (848)

Response to Comment 3.FFF.1:

The commenter points out that the performance assessment conservatively assumes that the ground water table rises to ground surface in the case of hypothetical future climate change. This is a way of setting a maximum limit on the effect of future climate changes for performance assessment and does not represent a predicted event nor does it have any implications about site history. The commenter's discussion about the hydrologic effects of water table rise assumes that there are open channels in the Rustler hydrologic system which are unaccounted for in exiting site models. The numerical site flow model accepted by the Conceptual Models Peer Review Panel [July 1996] is based on numerous hydrologic tests of large volumes of site rock and is representative of the actual site hydrologic properties and processes, and does not include karst hydrology. The assumption made is a conservative estimate in modeling and actinide transport. EPA also concluded that there is no evidence of karst channels, or sinkholes, as implied by the commenter.

The commenter's assertion that the Mescalero Caliche formed at a former position of the water table is in error. Caliche forms only in unsaturated soils. Caliche can only be formed in the unsaturated zone in a region in which evapotranspiration exceeds precipitation. This is the origin widely attributed to the Mescalero Caliche which began forming 550,000 years ago and is still being deposited. [Gile and Grossman,1981, Docket: A-93-02, V-B-1]

EPA believes that the lack of an extensive modern water table at the site is because the great exceedence of precipitation by evapotranspiration has resulted in conditions of almost no recharge in the region. Rainwater may undergo run off or limited infiltration, but is then returned to the surface by capillary or plant processes and evaporated. The commenter's assumption that the Mescalero Caliche implies the existence of a past ground water table of relatively high elevation in the site soil is an inaccurate interpretation of caliche formation, and in fact supports the contention that limited infiltration occurs because caliche forms where there is limited infiltration.

References

Gile, L. H., and R. B. Grossman, Soils and Geomorphology in the Basin and Range Area of Southern New Mexico-Guidebook to the Desert Project, Memoir 39 (Santa Fe, NM: New Mexico Bureau of Mines and Mineral Resources, 1981, Docket: A-93-02, V-B-1)

Issue GGG: All Rustler strata participate in the flow field.

1. Whereas DOE claims to have acted conservatively in the PA modeling, to treat the Culebra as confined is obviously incorrect for transport. All Rustler strata participate in the flow field, since they are interconnected by steep fractures, faults and dissolution chimneys. Future mine subsidence will produce cross-cutting features, as may repository driven hydrofractures. (850)

Response to Comment 3.GGG.1:

EPA concluded that the distribution of hydraulic head within the Culebra Dolomite conclusively points to the confined nature of this hydrologic unit beneath WIPP. Water levels (i.e., hydraulic heads) in wells completed across the Culebra within WIPP are typically 200 to 300 feet above the top of the Culebra. [Appendix T-FIELD, CCA Table TFIELD 1 and 3] By definition, this indicates that confined conditions are present in the Culebra in the vicinity of WIPP.

At test hole H-3 (located near the center of WIPP) the water level in the Culebra is 150 feet below the water level in the Magenta and 480 feet higher than the water level in the underlying Rustler-Salado contact residuum, supporting the concept of hydraulic isolation between these water bearing members of the Rustler. [Appendix HYDRO-CCA, p. 60] Not only is there a significant difference in hydraulic heads between the Culebra and Magenta Dolomites, but the potentiometric surfaces of these units infers substantially different ground water flow direction. Water level data indicate that the potentiometric surface in the Culebra decreases from north to south whereas the potentiometric surface in the Magenta generally decreases from east to west as shown in Figures 7-3 and 7-4 [pp. 7-8 and 7-9] of Appendix SER of the CCA.

EPA recognizes that there may be some degree of hydraulic communication between the various Rustler members in areas such as Nash Draw and that on a very large, regional scale, all water bearing members of the Rustler may contribute to the regional flow system. However, the predominant flow component, particularly in members that have relatively higher transmissivity, is anticipated to be horizontal. Because the Culebra is the most transmissive unit of the Rustler, modeling radionuclide transport as a predominately horizontal flow phenomenon is a conservative approach because this would result in the shortest travel time to reach the WIPP boundary.

The effects of future mining activities have been incorporated into the PA by uniformly scaling the transmissivity by a factor of 1 to 1,000 in regions considered to contain economically-extractable resources. In doing so, EPA concluded that the hydraulic conductivity increase imposed on the Culebra from mining would increase the lateral flow movement. In fact, assuming flow only in Culebra with increased hydraulic conductivity rather than a thicker rock mass is a more conservative approach in that flow is occurring in a single horizon rather than dispersed (with subsequent slowing of ground water flow) throughout the entire Rustler. EPA concludes that there is no evidence that "repository driven hydrofractures" will occur in the Rustler Formation.

Issue HHH: There is direct evidence of karst at the H-3 test well.

1. In the H-3 test wells, there is a 10.8-foot cavity, partially filled with mud, in the Forty-Niner member, 5.0 feet of broken and shattered Magenta dolomite; 14.0 feet of dissolution residue in the Tamarisk member; 17.7 feet of broken and shattered Culebra dolomite; and 12.6 feet of dissolution residue in the lower unnamed member. There is direct evidence of karst at the H-3 test wells in every member of the Rustler Formation. (1324)

Response to Comment 3.HHH.1:

EPA agrees that fractured Rustler is present at H-3 as indicated by the commenter. However, the presence of fractures does not necessarily indicate that karst features (i.e., features formed from surface-down dissolution) are present. EPA also points out that there is no hydrologic evidence to indicate Rustler units are interconnected at this location, which would be the case if pervasive, ground surface-downward karst feature development were apparent. For example, at H-3, the water level in the Culebra is 150 feet below the water level in the Magenta and 480 feet higher than the water level in the underlying Rustler-Salado contact residuum, supporting the concept of hydraulic isolation between these water bearing members of the Rustler. [Appendix HYDRO-CCA, p. 60] Not only is there a significant difference in hydraulic heads between the Culebra and Magenta Dolomites, but the potentiometric surfaces of these units infer substantially different ground water flow direction also indicative of hydrologic isolation [Figures 2-31, p. 2-125 and 2-32, p. 2-129 of the CCA, Docket: A-93-02, II-G-1] Water level data indicate that the potentiometric surface in the Culebra decreases from north to south whereas the potentiometric surface in the Magenta generally decreases from east to west as shown in Figures 7-3 and 7-4. [pp. 7-8 and 7-9 of Appendix SER of the CCA] If surface-down karst features had developed through the entire Rustler Formation, hydrologic isolation of the units could not persist. In addition, DOE and EPA has long recognized that a higher hydraulic conductivity zone in the Culebra is present near H-3 due to fractures in this area [Figure 2-20, Docket: A-93-02, Item II-G-1], and the modeling of this zone is included in performance assessment. DOE performed numerous aquifer tests in the Rustler Formation (e.g., hydropads H-3, H-11, and H-19), as well as tracer tests at six locations (H-2, H-3, H-4, H-6, H-11 and H-19 hydropads). [Docket: A-93-01, Item II-G-1, Chapter 2.2.1.4.1.2; Appendix MASS 15] DOE's data do indicate that the Rustler is a fractured dolomite (which is accounted for in PA modeling), but again no data acquired to date indicate that there is pervasive, cavernous, karst porosity. Based on this information, EPA concluded that while fractured rock is present at H-3, it does not indicate the presence of pervasive karst systems that interconnect Rustler rock units, and relatively higher hydraulic conductivities in this are included in PA. Performance assessment results indicated that CCDFs for radionuclide releases in the Culebra are below the EPA limits. [Figure 6-41, Docket: A-93-02, Item II-G-1]

Issue III: Direct evidence of dissolution in the WIPP exhaust shaft

1. In a report entitled "Geotechnical Activities in the Exhaust Shaft" (DOE-WIPP-86-008) there are maps of certain intervals of the shaft walls. One of these maps (Figure 11) depicts a "breccia zone" in the lower unnamed member of the Rustler, immediately beneath the Culebra. It is in the shape of a solution channel, 6 feet high and 5 feet wide. The upper half is described as consisting mainly (80%) of angular to subangular clasts of dolomite in an argillaceous dolomite matrix; the lower half is described as soft claystone, nearly fissile, and poorly indurated. . .it is direct evidence of dissolution in the exhaust shaft. If it is a solution channel, it would explain the existent hydraulic connection between the exhaust shaft and Nash Draw by way of WIPP-13 and WIPP-33. (1325)

Response to Comment 3.III.1:

EPA examined the "Geotechnical Activities in the Exhaust Shaft" [Ref.#309, Docket: A-93-02, II-G-1] and agrees that a breccia zone is described in exhaust shaft lithologic logs. However, detailed examination of Figure 11 shows that the breccia zone in question is "stratabound", meaning that the feature does not extend above or below Unit 6 of the Culebra and Unit 5 of the Unnamed Lower Member. Units above and below the feature are relatively undisturbed, indicating that whatever event happened to cause the breccia zone happened very soon after the rock interval (Unit 7 of the Culebra to Unit 4 of the Unnamed Lower Member) in question was deposited. EPA agrees that the features described could well be from sedimentary slumping perhaps due to physical removal or dissolution of material below Unit 7 of the Culebra, and subsequent collapse of Unit 7 downward. However, the event is clearly ancient (i.e., Permian in age), and the "channel" morphology could also easily be a point source event or very localized sedimontologic occurrence that is not pervasive throughout the WIPP, nor interconnected with other similar features. EPA points out that there is no direct hydrologic evidence which suggests any hydrologic interconnections of the shaft area and WIPP-13 or WIPP-33. Flow direction in the Culebra between the shaft(s) area and WIPP-33 is to the south [Figure 2-31, Docket: A-93-02, Item II-G-1]; there is no evidence of flow to the northwest in the Culebra, which is required for the "hydrologic connection" implied in the comment to occur. EPA concludes that while features described by the commenter are present in the Rustler, these in no way provide clear indication of "karst" features, particularly active surface-down karst features that completely disrupt the stratigraphic column. Further, the presence of these features in no way indicates that they will even be permeable; the description of the breccia zone states it has a basal clay unit that would not be permeable. [Figure 11]

Issue JJJ: The only reliable means of obtaining K_d values is to perform sorbing tracer tests. DOE should assume that there is no retardation in the Culebra.

1. The only reliable means of obtaining K_d values is to perform sorbing tracer tests. (26)

2. In the CCA these retardation coefficients (K_ds) are overestimated, so that the amount of radioactivity that escapes is underestimated. In the absence of valid retardation data, DOE should assume that there is no retardation in the Culebra. (145)

3. The only way to obtain reliable distribution coefficients is to perform sorbing tracer tests in the field. As recently as 1996 the EEG made the same objections to DOE's distribution coefficients (EEG-61, March 1996, pp. 6-8, 6-9; Neill to Salisbury, June 10, 1996). Even if EEG has abandoned this position, CARD has not done so. DOE has recently performed tracer tests at the H-19 hydropad, but the results of these tests are unpublished, unavailable to the public or to the peer review panel. (885)

4. [T]he nonsorbing tracer tests being implemented at the WIPP cannot be used to estimate actinide sorption properties because the residence times depend on different rock properties. Laboratory batch and column sorption tests being conducted on Culebra cores will be of marginal value in replicating field conditions. If credit for radionuclide retardation is to be taken in postclosure performance assessment, we recommend that field-scale sorptive tracer tests should be conducted. (1328)

Response to Comments 3.JJJ.1 through 3.JJJ.4:

EPA acknowledges that partition coefficients (K_ds) are important parameters for describing the mobilities of actinides in the Culebra formation. DOE provided a description of the laboratory testing performed and methodology used to establish ranges of matrix K_ds in Appendix MASS-1. EPA reviewed DOE's K_d values in detail, and did not find these values to be based on nonsorbing tracer test results (3.JJJ.4). In determining actinide K_d values in batch experiments, DOE used samples of the Culebra Dolomite and brine solutions that are considered to be representative of the field situation. [Brush, 1996] These data were supplemented by experiments with other natural dolomites and column experiments, in which the effects of a field-realistic solid to solution ratio could be investigated. The results from all of these studies were compiled into a range of values for the actinide K_ds, rather than merely selecting average values. It is reasonable to expect that the range of actinide K_d values obtained from the DOE experiments are inclusive of any scale-effects that might produce a different average K_d value than the experimental average in either the greater or lesser directions. That is, while field and laboratory K_d values could differ due to scale effects, the range of K_d values used by DOE encompassed the range of K_ds expected from both field and laboratory analysis. Based upon this review of DOE's data, methodologies, and conclusions, EPA concluded that the K_d ranges chosen by DOE are sufficient for performance assessment. Refer to EPA Technical Support Document for § 194.14: Assessment of K_ds Used in the CCA [Docket A-93-02, Item V-B-4] for EPA's detailed review. EPA does not believe that field tests using sorbing tracers are necessary because: 1) the batch tests and the column tests produce similar results that indicate retardation takes place in the Culebra, 2) these results are consistent with other similar types of tests, and 3) calculations indicate that even very low K_ds significantly retard radionuclides so that if DOE's range of K_d estimates are too high, there is a large margin for error. Additional field testing would not add substantially to the Agency's understanding of the WIPP's performance.

Issue KKK: Range for U(VI)K_d

1. There is no credible scientific basis/or setting the lower end of the range of K_ds for U(VI) to 0. The methods used by Brush (1996) to establish the ranges and probability distributions of K_ds for the CCA PA calculations included several conservative approaches and assumptions. For example, he established separate ranges and distributions for deep (Castile and Salado) and Culebra brines for each actinide element or elemental oxidation state and selected the range and distribution that resulted in less retardation (greater transport) of that element or oxidation state. In the case of U(VI), Brush (1996) established a range of 0.03 to 30 ml/g for the deep brines Brine A and ERDA-6 and 0 to 70 ml/g for the Culebra brines AISinR and H-17, specified a uniform probability distribution for both ranges, and selected the range established for the deep brines for the CCA PA calculations.

There is absolutely no scientific basis for setting the lower end of the range for the deep brines to 0. In fact, Brush (1996) probably should have increased the lower end of this range from 0.03 ml/g (a value obtained from Lucero's column-transport study) to 4 ml/g (obtained from Triay's batch sorption study). Use of data from the column transport study to set the lower limit of this range (and the lower limits of the ranges for Np) was inappropriate. Consideration of the multirate diffusion model (Holt, 1997) for the column-transport study indicates that results from the column-transport study are quite conservative, because a relatively small fraction of the porosity of the intact cores was accessed on the temporal and spatial scales of the these experiments. By similar arguments (presented at several meetings with the EEG), results obtained from the batch study are more appropriate than those obtained from the column-transport study. However, use of a lower limit of 0.03 ml/g did introduce additional conservatism to the U transport calculations. (927)

2. Dr. Leslie Smith (in his letter report in Appendix 8.6) has also raised questions about the U^{VI} K_d data. If the negative values are ignored, the low end of the sampling range for U^{VI} is 0.03 ml/g. The zero values assigned to the negative values for the batch tests with the Culebra brine did not get passed into the CCA calculation because of a lower average value of K_d for the batch tests using deep brines. The EEG recommends that the lower end for U^{VI} K_d value be set at zero. (1276)

3. Based on present data, ranges of K_ds for Pu(V) should include 9.8 based on tests with Culebra brine, and the ranges for Am(III) and Pu(III) should be 1-200 based on Np(V) results. The lower end of the range for U(VI) should be zero based on tests in Culebra brine. (991)

Response to Comments 3.KKK.1 through 3.KKK.3:

(Comments 3.KKK.1, 3.KKK.2, and Second Sentence of 3.KKK.3) The determination of negative K_d values for U(VI) from some experimental results reported by Brush [1996] has been interpreted to mean that the lower end of the K_d range for U(VI) should be zero. The determination of a negative K_d value in a batch experiment can result when the final U(VI) concentration in solution is greater than the concentration initially placed in the solid-solution suspension. This result would indicate that the solids in the experiment are releasing U(VI) at levels higher than those used initially in the experimental solutions. While this process is possible, it is unlikely to be true because it would imply that the solids (i.e., Culebra rocks) are a more important source of U(VI) than potential waste materials. It is more likely that the negative K_d results actually reflect analytical uncertainties in the determination of differences in U(VI) concentration between initial and final experimental solutions under conditions of low total U(VI) concentration. Because of the uncertainties in such experimental results, it is not considered reasonable that they be factored in with other experiments with more certain results. The fact that the uncertainties in the analytical data did not allow a valid K_d to be calculated is not a reason to assume that the K_d must be zero.

Additionally, information in the literature indicates that K_d values for U(VI) and various minerals and rock types are generally low but not zero [McKinley and Scholtis, 1993, Table 1, Table 2, Table 3, Table 4; Sheppard and Thibault, 1990, Table 1, Table A-1, Table A-2, Table A-3, Table A-4; Stenhouse and Pöttinger, 1994, Table 3, Table 4], particularly under the alkaline pH conditions produced by reactions with the MgO backfill, under which the surfaces of sorbents can be expected to become negatively charged, hence more conducive to the adsorption of cationic solutes. [Dzomback and Morel, 1990., p. 95-102; Langmuir, 1997, p. 344-351]

In cases of very low K_ds, it is advantageous to increase the ratio of solid to solution, such as in column experiments, to increase the amount of U(VI) adsorption that might occur so that analytical uncertainties become small in comparison with the amount of actual loss of U(VI) from solution. The lowest U(VI) K_d value that was determined in column experiments conducted by Lucero, as described by Brush [1996], was 0.03 ml/g. Based on the experimental results and information in the literature, a K_d of 0.03 ml/g for U(VI) is considered to be reasonable and conservative lower value for the K_d range for U(VI).

References

Brush (1996) Ranges and probability distributions of K_ds for dissolved Pu, Am, U, Th, and Np in the Culebra for the PA calculations to support the WIPP CCA. Report to M.S. Tierney, dated June 10, 1996, Sandia National Laboratory, Albuquerque, New Mexico, WPO #38801. Docket: A-93-02, V-B-1.

Dzomback, D. A. And F. M. M. Morel (1990) *Surface Complex Modeling, Hydrous Ferric Oxide*. John Wiley and Sons, New York, pp. 95-102. Docket: A-93-02, V-B-1.

Langmuir, D. (1997) *Aqueous Environmental Chemistry*, Prentice-Hall, Upper Saddle River, New Jersey, pp. 344-351.

McKinley, I. G. and A. Scholtis (1993) A comparison of radionuclide sorption databases used in recent performance assessments. *J. Contaminant Hydrology* 13, 347-363 (see Table 1, Table 2, Table 3, Table 4).

Sheppard, M. I. and D. H. Thibault (1990) Default soil solid/liquid partition coefficients, K_ds, for four major soil types: A compendium. *Health Physics* 59, 471-482 (see Table 1, Table A-1, Table A-2, Table A-3, Table A-4).

Stenhouse, M. J. and J. Pöttinger (1994) Comparison of sorption databases used in recent performance assessments involving crystalline host rock. *Radiochemical Acta* 66/67, 267-275 (see Table 3, Table 4).

Issue LLL: Use of Pu(V) K_ds to represent Am(III) and Pu(III)

1. Based on present data, ranges of K_ds for Pu(V) should include 9.8 based on tests with Culebra brine, and the ranges for Am(III) and Pu(III) should be 1-200 based on Np(V) results. The lower end of the range for U(VI) should be zero based on tests in Culebra brine. (991)

2. Dr. Leslie Smith (in his letter report in Appendix 8.6) has also raised questions about the U^{VI} K_d data. If the negative values are ignored, the low end of the sampling range for U^{VI} is 0.03 ml/g. The zero values assigned to the negative values for the batch tests with the Culebra brine did not get passed into the CCA calculation because of a lower average value of K_d for the batch tests using deep brines. The EEG recommends that the lower end for U^{VI} K_d value be set at zero. (1276)

Response to Comments 3.LLL.1 and 3.LLL.2:

(Comments 3.LLL.2 and 3.LLL.1 -- first sentence) The second sentence in 3.LLL.1 on a zero value for U(VI) is discussed above) A K_d of 9.8 ml/g for Pu(V) was not found in the data tables of Brush [1996] for experiments with Culebra brine (AISinR and H-17 brines), although a value of 9.61 ml/g is listed. [Experiment #12007, p. 27, Brush, 1996] The value of 9.61 ml/g for the lower end of the Kd range for Pu(V) was modified, based on the results of mechanistic experiments conducted by Brady at pH values (i.e., 9.87 and 9.88), which are similar to those expected in the repository under MgO backfill conditions. [p. 23 Brush, 1996] Also, the K_d of 9.61 ml/g was determined for a CO_2(g) partial pressure of 1.4%, which is significantly higher than is expected for the repository under MgO backfill conditions. Experiments at lower CO_2(g) levels generally produced much higher K_d values. Because the results of Brady are relevant to the expected repository conditions, it is considered reasonable that they be used to refine the K_d range for Pu(V). The resulting range of 20 to 500 ml/g should provide a sound representation of

Pu(V) partitioning between the brine and Culebra dolomite. It should also be noted that in the EPA PA calculations described in the PAVT, a loguniform distribution was used for the K_d ranges. [WPO# 47258; Docket: A-93-02, Item II-G-39] This procedure reduces the average K_d values used in the calculations to be closer to the low end of the overall K_d range, producing nearly the same effect as lowering the low end K_d value for Pu(V) from 20 to 10 ml/g. However, the PA calculations with this approach did not result in enough increase in the overall transport of the actinides to result in actinide releases above regulatory limits. [WPO# 47258; Docket: A-93-02, Item II-G-39]

The general order of K_d values reported for actinide oxidation states is reported to be:

$$+IV > +III > +VI > +V.$$

[Silva and Nitsche, 1995, pp. 386-387] Researchers at Sandia National Laboratory have also assembled empirical information from numerous scientific sources that trivalent actinides sorb more strongly than pentavalent actinides. [Nowak, 1997] Based on these observations, it is reasonable to expect that the use of either Pu(V) or Np(V) would provide a conservative representation of K_ds for Am(III) and Pu(III). Consistent with this generalization, the use of the K_ds determined for Pu(V) to represent Am(III) and Pu(III) is considered to be a reasonable approach.

References

Brush (1996) Ranges and probability distributions of Kds for dissolved Pu, Am, U, Th, and Np in the Culebra for the PA calculations to support the WIPP CCA. Report to M.S. Tierney, dated June 10, 1996, Sandia National Laboratory, Albuquerque, New Mexico, WPO #38801. Docket: A-93-02, V-B-1.

Nowak, J. (1997) Applicability of LANL Empirical Batch Sorption Results in the Culebra Transport Model. Presentation Notes dated 10/11/96, Sandia National Laboratory, Albuquerque, New Mexico.

Silva, R. J. and H. Nische (1995) Actinide environmental chemistry. *Radiochimica Acta*, 70/71, 377-396 (see pp. 386-387).

Issue MMM: K_d values - Representativeness of K_d experiments for the Culebra

1. The DOE data base for K_d values is very limited. The powdered-rock and core experiments have been conducted on a limited number of samples, and the most important K_d values are supported only by analogical data. (986)

2. The Consultation and Cooperation Agreement between DOE and the State of New Mexico states that without supporting data, DOE will assume zero retardation. DOE has not shown that

its retardation tests apply to the entire Culebra rock body and therefore cannot justify its greater-than-zero retardation factor. (1203)

3. The WIPP Project carried out numerous batch and column sorption experiments with Am(III) and Culebra brines for the performance-assessment (PA) calculations to support the WIPP Compliance Certification Application (CCA). Triay and her group at Los Alamos National Laboratory (LANL) carried out many empirical (batch) sorption experiments with Am(III) in two fluids representative of those in the Culebra Dolomite member of the Rustler Formation, AISinR and H-17 (see Brush, 1996). D. A. Lucero and his colleagues at Sandia National Laboratories (SNL) carried out one experiment each with Am(III) in each of three cores (C-3, D-3, and E-2) from the Culebra in the AIS, using a Culebra fluid (Brush, 1996). (926)

4. It is erroneous to assume that a minimum value for K_ds of, e.g., 3 ml/g is sufficient to establish compliance and to remove K_d values from discussion. (See, e.g., TSD V-B-4 at 24). (989)

Response to Comments 3.MMM.1 through 3.MMM.4:

The DOE set of data on actinide K_ds are derived directly from the results of a number of experiments (e.g., batch, mechanistic, columns) conducted with brine solutions that are representative of potential solutions that may infiltrate into the repository. [Brush, 1996] This data base is probably the largest available for the expected conditions, hence is not considered limited but reasonably well-focused on the relevant issues, that is actinide partitioning to dolomite in high ionic strength conditions. These experimental results show that each of the actinides tested is partitioned to the solid phase to varying extents, hence they will not migrate at fast as the overall rate of advective water flow (i.e., the actinides will be attenuated). These experimental results are also consistent with those reported by others [McKinley and Scalds, 1993, Table 1, Table 2, Table 3, Table 4; Shepard and Theobald, 1990, Table 1, Table A-1, Table A-2, Table A-3, Table A-4; Stenhouse and Pöttinger, 1994, Table 3, Table 4], and consistent with general theories of the adsorptive behavior of cationic solutes under alkaline pH conditions. [Dzomback and Morel, 1990 p. 25-32; Langmuir, 1997 369-395; Stumm, 1992, p. 3-37] For these reasons, the actinide K_d values developed by DOE are considered to be adequate for representing actinide mobilities in performance assessment calculations.

The Culebra Dolomite member of the Rustler Formation may have some variability in physical and mineralogical characteristics over its areal extent, but these variabilities are expected to occur primarily where it grades vertically into other rock formations or as its depositional conditions changed laterally. The Culebra Dolomite is characterized as being comprised predominantly of dolomite with subordinate gypsum and anhydrite. [Lambert, 1992, p. 516] Generally, rocks within a single formation have distinctive lithologies that are indicative of similar depositional histories. [Dictionary of Geological Terms, 1962, Dolphin Books, Garden City, New York] Consequently, the samples of Culebra Dolomite used in experimental studies are expected to be representative of the types of rocks that brines would encounter if they were to migrate through the Culebra Dolomite rock layer. Also, the non-Culebra dolomites used in the mechanistic experiments of Brady are considered to be useful in the determinations of actinide K_d values. In general, surface properties of dolomites can be expected to be approximately equivalent regardless of origin, because they are primarily a function of crystallographic properties [Stumm, 1992] not genesis or location. Because pathways through the Culebra are considered to be the most rapid routes away from the repository, the determination of actinide K_ds for the Culebra rocks are expected to provide a representative depiction of the potential actinide migration away from the repository.

The term "analogical data" in Comment 986 is assumed to refer to the reliance on analogs in actinide chemical behavior to represent K_d values for actinides for which experimental determinations failed. While it would have been preferable to have direct measurements for all of the actinides in all possible oxidation states, experimental difficulties experienced by DOE in obtaining K_ds at the very low concentrations required for actinides, such as Am(III), Pu(III), and Pu(IV), prevented them from obtaining robust values. Consequently, the available set of K_d values was extrapolated to represent the missing data based on analogies in actinide chemical behavior. This approach is considered to be a reasonable compromise between having direct measurements for everything and the practicalities of actually making the measurements.

In general, the actinide analogy for K_ds is based on empirical observations that the order of K_d values for actinide oxidation states is:

$$+IV > +III > +VI > +V$$

as reported by Silva and Nitsche. [1995, pp. 386-387] Based on this order, it is reasonable to expect that the use of either Pu(V) or Np(V) would provide a conservative representation of K_ds for Am(III) and Pu(III). Consistent with this generalization, the use of the K_ds determined for Pu(V) to represent Am(III) and Pu(III) is considered to be a reasonable approach. The K_d ranges obtained through this analogy are generally lower than K_d values reported in the literature for Am and Pu [McKinley and Scalds, 1993, Table 1, Table 2, Table 3 and Table 4; Shepard and Theobald, 1990, pp. 471-482; Stenhouse and Pöttinger, 1994, Table 3 and Table 4], providing some comfort that the values developed by DOE err on the side of conservatism (i.e., predict higher releases than would actually occur).

References

Brush (1996) Ranges and probability distributions of K_ds for dissolved Pu, Am, U, Th, and Np in the Culebra for the PA calculations to support the WIPP CCA. Report to M.S. Tierney, dated June 10, 1996, Sandia National Laboratory, Albuquerque, New Mexico, WPO #38801. Docket A-93-03, V-B-1.

Dzomback, D. A. And F. M. M. Morel (1990) *Surface Complex Modeling, Hydrous Ferric Oxide*. John Wiley and Sons, New York, pp. 25-32. Docket A-93-03, V-B-1.

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Silva, R. J. and H. Nische (1995) Actinide environmental chemistry. *Radiochimica Acta*, 70/71, 377-396 (see pp. 386-387).Docket A-93-03, V-B-1.

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Issue NNN: K_d values - Uniform K_ds and complex chemistry

1. The most critical issues relate to the use of homogeneous and uniform K_ds in each realization, and whether the very simple retardation factor concept adequately represents all of the complex reaction chemistry. This has certainly not been adequately demonstrated at the field scale. A related important issue is the accuracy of the definition of matrix diffusion processes and parameters. Another concern is the reliability of the regional transmissivity estimates for the Culebra, which were determined using inverse methods that assumed a non leaky two-dimensional aquifer. More recent three-dimensional analyses by Sandia clearly indicated that there is significant leakage into the Culebra. (1273)

Response to Comment 3.NNN.1:

(Comment 3.NNN.1, First Sentence) A technical review of actinide K_ds by EPA [Docket No: A-93-02, V-B-4] also concluded that the population of K_d values determined in DOE experiments was not well-represented by a uniform distribution, and recommended that a loguniform distribution be used in PA calculations. In the subsequent PAVT study conducted by EPA [WPO# 47258; Docket: A-93-02, Item II-G-39], loguniform distributions for the actinide K_ds were used. The results of the PAVT study using this approach resulted in compliance with regulatory release limits. Thus, it was concluded that although a loguniform distribution for the actinide K_ds was a better approach than the uniform distribution used by DOE, the ultimate conclusion that could be derived from PA calculations was unchanged. [Docket: A-93-02, Item V-B-4]

K_ds are widely used in transport modeling and are generally considered to be representative of the partitioning of solutes between the solid and liquid phases in systems where no strong chemical gradients are present and solute partitioning is reversible and linear with respect to solute concentrations. [Stumm, 1992, p. 229-232; Freeze and Cherry, 1979, p. 403-405] In the case of WIPP, brines that migrate away from the repository are expected to be relatively homogeneous in composition and to move very slowly through any permeable zone, so slow in fact that diffusion may be an important transport mechanism. In this scenario, it is expected that there will be sufficient time for attenuation reactions, such as adsorption, desorption, co-precipitation, solid-solution formation, etc., to reach a steady-state that is reasonably well-approximated by K_d values for specific actinides. In reality, given the probable long contact times between actinide-bearing brines and solids, some portion of actinide solutes that are adsorbed to the surfaces of minerals, such as dolomite, can be expected to be incorporated into the surfaces of minerals through surface precipitation or solid-solution formation. [Adamson, 1990 p. 433-435; Stumm, 1992] This actinide portion will not be reversibly desorbed back to solution, given a change in solution conditions. However, the use of K_ds to represent actinide migration in transport modeling inherently represents sorption as a reversible process, hence is expected to result in higher actinide mobilities than will actually occur. Consequently, the K_d ranges determined for the actinides are expected to provide a reasonable upper bound for the rates of actinide migration.

3.NNN.1, Second Sentence, is addressed in Section 23, Responses to Comment, Issue "Ground Water Flow and Radionuclide Transport into the Culebra."

References

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Stumm, W. (1992) *Chemistry of the Solid-Water Interface*, John Wiley & Sons, New York, pp. 229-233, pp. 370-371, pp. 229-232 (Docket: A- 93-02, II-G-1, Ref. No. 617).

Docket No: A-93-02; Item V-B-4 (1998) Technical Support Document for § 194.14: Assessment of K_ds used in the CCA. U.S. EPA, Office of Radiation and Indoor Air, Center for the Waste Isolation Pilot Plant, 401 M Street S.W., Washington, D.C., May, 1998.

Issue OOO: Use of laboratory K_ds to represent field conditions

1. A question remains of the transferability of lab data to a projection of field conditions. Dr. Brusseau has recommended additional analysis of the column tests to assess the transferability of such data. A particular concern is whether precipitation is affecting the results of the lab tests. (990)

2. The EEG has, however, accepted the validity of the approach of using the laboratory determined values to get an estimate of the values to be used for modeling contaminant transport in the field, because. Ground water diffusion into the rock matrix will provide opportunities for chemical retardation to occur. But this does not mean that a one-to-one correspondence may be assumed between the laboratory and field values. Dr. Brusseau has recommended additional analyses of the column experiments to help address whether the K_d values obtained under static batch conditions provide an accurate measure for dynamic field conditions. Both Dr. John Bredehoeft and Dr. Leslie Smith emphasized that the K_d range determined from batch tests applies only to the matrix porosity, and not to retardation in the fracture system with advective porosity. (1274)

<u>Response to Comments 3.OOO.1 and 3.OOO.2:</u>

An important consideration in modeling the transport of actinides in the Culebra Dolomite is whether the experimentally determined K_d values are applicable to the field. Issues related to the actinide K_ds were extensively reviewed in Docket: A-93-02, Item V-B-4. K_d values can be scale dependent. That is, small scale experimental studies may not yield the same results as large scale studies. Furthermore, K_ds are site-specific values because they combine all possible sorption processes into a single parameter. However, possible scale-differences can be minimized by using solids and solutions that are representative of the actual field site. In determining actinide K_d values in batch experiments, DOE used samples of the Culebra Dolomite and brine solutions that are considered to be representative of the field situation. [Brush, 1996] These data were supplemented by experiments with other natural dolomites and column experiments, in which the effects of a field-realistic solid to solution ratio could be investigated. The results from all of these studies were compiled into a range of values for the actinide K_ds, rather than merely selecting average values. It is reasonable to expect that the range of actinide K_d values obtained from the DOE experiments are inclusive of any scale-effects that might produce a different average K_d value than the experimental average in either the greater or lesser directions.

The only way to obtain K_ds that are directly representative of field conditions would have been to conduct a field experiment. However, EPA concluded [Docket: A-93-02, Item V-B-4] that such an experiment is impractical because:

- ♦ The large scale of the transport pathway in both length and time (over several kilometers and travel times on the order of tens of thousands of years);

- ♦ The hazardous characteristics of the solutes that would be used in such a test, that is the actinides, preclude the conduct of field tests of even a few years in length;

- ♦ The lack of experimental control on the physical system would make interpretation of the data difficult in that sorption processes could not be distinguished from hydrological and dispersive processes; and

- ♦ The large amount of resources required to conduct field tests reduces the number of experiments that could be conducted to investigate the effects of changes in physical and chemical conditions on the K_d values, thus, preventing the delineation of K_d ranges that could be used to define the upper and lower bounds of actinide migration rate.

K_d data could possibly be collected from scaled-down field experiments, but even scaled-down systems would suffer from the same problems as described for a full-scale experiment.

These impracticalities are not unknown in the field of transport modeling. As a result, laboratory experiments are generally conducted to determine K_ds. [Freeze and Cherry, 1979, p. 432-434; Stumm, 1992, p. 370-372] Laboratory experiments can be more easily designed to account for variabilities in physical and chemical conditions, so that ranges in potential K_d values can be efficiently determined. The K_d values used in mathematical transport models over reasonable ranges and the ranges are broad enough to include minimum K_ds for the actinides such that issues of field versus laboratory data becomes less important. In fact, the definition of K_d ranges, as was done by DOE, is expected to provide the best measure of the potential bounds of actinide partitioning that will occur in the field. For these various reasons, the actinide K_d ranges determined by DOE are considered to be adequate for describing the attenuation of actinides as they encounter and flow through the Culebra Dolomite.

Importantly, there has been a general consensus that flow through the Culebra will be so slow that there will be ample time for actinides to diffuse into the pore space of the dolomite. [EEG, 1998] Thus, the ratio of solid to solution in the field can be expected to be greater than the ratio used in the batch K_d experiments conducted by DOE. At the higher solid to solution ratio in the field, there will be more opportunity for sorption processes to reduce actinide concentrations than actually present in the laboratory experiments. In view of this conceptualization, the laboratory-derived K_d values are expected to overestimate the mobilities of the actinides, making them useful primarily as being reflective of upper bounds for predicting the maximum possible rates of actinide migration in PA calculations. EPA also points out that in PA modeling, K_ds are applied only to the rock matrix, and are not assumed for fracture porosity. Therefore, Drs. Bredehoeft and Smith's concerns regarding application of laboratory tests is unfounded because retardation in fractures was not assumed. Docket: A-93-02, Item V-B-4, Section 4.4 presents EPA's analysis of field K_d testing.

References

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Docket No: A-93-02; V-B-4 (1998) Technical support document for § 194.14: Assessment of K_ds used in the CCA. Prepared by TechLaw, Inc. for the U.S. EPA, Office of Radiation and Indoor Air, Center for the Waste Isolation Pilot Plant, 401 M Street S.W., Washington, D.C., May, 1998.

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Stumm, W. (1992) *Chemistry of the Solid-Water Interface*, John Wiley & Sons, New York, pp. 370-372. Docket A-93-03, V-B-1.

Issue PPP: Actinide analogy applied to K_ds

1. In the absence of measured K_d values for Plutonium at oxidation states III and IV, and inconclusive results for Am^{III}. the K_d values for these three most important actinides in the WIPP inventory have had to be estimated. These estimations are based on two questionable assumptions. The first is that K_d values for actinide cations of the same charge should roughly be the same. According to Dr. Langmuir, the weakness of this assumption lies in not considering the effect of the speciation behavior of the cations on their adsorption properties. The second assumption is that predictable trends exist for the K_d values of actinide cations of different charge. DOE used this assumption to argue that Pu^{V} data can be used for Am^{III}. Dr. Langmuir has shown in his letter report to EEG (Appendix 8.6) that this assumption is based on questionable data and interpretations of the experiments conducted with dilute ground water from the Yucca Mountain site, even though, fortuitously, the same trend has been reported by some other experimenters. Results of the intact core column tests are probably of questionable value as well, because the Am and Pu input concentrations to the cores were so close to saturation with solids that precipitation rather than adsorption may have occurred. (1275)

Response to Comment 3.PPP.1:

A number of reviews of the retardation behavior of the actinides in geologic media have reported that K_ds for actinides are dependent primarily on the oxidation state and decrease in the order of:

$$+IV > +III > +VI > +V.$$

[Silva and Nitsche, 1995, pp. 386-387; Bidoglio et al. 1990 cited by both Langmuir, 1997 p. 536 and Nowak, 1997; Turner, 1995 cited by Langmuir, 1997 p. 537] The experimental data developed by DOE on actinide K_ds generally follow this established trend for the +IV and +III oxidation states. The K_ds for the +V and +VI oxidation states are similar, although the lower value for the +Vstate is about two orders of magnitude lower than the +V oxidation lower end, as might be expected with the trend. This trend is strongest for Americium (III) and Pu(III)and (IV) which are expected to account for 99% of the activity.

	Th(IV)	Am(III); Pu(III)*	U(VI)	Np(V)
K_d (ml/g)	900 to 20,000	20 to 500	0.03 to 30	1 to 200

* Derived from experimental measurements on Pu(V).

The actinide K_ds developed by DOE were determined in brine systems that are similar to those expected to occur in the repository environment [Brush, 1996], hence, they can be considered to be site-specific values. The fact that a number of scientists, who have reviewed the retardation behavior of actinides in geologic media (cited above), have determined the same general trends in K_d values for the actinides, that is also observed in the brine solutions specific to WIPP, makes it unlikely that any similarities in the trends are fortuitous. Instead, the similarities in the conclusions from all these various parties indicates that the trends in actinide K_ds as a function of oxidation state are real, making them valuable for characterizing the general retardation behaviors of the actinides in the environment. With regard to the DOE application of the experimental K_d values, the establishment of the actinide trends in K_ds with oxidation state makes it clear that the use of the experimental K_ds determined for Pu(V) to represent the trivalent actinides is a conservative approach. This fact is acknowledged in the letter report from D. Langmuir referenced in the above comment. [EEG, 1998] It is also confirmed by DOE's mechanistic studies with Nd(III), which is an analog for Am(III), and Pu(III), in which measured K_d values for Nd(III) and Am(III) were all much higher than those measured for Pu(V) across the pH range from about 4 to 9. [Nowak, 1997]

The argument that speciation of the actinides, such as the formation of hydrolyzed species, can have a complicating effect on K_d values is a reasonable concern. However, it is most valid in comparisons of actinide K_d values between systems with different solution compositions, particularly with respect to different pH conditions. The K_d ranges developed by DOE were determined for the range of brine solution compositions that are expected to occur at the WIPP repository. The results of those experiments are consistent with the general trends in K_d values seen in other systems, as discussed in the paragraphs immediately above. Consequently, it can be concluded that although aqueous speciation can affect sorption constants, they do not result in such large effects that they manifest themselves in terms of changes in the general order of K_ds for the actinides. Clearly, aqueous speciation is a minor perturbation on actinide K_ds compared to oxidation state, on which the general order of actinide retardation is based.

The text of Dr. Langmuir's letter report to EEG on this subject states: "...Although the estimated Kd values in the CCA are probably conservative, it is most unfortunate that Am(III), Pu(III), and Pu(IV) adsorption has not been measured..." [letter dated August 5, 1997 to Dr. Robert H. Neill, EEG, from D. Langmuir in EEG, 1998] (Appendix 8.6 of the EEG-68, Docket: A-93-02, IV-G-43) Thus, he seems to concede that, although DOE should have used direct measurements, the values utilized in the CCA likely are conservative. This point is the most important one with regard to the PA calculations in that additional information on actinide K_d values might be nice to have but is unlikely to extend the ranges of actinide K_d beyond the conservative ranges already used by DOE.

The combination of 1) general trends in actinide K_ds reported in the literature, 2) consistency of the DOE K_d trends in brine solutions with the literature trends, 3) lack of empirical information on the effects of aqueous speciation on actinide K_ds in brines, and 4) acknowledgment of EEG's experts that the K_d ranges are "probably conservative" lead to the conclusion that the actinide K_ds used by DOE are appropriate and representative of the upper bounds of actinide migration rate in the Culebra.

References

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Nowak, E. J. (1997) Experimental Results and K_d Value Ranges in the CCA: K_d Meeting with EEG, July 30, 1997, Albuquerque, New Mexico, Sandia National Laboratory (see viewgraphs Nos. 8 and 15). Docket A-93-03, V-B-1.

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Turner, D. R. (1995) A Uniform Approach to Surface Complexation Modeling of Radionuclide Sorption, Report CN-WRA 95-001. San Antonio, TX. Center for Nuclear Waste Regulatory Analysis (cited by Langmuir, 1997, p. 537). Docket A-93-03, V-B-1.

Issue QQQ: Realism/conservatism of K_ds

1. It appears that discussions on several issues dealt by peer review groups may have been made without EPA's own analysis. An example is the new spallings code. The peer review accepted the conceptual model, without an actual testing of the code. The EEG found that after conducting a thorough sensitivity analysis with the codes, variations in several parameters may lead to conclude that the CCA spalled volumes are not conservative. If the EPA had conducted

their own analysis, they too would have reached to the same conclusion. The same can be seen with the issue of actinide solubility or actinide partition coefficient (K_d). (1314)

2. [In its proposed decision EPA did not use:]

*realistic retardation coefficients (see also II-D-117); (229)(1135)

Response to Comments 3.QQQ.1 and 3.QQQ.2:

A technical review of actinide K_ds by EPA [Docket: A-93-02, Item V-B-4] also concluded that the population of K_d values determined in DOE experiments was not well-represented by a uniform distribution, and recommended that a loguniform distribution be used in PA calculations. This approach provides for a more conservative depiction of the K_d population as applied to actinide migration in the Culebra Dolomite. In the subsequent PAVT [WPO# 47258; Docket: A-93-02, Item II-G-39], loguniform distributions for the actinide K_ds were used. The results of the PAVT using this approach still resulted in compliance with regulatory release limits. Thus, it was concluded that although a loguniform distribution for the actinide K_ds was a better approach than the uniform distribution used by DOE, the ultimate conclusion that could be derived from PA calculations was unchanged, that is, that the consideration of a more conservative representation of actinide K_d values did not result in exceedences of release limits.

DOE conducted an extensive set of experiments to determine K_d values for the actinides. In these experiments, the K_d values are calculated from the differences between starting actinide concentrations in solution and final concentrations in solution for a liquid-solid suspension. If the final actinide concentration is less than the initial concentration, then the missing amount must have been lost to the solid phase. If the actinide is partitioned to the solid phase then it is immobile until it is desorbed or the solid phase is dissolved and transported downgradient. In general, actinides are fairly strongly partitioned to the solid phase by sorption processes as was observed in DOE's experiments. For example, average K_ds measured in soils for Am(III) range from 1900 to 112,000 L/kg, depending on the soil type [Sheppard and Thibault, 1990, Table 1, Table A-1, Table A-2, Table A-3 and Table A-4], 500 to 8,000 L/kg for crystalline rock-water systems [Stenhouse and Pöttinger, 1994, Table 3 and Table 4], and 80 to 2,000,000 L/kg for clays and clayey sediments. [McKinley and Scholtis, 1993, Table 1, Table 2, Table 3 and Table 4] Measured K_ds for Pu, of non-specified oxidation state, also range to high values (550 to 5,100 L/kg for soils [Sheppard and Thibault, 1990]; 300 to 5,000 L/kg for crystalline rock-water systems [Stenhouse and Pöttinger, 1994]; and 70 to 500,000 L/kg for clays and clayey sediments. [McKinley and Scholtis, 1993]

Based on the K_d ranges reported for various geologic media and the experimental K_d results from DOE, which are directly applicable to brine systems, the K_d values determined for the dolomitic rocks of the Culebra are somewhat lower, hence are considered to be reasonable and realistic values for bounding the upper ranges of possible actinide mobilities downgradient of the repository. Previous reviews of WIPP PA have also determined that the conceptual model used to handle retardation of actinides in the Culebra through the use of K_ds is conservative. [IRG, 1997]

References

International Review Group (IRG) (1997) OECD/NEA - IAEA Joint International Peer Review Waste Isolation Pilot Plant 1996 Performance Assessment. OECD Nuclear Energy Agency and International Atomic Energy Agency, Issy-les-Moulineaux, France. Docket A-93-03, V-B-1.

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Shepard, M. I. and D. H. Theobald (1990) Default soil solid/liquid partition coefficients, K_ds, for four major soil types: A compendium. *Health Physics* 59, 471-482 (see Table 1, Table A-1, Table A-2, Table A-3, Table A-4). Docket A-93-03, V-B-1.

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Issue RRR: K_ds and organic ligands

1. The WIPP Project has demonstrated on numerous occasions that organic ligands will not affect actinide K_ds in the Culebra (see, for example, US Department of Energy, 1996; Bynum et al., 1997, included as Attachments). Bynum et al. also reviewed the reasons why organics will not affect the chemical behavior of these actinides in this response. Based on these arguments, Hrncir et al. (1996, p. 12) concluded: "The [Waste Characterization Analysis Peer Review] Panel agrees that under the conditions of MgO backfill chelating agents will have a negligible effect on repository performance. The Panel agrees that, even at the basic pH in the repository, the availability of transition metals may be enhanced due to the formation of soluble halo complexes, making an even stronger case that base metals control ligand chemistry."

Despite the fact that there is no credible scientific evidence that organic ligands will affect actinide K_ds in the Culebra, the WIPP Project carried out a sensitivity study of the effects of actinide K_ds on the overall performance of the repository and presented the results to the EEG on July 30, 1997. Although this study does not constitute evidence that organic ligands would actually affect actinide K_ds, the results can be used to assess the potential impact of organics. (928)

Response to Comment 3.RRR.1:

As is indicated in these comments, the effects of organic ligands at their expected levels were included in the CCA calculations and studies [DOE, 1996, CCA, Appendix SOTERM] and were found to be negligible in affecting the speciation of the actinides, implying that they would also not affect the values of the actinide K_ds. EPA also investigated the potential effects of organic ligands on actinide speciation by conducting calculations of the changes in Th(IV) speciation caused by arbitrarily increasing the concentration of EDTA beyond the estimated concentration for the repository. [Docket: A-93-02, Item V-B-17] EDTA was used in these calculations because, of all the organic ligands expected to be present in the waste inventory in bulk quantities, it has the greatest affinity for forming aqueous complexes with the actinides. These calculations indicated that the EDTA concentration would have to be increased at least 1,000-fold to result in any significant Th(IV)-EDTA complex formation, and that complex formation was limited to acidic pH conditions that are not expected for the repository because of alkaline pH conditions that will be imposed by reactions with the MgO backfill.

Additionally, the organic compounds in the repository are expected to be completely degraded by microbial processes after 2,000 years. [CCA, Appendix SOTERM] In the absence of organic compounds, no organic complexation of the actinides will occur.

Based on these considerations of lack of an appreciable effect on actinide aqueous speciation and degradation, the organic ligands are not expected to have an impact on the ranges of K_ds developed for the actinides for characterizing actinide migration through the Culebra.

References

U.S. Environmental Protection Agency.(1998) Technical Support Document for § 194.24: EPA's Evaluation of DOE's Actinide Source Term,1998. (Docket: A-93-02, Item V-B-17).

Issue SSS: Nonlinear K_ds

1. Effective K_d values should be calculated based on a nonlinear isotherm and compared with the existing K_d linear values. (995)

2. Dr. Brusseau has recommended investigating the potential impact of nonlinear sorption on radionuclide transport. This could be accomplished by calculating effective K_d values for pertinent C_0 values, using the nonlinear isotherm data available. These values should then be compared to the existing K_d range. (1279)

3. Inclusion of nonlinear sorption in the CCA PA would have resulted in less transport (greater retardation) of Am(III) in the Culebra. The ranges of nonlinear Am(III) K_ds obtained by Triay during her batch sorption study are 70 to 2,000 ml/g for the deep brines and 80 to 900 ml/g for the Culebra brines (see Brush, 1996). Both of these ranges of nonlinear Am(III) K_ds predict less transport than the range of linear K_ds for Pu(V) used by Brush (1996) to establish the range for Am(III) (and Pu(III)) used in the CCA PA, 20 to 500 ml/g.

The nonlinear Am(III) K_ds discussed above probably resulted from precipitation and/or coprecipitation of Am(III), mechanisms that were conservatively excluded from the CCA PA.

(The SECO-TP model used to predict radionuclide transport in the Culebra included only linear reversible sorption, it did not include potential retardation mechanisms such as precipitation and co-precipitation of radionuclides.) Therefore, inclusion of nonlinear K_ds and retardation mechanisms such as precipitation and co-precipitation would have resulted in less transport. (930)

Response to Comments 3.SSS.1 through 3.SSS.3:

The depictions of actinide transport used by DOE rely on K_ds, which provide for the reversibility of sorption processes, are based on a linear dependence between the actinide concentrations in the solid and liquid phases. Nonlinear adsorption of solutes to a solid substrate only occurs at some concentration level above a threshold at which the highest energy adsorption sites are increasingly saturated. However, the effective K_d value still tends to increase with increasing actinide but at a less than linear dependence on actinide concentration. Actinide concentrations may not reach the concentrations at which nonlinear sorption occurs because of the low solubilities of the phases that incorporate actinides. As noted in Comment 930, the inclusion of K_ds from the nonlinear sorption concentration ranged for Am(III) would have increased that range to higher values. This approach would have reduced the mobilities of the affected actinides or, rather, reduced calculated release rates. In view of this fact, the exclusion of K_ds from the nonlinear range of Am(III) sorption is actually expected to result in over predictions of actinide mobilities in transport calculations, which can be reasonably understood to be a conservative or bounding approach.

Additionally, nonlinear sorption processes are also operative in the opposite sense of that described in this comment. That is, in aqueous-solid systems, solutes that are sorbed are not necessarily reversibly desorbed. [Adamson, 1990, pp. 433-435] The sorption process reflects a continuum between the solution and solid phases that includes free ions solution, a portion of surface sites on which solutes are reversibly sorbed, sites at which solutes become strongly or irreversibly adsorbed, to surface precipitation, in which solutes are incorporated in the solid phase by solid-solution formation or interstitial ion substitution. [Adamson, 1990, pp. 433-435; Stumm, 1992, pp. 229-232, Docket: A-93-02, Item II-G-1, Ref. # 617] Solutes sorbed by these last two processes, strongly adsorbed and surface precipitation, may not be reversibly desorbed and released back to solution unless the rock matrix is dissolved. However, DOE's modeling approach uses the K_d formulation, which implicitly assumes that all sorption processes are reversible.

Based on these various considerations, the use of K_ds (and implicit linear sorption model) to represent the mobilities of the actinides is expected to produce actinide release rates that reflect the uppermost bounds of possible release rates that occur in the field. Consequently, the inclusion of nonlinear representations of actinide adsorption processes will not improve the reliability of PA calculations or better represent the potential hydrogeochemical processes involved in actinide migration.

References

Adamson, A. W. (1990) *Physical Chemistry of Surfaces, 5th Edition*, John Wiley & Sons, New York, pp. 702-703, pp. 433-435. Docket: A-93-02, V-B-1.

Stumm, W. (1992) *Chemistry of the Solid-Water Interface*, John Wiley & Sons, New York, pp. 229-232 (Docket: A- 93-02, II-G-1, Ref. No. 617). Docket: A-93-02, V-B-1.

Issue TTT: K_d values from core column tests are questioned.

1. Dr. Langmuir has questioned the results of the core column tests because of the high concentrations of Pu^{V} and Am^{III} in intake solutions possibly resulting in their precipitation as solids rather than adsorbed in the columns. If precipitation did occur, the concentrations in the rock cannot be used to define K_d values. In order to prove or disprove this concern, it is recommended that the core materials that have been drilled out be examined to identify whether the Pu and Am are present in adsorbed or crystalline solid phase.

Dr. Langmuir has also suggested that it is possible to obtain K_d values for the important actinides in a short period of time from accelerated intact core experiments performed in an ultracentrifuge. Because of the time constraints, the DOE should examine this option. (1278)

2. A question remains of the transferability of lab data to a projection of field conditions. Dr. Brusseau has recommended additional analysis of the column tests to assess the transferability of such data. A particular concern is whether precipitation is affecting the results of the lab tests. (990)

3. Existing column test cores should be examined for evidence of precipitation. (993)

4. Ultracentrifuge tests should be considered to accelerate results where column test data are lacking. (994)

Response to Comments 3.TTT.1 through 3.TTT.4:

The post-test cores used in the column experiments were examined to determine the distributions of Pu(V) and Am(III) as a function of distance from the influent ends. These results were presented to EEG in the presentation by W. G. Perkins and Lucero, January 30, 1997, Albuquerque, New Mexico. [Docket: A-93-02, Item IV-G-34] The Am(III) was found to nearly all be present in the top 1 mm of the core, implying that it had been attenuated by a precipitation reaction as suggested in this comment. Depending on the solubility of the Am(III) solid precipitated, the solution concentration would have been decreased, but some amount of Am(III) would have been left in solution and available for transport through the column, as suggested by the low concentrations in the solid phase beyond 1 mm from the influent end. However, no

Am(III) was detected in the effluent solution, indicating that all of the Am(III) was effectively attenuated and that some sorption did occur.

The concentration profile for Pu(V) showed a more smeared out concentration gradient from the influent end that is suggestive of sorption attenuation processes, not precipitation. Based on these results, Perkins and Lucero calculated minimum K_ds in the range of 175 to 282 ml/g for Pu(V) and 190 to 327 ml/g for Am(III). These K_d values are within the range of 20 to 500 ml/g determined for Pu(V) in batch experiments as reported by Brush [1996], which did not exhibit precipitation.

The lack of any significant mobility of the Am(III) and Pu(V) in the column experiments confirms the results of the batch experiments and ranges of K_d determined from the batch experiments and additional analysis of precipitates is not required. Additional data could possibly be obtained using an ultracentrifuge or in additional batch experiments. However, wide ranges of K_ds for the actinides have already been determined from the results of batch and column experiments. It is not expected that any additional experiments would greatly change these K_d ranges, hence would not change the results of actinide transport calculations conducted as part of the PA.

References

Brush (1996) Ranges and probability distributions of Kds for dissolved Pu, Am, U, Th, and Np in the Culebra for the PA calculations to support the WIPP CCA. Report to M.S. Tierney, dated June 10, 1996, Sandia National Laboratory, Albuquerque, New Mexico, WPO #38801. Docket: A-93-02, V-B-1.

DOE (1998) DOE's Response to Comments Made by EEG to Docket: A-93-02, dated 12/31/97. U.S. Department of Energy, Carlsbad Area Office, Carlsbad, New Mexico, Attachment 10, Perkins, W.G. and Lucero 1997. "Intact-Core Column Results." Unpublished presentation to the Environmental Evaluation Group, January 30, 1997, Albuquerque, New Mexico: Sandia National Laboratories, Docket No: Docket: A-93-02; Item IV-G-34.

Issue UUU: Mining and effects on K_d

1. The transport of radionuclides through the Culebra was also modeled, with slight changes from what was assumed in the CCA performance assessment. Two experiments were conducted using the flow results of the Modified Mining Scenario to compare the results to previous modeling studies. The first experiment simulated Plutonium through the Culebra unretarded. The second experiment modeled Uranium with generated Kds to compare the results to those in the performance assessment. . . Modeling Plutonium with no sorption to the surrounding matrix with BLM flow characteristics demonstrated to have the highest release probabilities. When compared to the 1% Kd=0 ml/g with purely Full Mining of the CCA, release differences of up to 1.5 orders of magnitude are noticed. However, when comparing the Full Mining with no

sorption to BLM Mining with sorption, the Full Mining Scenario dominates the release probabilities, indicating that low sorption is much more important than high velocities. (1085)

Response to Comment 3.UUU.1:

The commenter discusses actinide transport modeling in the Culebra dolomite. The commenter's modeling, Figure 8.12 of EEG-69 [Docket: A-93-02, Item IV-G-43] indicates that the assumptions used by the commenter affect releases from the ground water pathway, but releases are still very low relative to EPA's standards. EPA agrees that releases from the ground water pathway will be low even if different assumptions are assumed for the potash mining, however, EPA does not agree with the no K_d premise used in the modeling except for use as a scoping study.

The modeling done by the commenter assumed no retardation in one case, and no retardation for 1% of the plutonium in a second case. Results of the commenter's modeling analysis and subsequent CCDF generation are presented in Figure 8.12. [Docket: A-93-02, Item IV-G-43] This figure shows that the CCA mean release from the Culebra assuming no K_ds and "slower" velocity from the Culebra is greater than the release using the modified mining scenario (higher velocity) and modified (lower) K_ds for uranium. That is, the "higher" velocities of the modified mining scenario did not "compensate" for the increased sorption relative to potential releases. With a 1% of plutonium having a K_d of 0, the release from the commenters' modified mining scenario is higher than that in the CCA, meaning that if K_ds are "equal", the higher velocities of the commenter's modified mining scenarios result in higher releases.

These modeling assumptions of no K_d for all or part of the radionuclides are different from the accepted conceptualization of actinides used in the CCA [EPA's Technical Support Document for § 194.23: Models and computer codes, section 1.3.18, Docket: A-93-02, Item V-B-6; CCA Chapter 6.4.6.2; Appendix MASS, Section 15], and thus EPA believes that, since DOE has demonstrated retardation of actinides in the Culebra [Docket: A-93-02, Item V-B-4], the approaches used in the modeling are not applicable to EPA's compliance decision. EPA reviewed DOE's K_d values in detail [Docket: A-93-02, Item V-B-4] and EPA concluded that the K_d ranges chosen by DOE are sufficient for performance assessment, and more accurately reflect how radionuclides will be transported within the Culebra than an assumption of no retardation, even if only a small quantity is assumed not to undergo sorption, as indicated by the comment.

Issue VVV: No K_d values have been obtained on rock from the Dewey Lake Redbeds.

1. No K_d values have been obtained on the DLR rock, in situ or in the laboratory, and the reported values from the literature search are meaningless because they were conducted on a variety of soils under a variety of conditions unrelated to the DLR Formation. The EEG therefore rejects the CCA assertion about the contaminant transport through the DLR. (1226)

Response to Comment 3.VVV.1:

Geological and transport studies by DOE have indicated that the Salado markerbeds are the primary hydrologic radionuclide transport pathways for the undisturbed release scenarios, and that the Culebra Dolomite is the primary migration pathway for intrusion scenarios. [Docket: A-93-02, Item II-G-1, Chapters 6 and 8] These modeling results also indicated that the Dewey Lake Redbeds did not play an active role in actinide release scenarios. EPA believes that DOE has appropriately identified that the Salado interbeds and the Culebra dolomite as the potential pathways for transport at WIPP. DOE has also identified that no contaminated brine enters units above the Culebra [Docket: A-93-02, II-G-26], rendering moot the issue of transport in the Dewey Lake Redbeds. [Docket: A-93-02, V-B-2, CARD 14, Section 14.A]

Issue WWW: CCA's lack of consideration of actinide colloids is not justified.

1. CCNS is aware of experiments conducted as early as 1990 by Oak Ridge which show that plutonium attached to colloidal molecules is more soluble and travels faster through various media. The CCA's failure to include the possibility that colloidal particles may travel faster than soluble actinides is not justified in view of the Oak Ridge studies. (1205)

Response to Comment 3.WWW.1:

The commenter is incorrect, the transport of actinides as colloids was considered by DOE, and a substantial portion of Appendix SOTERM of the CCA [DOE, 1996] is devoted to that subject and the studies on actinide-bearing colloids conducted by DOE. The summary of this work in Appendix SOTERM indicates that the greatest potential for colloid transport of actinides in the repository environment is as humic-colloids and, possibly, microbial colloids. Both of these mechanisms are dependent on the presence of organic materials, which are estimated to be present in the repository environment for only the first 200 to 2,000 years. [Appendix SOTERM of the CCA, p. SOTERM-5] After the organic materials have been degraded, the potential for colloidal transport is eliminated.

Prior to the degradation of the organic materials, colloidal transport of the actinides is possible, although it is not expected to result in greater rates of actinide migration than solute transport. In general, colloid transport has been considered a possible mechanism for contaminant transport in permeable systems with low ionic strength solutions. [Roy and Dzomback, 1997, pp. 661-663; Ryan et al., 1998, pp. 481-482] However, the rate of solution movement through or away from the repository is generally acknowledged to be so slow that diffusional transport may be a significant component of the overall transport. Colloids can only migrate as fast as the bulk solution velocity, hence are limited to the rate of advective flow. In the event that diffusion is more rapid than advective flow, the colloids will be limited by their rate of diffusional transport, as will the solutes. In the case of slow transport of colloids by either or both advection and diffusion, movement through the interstices of the geologic formations is expected to filter out many of the colloids.

Additionally, the stabilities of colloids are dependent on the ionic strength of the transporting solution. Colloids are generally destabilized under high ionic strength conditions [Stumm and Morgan, 1996, pp. 837-842], such as those existent in the WIPP brines. Hence, if colloids are formed in the repository, they can be expected to aggregate and diminish in concentration after encountering brines characteristic of the Castile and Salado formations. In actinide-specific studies, colloids have not been found to be an important mechanism for actinide transport [Marty et al., 1997, pp. 2020, 2026; Wolf et al., 1997, p. 470], making it evident that a number of site-specific factors are important for governing colloid generation and transport in porous media.

In summary, while colloidal transport is an important consideration in permeable, dilute ground waters, they are not expected to cause actinides to be transported at rates greater than soluble actinide forms in the repository environment.

References

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Stumm, W. and J. J. Morgan (1996) Aquatic Chemistry, Third Edition, John Wiley & Sons, New York, pp. 837-842. Docket: A-93-02, V-B-1.

Wolf, S. F., J. K. Bates, E. C. Buck, N. L. Dietz, J. A. Fortner, and N. R. Brown (1997) Physical and chemical characterization of actinides in soil from Johnston Atoll. *Environ. Sci. Technol*. 31, 467-471 (see pp. 470). Docket: A-93-02, V-B-1.

Issue XXX: K_d values

1. As described in the EEG's August 29, 1997 letter, the EEG has recommended conducting both batch and column tests for at least the actinides Pu(III), Pu(IV), and Am(III) in the Culebra brine; setting the lower end of K_d for U(VI) to be zero; conducting sensitivity analysis for potential impact of organic ligands; extending performance assessment calculations beyond 10,000 years to see how long the chemical retardation delays the releases to the environment; investigating the potential impact of nonlinear sorption on radionuclide transport; and, checking the validity of the K_d values derived from the column tests by examining the cores to identify whether the Pu and Am are present in adsorbed or crystalline solid phase. (707)

Response to Comment 3.XXX.1:

DOE conducted an extensive set of experiments to determine K_ds, which unfortunately did not provide results that were robust enough for direct representation of Pu(III), Pu(IV), and Am(III). The reasons for the difficulties encountered in determining K_ds for these actinides include their characteristically high K_d values and sparingly low solubilities of their solids; factors that can effectively lower their aqueous concentrations to values below detection limits. For example, average K_ds measured in soils for Am(III) range from 1,900 to 112,000 L/kg, depending on the soil type [Sheppard and Thibault, 1990], 500 to 8,000 L/kg for crystalline rock-water systems [Stenhouse and Pöttinger, 1994], and 80 to 2,000,000 L/kg for clays and clayey sediments. [McKinley and Scholtis, 1993] Measured K_ds for Pu, of non-specified oxidation state, also range to high values (550 to 5,100 L/kg for soils [Sheppard and Thibault, 1990]; 300 to 5,000 L/kg for crystalline rock-water systems [Stenhouse and Pöttinger, 1994]; and 70 to 500,000 L/kg for clays and clayey sediments. [McKinley and Scholtis, 1993]

Additionally, a cursory inspection of data in the literature indicates that the solubility of $Am(OH)_3$ and $AmOHCO_3$, solids that might be expected to control Am(III) concentrations under repository conditions, range from approximately 10-9 to 10-7 molal at pH 7 to 9 and CO_2(g) at 10-3 atm (Felmy et al. 1990). Similarly, the solubility of PuO_2xH_2O in the absence of CO_2(g) is about 10-8 to 10-7 M Pu(IV) at pH 8. [Rai, 1984] This combination of high K_ds and low solubilities make it difficult to conduct K_d experiments with brines because of the very low concentrations that must be used to avoid the formation of actinide solids. However, these very low concentrations are also indicative of the lack of mobility of Am(III), Pu(III), and Pu(IV) under most environmental conditions. [Technical Support Document: Assessment of K_ds Used in the CCA, Docket: A-93-02, Item V-B-4, section 3.4 and 6.0]

Setting the K_d for U(VI) to a value of zero may have some merit in that U(VI) generally is fairly mobile under oxidizing conditions. [Langmuir, 1978] However, the repository is expected to be predominantly anoxic and reducing after a relatively short time period (app. 200 years) as can be expected for the deep aquifers in its vicinity. [Technical Support Document: Overview of Major PA Issues, Docket: A-93-02, Item V-B-5, section 4.8] Under anaerobic conditions, it is unlikely that uranium will be as mobile as a tracer ion because of the sparingly low solubilities of the U(IV) solids [Rai et al. 1990; 1997], hence assigning it a low positive K_d value is a very conservative approach.

The effects of organic ligands at their expected levels were included in the CCA calculations and studies and were found to be negligible. An investigation of the concentrations of ligands that would be required to affect the solubilities of the actinide solids would be an interesting but largely hypothetical exercise that would not be directly relevant to the expected repository chemical conditions.

The goal of extending the transport calculations beyond 10,000 years is not clear. Based on radiocarbon dating and hydrogeochemical patterns, the rate of ground water flow cycling through the Rustler Formation in the vicinity of WIPP has been estimated to take on the order of

13,000 years. [Lambert, 1992] Hence, at least 13,000 years would be required for any non-attenuated solute to migrate through the system. Solutes with K_ds greater than zero would take proportionately longer.

The depictions of actinide transport used by DOE rely on K_ds, which provide for the reversibility of adsorption, and are based on a linear dependence between the actinide concentrations in the solid and liquid phases. Nonlinear adsorption of solutes to a solid substrate only occurs at some concentration level above a threshold at which the highest energy adsorption sites are all filled. Actinide concentrations are not expected to reach these levels. More importantly, nonlinear adsorption is also operative in the opposite sense, that is nonlinear desorption. In most aqueous-solid systems, solutes that are adsorbed are not desorbed at the same rate as they are adsorbed. [Stumm, 1992] However, in DOE's modeling approach with K_ds, solutes that are adsorbed are assumed to be reversibly desorbed, as well.

The K_d values calculated in the batch and column experiments are based on the differences between starting actinide concentrations in solution and final concentrations in solution for a liquid-solid suspension. If the final actinide concentration is less than the initial concentration, then the missing amount must have been lost to the solid phase. The K_d determination does not infer any specific mechanism for the loss of the actinide from solution, just that it was somehow partitioned to the solid phase. If it is partitioned to the solid phase then it is immobile until it is desorbed or the solid phase is dissolved and transported downgradient. A determination of the mechanism of actinide removal either by a surface adsorption process or incorporation into the solid phase by coprecipitation or solid-solution substitution would be interesting but would not change the basic approach for calculating the mobility of the actinides in the aquifer.

<u>References</u>

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Rai, D. (1984) Solubility product of Pu(IV) hydrous oxide and equilibrium constants of Pu(IV)/Pu(V), Pu(IV)/Pu(VI), and Pu(V)/Pu(VI) couples. Radiochimica Acta 35, 97-106. Docket: A-93-02, V-B-1.

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Section 4 Quality Assurance -- Section 194.22

Issue A: The Carlsbad Area Office (CAO) quality assurance program document (QAPD) compliance with Nuclear Quality Assurance (NQA) standards

1. The CCA contains objective evidence (Chapter 5 and Appendix QAPD), and the Proposed Rule shows that the EPA has verified compliance -- for disposal considerations. However, the CAO QAPD does not apply the complete NQA standards to all WIPP activities. (53)

2. The CAO QAPD Revision I (in CCA Appendix QAPD) does not require full implementation of NQA standards for all activities, but only for those listed in Section 194.22(a)(2), other radioactive materials handling, and processes related to transportation containers. This is established in the CAO QAPD in section 1.1.2.3, Applicability of QAPD Requirements, where the difference between general requirements and additional requirements is introduced, and subsections A through J list the areas that fall under the additional requirements. The additional requirements generally seem to be those which are found in the NQA standards, but not in DOE Order 5700.6C, DOE's internal QA requirements document (which follows 10 CFR 830.120). For compliance with 40 CFR 194.22(a)(1), the NQA standards may need to be the primary criteria.

There is no indication in Section 194.22(a)(1), or anywhere else in the criteria, that some WIPP activities can be granted a variance from the requirements of the NQA standards. (739)

3. Page 5-2, line 6 -- Revision I of the CAO QAPD may incorporate the requirements in the NQA standards, they are split between general requirements (for all activities) and additional requirements (applied to activities in which radioactive materials, shipping packages, or the eight compliance activities specified by Section 194.22(a)(2) are involved). This division indicates that DOE Order 5700.6C is the basis of the CAO QAPD rather than the NQA requirements, . . . There is no variance granted in Section 194.22(a)(1) for activities in the QA program, and Chapter 5 presents no evidence of any agreement for such a variance. The intent of the regulation seems to be that the WIPP will adhere to NQA standards for at least all disposal-related activities, and arguably for the entire QA program. (745)

Response to Comments 4.A.1 through 4.A.3:

EPA assumes that these comments can refer to two different questions. First, does the CAO QAPD apply the complete NQA standards; and second, does the CAO QAPD apply the complete NQA standards to all WIPP activities?

First, the CAO QAPD was included with the CCA as Appendix QAPD, and incorporates the following requirements: (1) American Society of Mechanical Engineers (ASME) NQA-1-1989 edition (the eighteen basic requirements, including supplemental requirements); (2) ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition (the computer software requirements); and (3) ASME NQA-3-1989 edition (excluding Section 2.1 (b) and (c), and Section 17.1) (the collection of scientific and technical information requirements for site characterization of high level nuclear waste repositories). Therefore, the CAO QAPD applies all the complete NQA standards required by Section 194.22(a)(1).

Second, the comments do not identify specific WIPP activities where the CAO QAPD does not apply the NQA standards, but rather refer to: “all WIPP activities,” or “additional requirements.” Section 194.22(a)(2) requires that QA be established and executed for eight specific areas. EPA has determined that QA programs have been established and executed for the areas identified in Section 194.22(a)(2)(i)-(viii), with one exception. This single exception is the waste characterization activities and assumptions. [Section 194.22(a)(2)(i)] At this time, EPA has confirmed the establishment and execution of a QA program for waste characterization activities and assumptions for only one waste generation site, the Los Alamos National Laboratory (LANL). [Docket: A-93-02, Item II-A-51] Therefore, EPA’s certification of WIPP is conditioned on each waste generator site demonstrating compliance with Section 194.22(a)(2)(i) prior to such site shipping any transuranic waste for emplacement at WIPP. For additional information, refer to Condition 2 of the certification.

Finally, EPA conducted an audit of CAO’s quality assurance program from December 9-13, 1996. [Docket: A-93-02, Item II-A-43] The audit determined that CAO adhered to a QA program that implements the requirements of 40 CFR 194.22(a)(1), including CAO adherence to the requirements of NQA-1 element #18, entitled Audits , and its supplement. The CAO QAPD requires that QA be applied to all items, activities, and processes, however, EPA only requires that DOE establish and execute QA programs for the items and activities listed in Section 194.22(a)(2). Moreover, EPA has determined that DOE implemented all necessary QA requirements, except with respect to waste characterization activities. The basis for these determinations are set forth in Compliance Application Review Document (CARD) 22 and the accompanying audit reports.

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4. Section 194.22(b) -- Chapter 5 offers no demonstration of EPA approval of any of the methods used. While the EEG understands that the EPA has not provided approval/disapproval to the DOE for the various methods the DOE has utilized, Section 194.22(b) clearly requires information demonstrating approval to be in the CCA. The CCA should at least contain a statement concerning qualification of the methodology by the EPA. (741)

Response to Comment 4.A.4:

DOE conducted three peer reviews to qualify existing data. The Engineered Systems, Natural Barriers, and Waste Form and Disposal Room Data Qualification peer reviews were conducted to qualify existing data as required by Section 194.22(b). CCA, Chapter 9 and Appendix Peer. EPA conducted quality assurance audits at Sandia National Laboratory on April 16-18, 1997, and May 12-16, 1997, to, inter alia, review DOE's compliance with Section 194.22(b). During these audits, EPA reviewed (1) the procedures and management plans for independent review of data; (2) peer review procedures; (3) purported equivalent QA procedures; (4) documentation such as notebooks, checklists peer review process confirmation; parameter value determination records; and other documentation supporting DOE's qualification decisions. EPA determined that all of the parameters and data reviewed were traceable and qualified. [Audit of Parameter Traceability and Qualification of Existing Data, Docket No. A-93-02, Item II-A-48] EPA agrees that the CCA contains no evidence that DOE obtained prior approval of its alternate methodology for qualifying existing data. However, DOE did qualify relevant existing data utilizing methodologies identified in Section 194.22(b), such as peer reviews and QA programs equivalent to ASME documents. EPA conducted an audit of DOE's data qualification and determined it to be acceptable. Therefore, the primary purpose of the criterion, i.e., "that all data used in the compliance demonstration [are] assessed to be adequate to meet the quality needs of their intended use," has been met. [Response to Comments Document for 40 CFR Part 194, Docket: A-92-56, V-C-1, 4-12] EPA approves the use of any of the following three methods for qualification of existing data: (1) peer review, conducted in a manner that is compatible with NUREG-1297; (2) a QA program that is equivalent in effect to ASME NQA-1-1989 edition, ASME NQA-2a-1990 addenda, part 2.7, to ASME NQA-2-1989 edition, and ASME NQA-3-1989 edition (excluding Section 2.1(b) and (c) and Section 17.1); or (3) use of data from a peer-reviewed technical journal.

Issue B: Objective evidence for the eight areas listed in Section 194.22(a)(2)

1. Section 194.22(a)(2) -- Objective evidence for most of the eight areas was neither described in the CCA nor appropriately verified by the EPA. (54)

2. The EEG has also expressed concerns on the quality assurance sections of the proposed rule. The EPA has yet to adequately respond to these EEG concerns. More importantly, the proposed rule and supporting documents do not provide objective evidence that the QA criteria in 40 CFR 194.22 have been met. (722)

3. Section 194.22(a)(2) -- The requirement is misinterpreted in Chapter 5 as "40 CFR 194 stipulates that the DOE apply QA controls to eight areas" (p. 5-3, line 28). The misinterpretation is essentially an echo of page 5-2, lines 6 and 7. This statement is far from presenting evidence that the program has been established and executed. Demonstration of execution would presumably be by citing independent assessments (audits and surveillances) for the different areas. The chapter does provide separate sections for each of the eight activities, but demonstration of establishment and execution of adherence to the NQA standard requirements is weak or nonexistent in these sections and references from these sections. (740)

4. Page 5-2, lines 6-7 -- Section 194.22(a)(2) does not require the application of QA programs to the areas described in its eight subparagraphs. The requirement is for the compliance application: the CCA must demonstrate that the requirements of the NQA standards have been applied for each of the eight subparagraphs. . . Demonstration of execution of the requirements of the NQA standards would presumably be by describing QA assessments which confirm adherence to the NQA standards for each of the areas. The difference in approach to the requirement is critical. Chapter 5 describes the general QA program which includes the eight critical area specified by Section 194.22(a)(2), but is ineffective in demonstrating that the QA program has been established and executed for each of them. . . The chapter should address the requirements as stated. (746)

Response to Comments 4.B.1 through 4.B.4:

Section 194.22(e) requires EPA to verify that DOE has established and executed a QA program for the areas indicated in Section 194.22(a)(2). It is important to note that the "objective evidence" for determining whether or not this QA program has been established and executed exists at the WIPP and generator sites, and is gathered in the field audits and inspections. [Docket: A-93-02; Items II-A-43, II-A-44, II-A-45, II-A-46, II-A-47, II-A-48, II-A-49, II-A-50, and II-A-51] The function of the audits and inspections is to gather objective evidence of compliance with the QA programs.

Several WIPP organizations were responsible for establishing and executing the activities and items listed in the eight areas of Section 194.22(a)(2). The CCA, Chapter 5, does not alone provide all the documentation to verify compliance with the requirement of Section 194.22(a)(2). However, Chapter 5.1 [pp. 5-1 to 5-3] of the CCA states that DOE provides the overall QA program requirements for WIPP via the CAO QAPD. The CAO QAPD requirements are further supported and amplified by the next tier of QA program documents, which includes the SNL quality assurance procedures (SNL QAPs), the WID Quality Assurance Program Description, and the quality assurance program plans (QAPPs) for the individual waste generator sites. More documentation is found in DOE, WID and SNL *Corrective Action Reports* that provide objective evidence of implementation of element #16 of NQA-1, titled Corrective Action, and Audit Reports that provide objective evidence of implementation of element #18 of NQA-1, titled Audits. Therefore, EPA finds that sufficient information for Section 194.22(a)(2)(ii)-(viii), and for QA program implementation for waste characterization activities at LANL [Section 194.22(a)(2)(i)] were described in the CCA and supporting documents to the extent practical.

EPA verified that QA programs were established in accordance with Section 194.22 through the CAO QAPD and supporting documents. EPA expected to find objective evidence of compliance or noncompliance with the QA requirements within the QA records and activities of the WIPP organizations, including CAO, SNL, and WID. In accordance with Section 194.22(e), the Agency conducted audits [Docket: A-93-02; Items II-A-43, II-A-44, II-A-45, II-A-46, II-A-47, II-A-48, and II-A-49] of these WIPP organizations to verify the appropriate execution of QA programs. Evidence verifying the execution of the QA programs is found in EPA's audit reports. EPA's audits of SNL and WID covered all aspects of the programs including, but not limited to: the adoption of the requirements of Section 194.22 through the CAO QAPD, quality assurance procedures (QAPs), reports from previous audits, surveillance reports, and corrective action reports (CARs). The audits assessed the adequacy and implementation of the SNL and WID quality assurance programs in accordance with the requirements of Section 194.22(a)(1). For example, for Section 194.22(a)(2)(iv), the "Computations, computer codes, models and methods used to demonstrate compliance with the disposal regulations," EPA conducted audits of the SNL and WID quality assurance programs for computations, computer codes, methods and models. For all of the other areas in Section 194.22(a)(2), CARD 22 [Section 22.B, pp. 22-5 through 22-19] should be consulted for information and citations to audit reports. Also, EPA conducted inspections of the CAO audits of Idaho National Engineering and Environmental Laboratories (INEEL) and LANL. [Docket: A-93-02, Items II-A-50 and II-A-51]

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5. Page 5-3, line 41 - Page 54, line 12 -- The EEG is unaware of any demonstration that compliance with the WAC criteria has been officially met for any waste container, so it seems unlikely that the NQA requirements can be said to have been "executed". . . The DOE now has a strict program for certification of generator sites before waste characterization can take place. Information on a demonstration of a full execution of the requirements of the NQA standards at the generator sites, including the certification audits, should have been provided in the CCA. (752)

Response to Comment 4.B.5:

EPA agrees that information to demonstrate compliance with the WIPP Waste Acceptance Criteria (WAC) was not provided in the CCA or supplemental information, except for LANL. EPA's certification is conditioned upon DOE demonstrating compliance with the Section 194.22(a)(2)(i) requirements at other waste generator sites prior to such generator sites shipping any transuranic waste for disposal at WIPP:

> "Therefore, EPA imposed Condition 2. Condition 2 of the proposed rule provides for each generator site to comply with the requirements of 192.22, before they are allowed access to WIPP. To fully comply with Condition 2, DOE must submit site specific documentation regarding waste characterization activities. EPA must verify and approve all activities associated with waste characterization prior to shipment to WIPP." [62 FR 58814 (October 30, 1997)]

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6. Page 5-5, lines 3-25 -- The CAG (Compliance Application Guidance for 40 CFR Part Section 194; EPA 402-R-95-014) states (p. 18-19) that the EPA expects much more information on waste characterization activities and assumptions than is included in this section. Among these expectations are several that relate to objective evidence for various QA activities; a listing of dates when conformation to the NQA standards for each activity became effective; a description of not only DOE but principal contractor QA assessment activities; and the schedules for these activities. None of these are supplied in the CCA, though Appendix AUD lists by title (which is not a description) and date a general list of assessments that includes CAO's waste characterization assessments. The list does not however, show assessments by "principal contractors", which for waste characterization would be the generator site QA programs. (755)

Response to Comment 4.B.6:

The CAG contains a disclaimer which states, among other things, that the "CAG is intended solely as guidance [and it] does not establish compliance criteria or any other binding rights and duties." EPA expects much more information on waste characterization activities and assumptions when the generator site is ready to ship waste. Before any facility can send any waste to WIPP, the facility must first comply generally with 40 CFR 194, and specifically with Section 194.24(c)(3)-(5) for each waste stream or groups of waste streams characterized using processes inspected and approved by EPA. Sections 194.24(c)(3)-(5) requires that DOE: 1) submit specific information demonstrating that the use of process knowledge (PK) or acceptable knowledge (AK) to quantify components in the waste conforms with the QA requirements in Section 194.22, 2) demonstrate that a system of controls has been and will continue to be implemented to confirm that the waste in WIPP will not exceed the upper limit or fall below the lower limit calculated in accordance with Section 194.24(c), and 3) demonstrate that this system of controls conforms with the QA requirements in Section 194.22. Once this information is available, EPA will conduct an audit, or an inspection of a DOE audit, at each site to evaluate the use of PK/AK and the establishment of a system of controls for each waste stream or group of waste streams including the demonstration of the WIPP Waste Information System (WWIS), and application of the relevant QA requirements.

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7. Page 5-5, lines 30-38 -- The section offers no demonstration that the "monitoring plans" have been established in accordance with the NQA standards; the "monitoring plans" are not even identified, though one can infer that the appendices may contain them. The section itself offers no demonstration that a QA program adhering to the requirements of the NQA standards has been

established and executed for the titular areas -- no QA documents specific to the activities are listed, no procedures that would demonstrate QA requirements at the working level. (756)

Response to Comment 4.B.7:

This question has three parts. The responses for the first part on demonstrating that "monitoring plans" have been established in accordance with NQA standards, and the third part, demonstrating that the QA program adheres to the NQA standards for the titular areas, are found in the general response to Issue B. The remaining part of this question deals with where the monitoring plans were identified. They were identified in the Appendices MON and EMP.

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8. Page 5-5, lines 43 to Page 5-6, line 4 -- No statements related to QA are attached to the description of measurement of geological factors. (757)

Response to Comment 4.B.8:

Measurements of geologic factors conducted prior to April 9, 1996, were classified as existing data. The requirements for qualifying existing data are found in Section 194.22(b) of the rule and discussed in section 4.2.2.2, p. 5-50 of the CCA. The Agency conducted audits of the QED process, including peer reviews [Docket: A-93-02, Item II-A-46] and IRT. [Docket: A-93-02, Item II-A-48] The audits concluded the QED process adhered to the requirements of Section 194.22(b).

Current measurements of geologic factors are the responsibility of WID. EPA conducted an audit of WID in February 1996. [Docket: A-93-02, Item II-A-45] The audit concluded that WID had implemented a QA program in accordance with the requirements of Section 194.22.

9. Section 194.22(a)(2)(vi) -- Recommendation: The EPA should establish which programs and activities relate to design of the disposal system, and include a demonstration of establishment and execution of the NQA standards for these programs and activities in the documentation for the final rule. Since much of the information predates the use of the NQA standards for WIPP activities, the EPA should consider whether or not a QED process as allowed by Section 194.22(b) has been applied to these areas, and include that information in documentation of the final rule. (1290)

Response to Comment 4.B.9:

The design of the disposal system was qualified by Peer Review 9.5, National Academy of Science, Review of Criteria of Site Suitable, Design, Construction and Operation of Proposed WIPP. EPA conducted an audit of the peer review process in February 1997. [Docket: A-93-02, Item II-A-46] The audit concluded that peer review were conducted in accordance with the requirements of NUREG-1297.

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10. Section 194.22(a)(2)(iii) -- Recommendation: The EPA should review the CCA for field measurements of the four areas cited in this criterion to ascertain if the QA processes utilized by the DOE for these field measurements meet the criterion. Measurements of geologic factors and groundwater used in support of the PA were the targets of the IRT reviews listed in Table 5-5 of the CCA. The EPA should correct the support documentation in the final rule to reflect that QA for field measurements of geologic factors and groundwater measurements is covered by Section 194(b), and cite data for specific parameters examined during the EPA's Audit of the Parameter Traceability and Qualification of Existing Data (II-A-48) as verification of the QED for this criterion. For meteorological and topographical characteristics, the EPA should require that the DOE demonstrate that the measurements presented in the CCA was gathered under QA program that established and executed the NQA standards, or present traceable evidence that these measurements were processed under Section 194.22(b). Reference to these statements should be a part of the EPA's documentation for the final rule. (1287)

Response to Comment 4.B.10:

Geologic factors and groundwater measurements conducted prior to April 9, 1996 were qualified as existing data. Future geologic and groundwater measurements will be conducted under programs verified to have implemented the requirements of Section 194.22. Therefore, QA for field measurements of geologic factors and groundwater measurements conducted after April 9, 1996, are not covered by Section 194.22(b).

The specific parameters reviewed during the QED audit are presented as Attachment 2 of the report. [Docket: A-93-02, Item II-A-48] Attachment 5 of the QED report provides all of the references used in the evaluation, and the corresponding SNL WPO numbers. EPA verified through random sampling that DOE had an adequate process of ensuring that all data important to the containment of waste was qualified in accordance with the requirements of Section 194.22.

Issue C: Qualification of waste characterization data, baseline inventory report (BIR),and acceptable knowledge (AK)

1. Section 194.22(b) -- Only SNL activities under its QED program are described in the proposed rule and CARD 22. Waste characterization data--both BIR and AK on existing waste--are obvious examples. The Waste Characterization Peer Review Report clearly states that NQA-1 was not applied to BIR data gathering activities. (55)

2. Section 194.22(a)(2)(i) -- No evidence is presented either by EPA or DOE which shows that BIR data was gathered under NQA standards -- the Waste Characterization Peer Review flatly states that no QA was performed. No evidence is presented that preexisting acceptable knowledge at generator sites was, or will be, gathered under the NQA standards. Only one generator site has demonstrated an established and executed QA program. (87)

3. Section 194.22(b) -- Only SNL activities are described. The BIR is based on data that apparently pre-exists adherence to NQA standards at the generator sites, and there is no evidence that acceptable knowledge from the generator sites was gathered under NQA standards, but neither has undergone QED. Peer review by NUREG 1297 would be more stringent and controlled than normal article peer reviews; for instance, review by other DOE personnel is limited under NUREG 1297.(100)

4. Page 5-3, lines 34-39 -- None of the data in any of the TWBIR versions seems to have been gathered under the NQA standards as required by Section 194.22(a)(2)(i). Sources of information included extrapolations from, among other sources, safety documentation and interviews with workers (TWBIR 2 p. 1-2 1; DOE/CAO-95-1121). EEG-61, Review of the WIPP Draft Application To Show Compliance with EPA Transuranic Waste Disposal Standards (EEG; March, 1996) on page 4-5 quotes a 1995 ORNL report that "TRU waste streams at ORNL are not as yet fully characterized ... waste sludge ... physical data such as particle size, hardness, viscosity and particle distribution are unknown."

The bulk of the source data may be more reliable, but is based primarily on acceptable knowledge (TWBIR 2, p. 1-20), which is in turn predominantly process knowledge. Use of process knowledge to quantify components in waste, which is how the TWBIR data is used in the CCA, is required by Section 194.24(c)(3) to conform to the NQA standards, also. There is no evidence in the CCA that any of the process knowledge activities were conducted under the requirements of the NQA standards.

The Waste Characterization Analysis Peer Review Report (p. 4-3) mentions both cost and time restraints as justification for the lack of QA on the TWBIR. The NQA standards contain no variances for cost and time considerations. (749)

5. Page 5-3, lines 36-38 -- Chapter 5 is offering incomplete and misleading data here. Note that the data (taken from Revision 2) used for the CCA was published months after the single assessment (a surveillance by one auditor, not an audit) cited, and QA of the additional data requested by the EPA (in 1996) included in CCA TWBIR was certainly not assessed during the surveillance. The surveillance issued one significant finding, which essentially stated that there was no analysis or data collection plan to assess the TWBIR against, as is required by the NQA standards. (750)

Response to Comments 4.C.1 through 4.C.5:

The comments state that only SNL activities were properly qualified and described in the proposed rule and CARD 22, via the qualification of existing data requirements, but that the waste characterization data found in the BIR and AK were not properly qualified by a QED process or application of the NQA requirements.

Much of the transuranic waste for the WIPP has not been generated yet but is currently estimated to be generated at some time in the future. The information in the BIR contains *estimates* of

DOE's inventory of transuranic waste; it is not a summary of data obtained from WIPP measurements of the waste. However, as identified in the comments, the Waste Characterization Peer Review Report examined the BIR estimates. In this Report, DOE's Peer Review Panel of independent experts states that the BIR estimates received proper qualification through the Panel's peer review. As stated in the report: "Because there had been no prior requirements to gather these types of data under a formal QA program consistent with NQA-1 requirements, and a very short response time was imposed, the sites compiled their inventories using the best available information. The Panel concluded that, given these constraints, the data submitted are conservative (overstates quantities) and the best that could be obtained within reasonable time and cost." [Waste Characterization Peer Review Report, Section 4.1.1.1, p. 4-3] The qualification of existing data does include the use of peer review as one of the alternatives to properly qualifying data. Therefore, the BIR was properly qualified by the Peer Review Panel.

AK was not used in the Performance Assessment (PA) and therefore did not require qualification as contemplated by Section 194.22(b).

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6. Section 194.22(a)(2)-- Recommendation: The EPA could examine the audit report of the TWBIR process to ensure that the NQA standards were applied to the gathering and processing of waste characterization assumptions used in the PA, despite the Waste Characterization Peer Review's statement to the contrary. Alternatively, the Waste Characterization Peer Review accepted TWBIR data even though the panel was aware of the data's QA deficiencies. . . The EPA could consider whether the Peer Review Report can be used as a "qualification of existing data" as allowed by Section 194.22(b) as a method of meeting the criterion for TWBIR data used in the PA. Documentation of these activities should be included in the final rule or its supporting materials. (1285)

Response to Comment 4.C.6:

The Peer Review Process was performed because there was no NQA-1 program in place at the time the assumptions were made. If the NQA-1 was applied, then the Peer Review Process would have been unnecessary. The Peer Review Panel approved the process. Moreover, Section 194.22(b) requirements state that peer review is an alternative methodology for qualifying data and information prior to the implementation of the QA program required pursuant to Section 194.22(a)(1).

Issue D: Verification of data quality characteristics (DQCs)

1. Section 194.22(c) -- Criterion was not met either by DOE in the CCA or by EPA's attempts to fulfill it using DOE's data. The proposed rule states that DOE did not supply the information in the CCA, or in supplementary information requested by the EPA. EEG notes that the CCA cites two areas (waste characterization, environmental monitoring) that the PARCC characteristics should be applied to either, but neither the CCA nor later additions describe DQCs for these.

CARD 22 describes parameters that EPA evaluated, but does not show how the PARCC characteristics were assessed for these parameters. (56)

2. Section 194.22(c) -- DOE lists waste characterization and environmental monitoring as applicable, but neither DOE nor EPA supply information that describes how DQCs for these have been assessed. The SNL data parameters addressed in CARD 22 do not show that the PARCC requirements were considered. (101)

3. Section 194.22(c) -- The application provides an argument that it is not practicable to apply the PARCC characteristics to "most scientific investigations used to support performance assessment in which there is uncertainty in conceptual models and the resultant ranges of parameters" (section 5.2 1.1, lines 40-42). The characteristics are not provided as required. While it may be that evaluation of these characteristics did not take place at the sampling level, some assessment should have been made to establish how much uncertainty in models and parameters would be not only practicable, but necessary. Note also that apparently some of the scientific investigations are not covered by the argument, and information which describes how PARCC was assessed for these, at least, should have been included. (742)

4. Page 5-43, line 38-40 -- The requirement does not state that the data must be assessed the PARCC characteristics, only that the CCA include a description of how the assessment was performed. It is also important to note that the requirement does not limit the DOE to only considering the PARCC characteristics -- the DOE could also take the opportunity to describe how other quality characteristics of the data were assessed. (799)

5. Page 5-43, line 39 to Page 5-44, line 2 -- The DOE agrees that waste characterization and environmental monitoring activities could be assessed using the PARCC characteristics, but no description of how data from these areas were assessed is included in this section, chapter 5, or elsewhere in the CCA. (800)

6. Page 5-44, lines 4-21 -- The requirement is for the data, not for the computational modeling use of it. If the low level data, based on measurements, have not been assessed for their quality, how much assurance can there be that the parameter distributions based on it are a measure of reality? An original measurement that represents a sample three orders of magnitude from the mean of the population is not much improved by establishing a three orders of magnitude range. The last sentence implies again that the PARCC characteristics are a requirement to reduce the range; they aren't. The PARCC characteristics help establish what sort of range should be used. This relates to the confidence which can be placed on the model accuracy, not the accuracy itself. (801)

7. Page 5-44, lines 31-26 -- This paragraph doesn't address the requirement at all. PARCC characteristics are not intended to reduce uncertainty, but to establish the quality of whatever uncertainty used. The requirement is to ensure that an attempt has been made to address the uncertainty at the experimental data level. Uncertainty and sensitivity analyses at SNL determine

the most important parameters, but it is the level of confidence in the underlying data for parameters that the application of quality characteristics is meant to establish. (802)

<u>Response to Comments 4.D.1 through 4.D.7:</u>

The commenters makes four points: (1) The CCA did not adequately demonstrate DOE's compliance with Section 194.22(c); (2) EPA's review of DOE data was not sufficient to demonstrate compliance with this criterion; (3) The CCA does not explain how data quality characteristics (DQCs) were evaluated in the areas of waste characterization and environmental monitoring; and (4) CARD 22 does not show how EPA assessed DQCs for parameters. This response addresses the commenter's four points by explaining DOE's position on DQCs, EPA's interpretation of that position, and why EPA found DOE to be in compliance with the criterion.

EPA agrees with the commenters' first point, to the extent that the CCA did not contain the detailed information regarding DOE's assessment of DQCs that EPA had requested. Instead, the CCA contained two brief arguments: any uncertainties in data involved in the performance assessment are immaterial given the substantially greater uncertainties associated with the conceptual models; and it is not practicable to apply DQCs retroactively to data generated prior to issuance of the Compliance criteria. DOE argued that qualification of existing data was sufficient to provide confidence in data used in the performance assessment:

> It is often not practicable for DOE to document. . . [DQCs] for the scientific investigation and characterization of natural systems. As an example, data accuracy would be very difficult to assess for geologic site characterization activities because reference or true values do not exist. . . It is not practicable to apply data quality characteristics to most scientific investigations used to support a performance assessment in which there is uncertainty in the conceptual models and the resultant ranges of parameters. Instead, controls established by the QA program provide the necessary quality. [CCA Chapter 5, p. 5-44]

This position was reiterated in supplemental information sent to EPA by DOE: "This performance assessment includes many complex, highly interactive processes which make it impracticable to work backwards from the regulatory requirement to data quality objectives." [Docket: A-93-02, Item II-I-24, p. 4] In making this argument, DOE relied upon the statement in Section 194.24(c) that the CCA must describe DQCs "to the extent practicable."

DOE's point that the performance assessment is designed to account for much greater uncertainties than those associated with data measurement, and that it does so by employing distributions for parameters whose processes and outcomes are understood incompletely, is completely irrelevant to compliance with Section 194.22(c). EPA required DOE to address data quality characteristics in the CCA in order to establish a level of confidence in DOE's measured data -- whether such data are used to support parameters, waste characterization assumptions, or baseline environmental conditions at the WIPP site. Assessing DQCs for waste characterization and monitoring is discussed below.

EPA added the words "to the extent practicable" to the final criterion directly in response to comments from DOE and others that DQC requirements should not be applied retroactively or to the assessment of a heterogeneous natural system's performance over 10,000 years: "EPA recognizes that the evaluation of some data quality characteristics is difficult to apply to 'old data' or. . . over a 10,000-year regulatory time frame. Thus, EPA has stated in the final rule that such documentation of these characteristics must be provided to the extent practicable, and has also clarified that all data must be qualified with a rigor that is commensurate with the intended use of the data in any compliance demonstration." [Response to Comments Document for 40 CFR Part 194, p. 4-8, Docket A-92-56, V-C-1] In other words, EPA acknowledged that it would not be reasonable to expect DOE to develop documentation of DQCs long after data had been collected and used, or to attempt to apply DQCs to uncertain parameters. Nevertheless, EPA still expected that DOE would at least attempt to appear to demonstrate that data serving an important function relative to compliance in any area have been or will be subjected to rigorous review against objective standards.

As stated in CARD 22 -- Quality Assurance, "EPA did not find that DOE had documented its assessment of DQCs or adequately justified why such assessment was impracticable in all cases." [CARD 22, Section 22.K.5] Neither Chapter 5 of the CCA nor the supplementary information stated explicitly which data DOE considered eligible for assessment or described how DQCs were evaluated for those data. DOE also did not specify the data for which assessment of DQCs was considered impracticable.

DOE stated in a case study submitted to EPA, "To establish compliance-based DQOs [i.e., Data Quality Objectives, against which data may be assessed for DQCs] for the WIPP PA, one would need to start with the compliance calculation and work backwards to the DQCs for the individual data sets used in the WIPP PA. . . [O]ne would start with the calculated [CCDF] which integrates the results of many coupled process calculations, and then attempt to untangle the impact of an individual data characteristic on that integrated result." [Docket: A-93-02, Item II-I-52, p. 2] While EPA accepts that in some cases the conditions of compliance with the disposal standards may be used to set data quality objectives that serve as performance measures for data, the purpose of assessing data for DQCs generally is to build confidence in the outcome by establishing that the inputs themselves are reliable. In this respect, assessment of data for DQCs is a process that should be contiguous with data development, approval, and use.

DOE observed, however, that data quality received considerable attention from peer reviewers and Independent Review Teams assembled by DOE, and was subject to NQA requirements as specified in the QAPD. [Docket: A-93-02, Item II-I-24, p. 5] DOE was obliged to comply with Section 194.22(a), which requires DOE to implement NQA-3-1989 in its quality assurance program. NQA-3-1989 states, "Planning shall establish provisions for data quality evaluation to assure data generated are valid, comparable, complete, representative, and of known precision and accuracy." [NQA-3-1989, p. 11] This requirement was satisfactorily incorporated in Section 5 of the QAPD, which is the quality assurance "master" document that establishes QA requirements for all activities overseen by the DOE Carlsbad Area Office (the QAPD constitutes Appendix QAPD of the CCA). EPA determined by means of audits that DOE adequately implemented the requirements of the QAPD [CARD 22, Section 22.A.6], and also determined that DOE adequately qualified existing data in accordance with Section 194.22(b). [CARD 22, Section 22.J.5] Therefore, EPA believes that DOE's data qualification was sufficiently rigorous to account for the DQCs identified in the Compliance criteria. As stated in CARD 22 , "EPA agrees with DOE that data that were adequately qualified may be considered to have been assessed for data quality characteristics and found acceptable to support the CCA." [CARD 22, Section 22.K.5]

In addition to accepting DOE's qualification of existing data, EPA independently examined whether DOE records revealed the extent to which data supporting parameter development had been assessed for the DQCs identified in Section 194.22(c). The Agency sought evidence that DOE had evaluated the acceptability of parameter data prior to employing them in the performance assessment (e.g., were data that were used to represent a geological feature of the disposal system assessed for their representativeness?). EPA reviewed data record packages, laboratory notebooks, and other documents and found that newer data (less than ten years old) were supported by a great deal of documentation related to DQCs. EPA also found that documentation for older data (more than ten years old) was less voluminous but still adequate to give the Agency confidence that DOE had considered DQCs. Specific parameters for which EPA reviewed the underlying data are identified in CARD 22, Section 22.K.5. EPA did not, as the commenter suggests, "assess" DQCs for DOE parameters. First, DQCs apply not to parameters, but to the data that support those parameters. Second, this assessment was conducted by DOE and its contractors -- not by EPA -- as data were developed and approved for use in the PA. EPA took advantage of its access to parameter records to determine whether DOE could in fact show that various data quality characteristics had been considered.

In summary, EPA based its compliance determination for Section 194.22(c) on the following conclusions: (1) DOE's quality assurance program adequately incorporates procedures that account for the acceptability and use of data; and (2) Given the Agency's independent consideration of parameter development in particular, DOE satisfactorily demonstrated in its documentation that DQCs had been applied in the manner that EPA intended. With respect to the second and fourth points identified above, the commenter has not demonstrated to EPA why this approach is less than sufficient to illustrate DOE's compliance with the requirement.

With reference to the commenter's third point, EPA agrees with the commenter that Chapter 5 of the CCA says that DQCs apply to waste characterization and monitoring data but does not elaborate on this statement. Specifically, Chapter 5 of the CCA contains the following statement:

> DOE believes that. . . data quality characteristics are applicable to tasks involving the quantification through sampling and analysis of specific constituents in an environmental medium. DOE also believes that these requirements are intended to address activities such as the determination of the presence or absence of pollutants in waste streams. Waste characterization and environmental monitoring are examples of the types of activities at the WIPP in which data quality characteristics apply. In these cases, the performance measurement is the concentration of the constituent of interest. [Chapter 5, pp. 5-43 to 5-44]

DOE further stated in supplementary information that "DQOs and DQCs were assessed for waste characterization and environmental monitoring data, and can be provided if desired; however, these data were not necessary to support performance assessment." [Docket: A-93-02, Item II-A-24, p. 3] Although the supplement made reference to documentation of DQCs for waste characterization and environmental monitoring data, DOE did not submit any additional documentation on those topics.

Section 194.22(c) requires that DOE apply DQCs to "all data used to support the compliance application," not just to data used to support the performance assessment. Again, the purpose of this requirement is to establish that data are reliable because they have been subjected to controls over their acceptability, as represented by DQCs. EPA believes that it is important that DOE assess any measured data for DQCs, if such data will be used to demonstrate the WIPP's compliance with the Compliance criteria. For example, DOE should be able to show that enough useful data will result from waste drum sampling to draw conclusions about the contents of the waste stream that originated the drum (data completeness). Also, DOE should be able to show that measurements of groundwater flow around the disposal system will be checked against baseline values (data accuracy).

Although the CCA lacked an explicit discussion of the subject in Chapter 5, EPA is satisfied that DOE has controls in place to control the quality of data related to both waste characterization and monitoring. In the case of waste characterization, the QAPP [CAO-94-1010] describes controls that will enable generator sites to demonstrate an acceptable level of assurance in the quality of their data. Specifically, the QAPP identifies data quality objectives for each type of measurement data. In order to verify that data meet the data quality objectives, generator sites must consider the salient characteristics of those data -- i.e., precision, accuracy, representativeness, comparability, and completeness (PARCC). Section 1 of the QAPP describes the general data quality requirements for waste characterization activities at all generator sites. Data quality objectives for the crucial measurement technologies in waste characterization, nondestructive assay and radiography, are documented in Sections 9 and 10 of the QAPP. DOE adopted these objectives in accordance with EPA guidance on data acquisition. [QAPP, p. 31] As identified in Condition #3 of the certification, EPA intends to monitor generator sites' conformance with the QAPP.

In the case of monitoring, EPA reviewed monitoring plans that DOE submitted in the CCA and found that these plans explicitly incorporated data quality characteristics in the data quality objectives for measurements. DOE will monitor certain parameters at the WIPP site during the pre- and post-closure periods, in accordance with Section 194.42. The parameters to be monitored are described in Section 42.C.4 of CARD 42 -- Monitoring. The monitoring plans included in the CCA and reviewed by EPA with respect to DQCs are Appendices VCMP (volatile organic compounds), GWMP (groundwater), SMP (subsidence), and GTMP (geotechnical). On the basis of the data quality objectives identified in these documents, EPA found that DOE has sufficiently accounted for DQCs in the area of monitoring.

Issue E: Certification of LANL

1. Section 194.22 --- Was EPA aware that individuals who purportedly certified adherence to QA at LANL were not present at the activity in question? (4)

<u>Response to Comment 4.E.1:</u>

It is not clear what "activity" the commenter refers to. EPA's Office of Radiation and Indoor Air (ORIA) conducted inspections of the audits conducted by DOE of LANL's quality assurance program. EPA's inspections of DOE's audits of LANL were performed May 12, August 18-20, and September 10-11, 1997. The purpose of the EPA inspections was to verify the appropriate execution of the requirements of 40 CFR 194.22(a), which addresses quality assurance for activities associated with the WIPP. These inspections also served to verify appropriate execution of the requirements of 40 CFR 194.22(2)(I), which addresses the quality assurance program associated with waste characterization activities and assumptions.

The EPA inspection teams always consisted of one representative of EPA and at least one ORIA support contractor person. The EPA individuals were responsible for recommending EPA approval of the QA program at LANL.

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2. I have concern about the manual entry of data and I have a concern that EPA has not been as careful as it needs to be about the quality assurance supervisory checks, and I submitted a document that shows that at least by 1996, we had LANL using -- assigning people to one task, which was different from the one they were checking and they were signing off on procedures which they were not assigned to. (504)

<u>Response to Comment 4.E.2:</u>

NQA-1 Element #1, titled <u>Organization</u>, requires that "checkers" be independent of the "doers." The Agency verified that this requirement has been properly executed at LANL. Specifically, EPA verified that persons responsible for verifying that activities affecting quality have been correctly performed must have sufficient authority, access to work areas, and organizational freedom to: (a) identify quality problems; (b) initiate, recommend, or provide solutions to quality problems through designated channels; (c) verify implementation of solutions; and (d) assure that further processing, delivery, installation, or use is controlled until proper disposition of a nonconformance, deficiency, or unsatisfactory condition has occurred. [NQA-1, Basic Requirement 1: Organization] Therefore, EPA has verified that the "checkers" have sufficient authority and independence to examine the issue that LANL personnel who are assigned to verify a particular task are actually verifying that task.

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3. Page 5-4, line 14-16 -- The first three sites to ship waste to WIPP will be INEEL, Rocky Flats, and LANL. The three CAO formal assessments of waste characterization QA at these sites previous to CCA publication found that at INEEL (August 1995; INEL at the time), that ANL-W QA was inadequate; at Rocky Flats (September 1995), that the program was marginal; at LANL

(August 1996), that software QA had only just begun. LANL waste characterization has not yet been formally audited by CAO to the NQA standards, though several surveillance type activities have taken place. None of these would qualify as a demonstration that a QA program adhering to the requirements of the NQA standards had been established and executed for waste characterization activities and assumptions. (753)

Response to Comment 4.E.3:

Section 194.22 (a)(1) requires that DOE shall adhere to a program that implements the requirements of NQA-1, NQA-2, part 2.7 and NQA-3 after April 9, 1996. Therefore, EPA did not require QA programs to be established before April 9, 1996.

Section 194.22(a)(2)(i) requires that the requisite QA program be "established and executed" for waste characterization activities and assumptions. In the certification decision, EPA has certified that a compliant quality assurance program for waste characterization activities and assumptions has been established and executed at LANL. However, EPA has not certified the establishment and execution of quality assurance programs for waste characterization activities and assumptions for any other waste generator site. Therefore, the certification is conditioned on each waste generator site demonstrating compliance with Section 194.22(a)(2)(i) prior to such site shipping any transuranic waste for emplacement at WIPP. For additional information, refer to Condition 2 of the certification.

Issue F: Qualification of waste characterization data

1. Section 194.22(d) -- Criterion was met only for SNL activities; qualifications of shipping waste characterization data, or WID programs are not described. (57)

2. Section 194.22(d) -- Criteria was met only for SNL activities, which do not include other processes and organizations for waste characterization at generator sites, or WID's environmental monitoring program. Audits of processes do not demonstrate how data as been qualified for use. (102)

Response to Comments 4.F.1 and 4.F.2:

Qualifying the waste to be shipped to WIPP ("shipping waste characterization data") will occur once DOE determined that the waste is ready to be shipped. Information about the waste to be shipped to the WIPP (i.e., estimates of the waste) is found in the BIR; and the qualification of the BIR was verified during the February 10-12, 1997 EPA audit of the Peer Review Process. [Docket: A-93-02; Item II-A-46] A purpose of the audit was to verify that the BIR information had been properly qualified in accordance with Section 194.22(b) requirements.

WID's QA program and its procedures were audited on February 10-14, 1997. The audit assessed the adequacy and implementation of the WID quality assurance program through extensive interviews with WID staff responsible for the implementation and management of

WID's quality assurance program and its procedures. [Docket: A-93-02, Item II-A-45] [See CARD 22] The EPA audit determined that WID has properly established and executed a QA program. The monitoring of performance of the disposal system has not started, but EPA has no reason to believe that the QA process for this activity will not be similar to the QA process for existing monitoring activities. In addition, EPA will perform periodic audits or inspections of CAO audits of WID to verify proper maintenance of WID's QA program in the future. Monitoring of the performance of the disposal system and sampling and analysis activities will be implemented during the pre- and post-closure of the WIPP. EPA could not assess whether QA activities related to monitoring of the performance were properly implemented because implementation of pre-closure monitoring has not begun. However, EPA did review all QA procedures established for environmental monitoring activities and determined that the necessary QA procedures had been established to meet the requirements of Section 194.22(a)(2)(ii).

Issue G: More review of WIPP as required by Section 194.22(e)

1. Section 194.22(e) -- Criterion would seem to require more review activities and/or explanatory material in several areas. (58)

2. Section 194.22(e) -- Criterion would seem to require more review activities and/or explanatory material in several areas. (103)

Response to Comments 4.G.1 and 4.G.2:

Section 194.22(e) is applicable to EPA, and not to DOE or its WIPP contractors. EPA used audits and sampling to determine by investigation, examination, or evaluation of objective evidence at the WIPP facilities the appropriate execution of quality assurance programs. EPA conducted audits to verify the proper execution of QA programs at CAO, SNL, LANL, and WID. [Docket: A-93-02; Items II-A-43, II-A-44, II-A-45, II-A-46, II-A-47, II-A-48, II-A-49, and II-A-51] On average, each audit required 4 days and 5 auditors, or 20 person-days per audit. The audits of QA programs were performed in accordance with written checklists that are based on the NQA requirements. For example, NQA-1 basic element #16, entitled Corrective Action, begins, "Conditions adverse to quality shall be identified promptly and corrected as soon as practical." Correspondingly, EPA's audit checklist contains the following question: "Are conditions adverse to quality identified promptly and corrected as soon as practical?" The auditors reviewed the organizations' procedures to determine if this requirement had been established, and then the auditors selected random samples of WIPP reports, entitled Corrective Action Reports, to verify that this requirement had been implemented/executed. For a list of audit reports generated by EPA, see CARD 22 Section 194.22(e). Therefore, EPA has conducted sufficient review of QA activities to verify that DOE has appropriately executed all QA programs with the exception of waste characterization.

3. Section 194.22(a)(2)(viii) -- Criterion has been met. However, no evidence is presented that either the DOE or the EPA has made an attempt to identify other possibilities.(99)

Response to Comment 4.G.3:

EPA searched for other items or activities important to the containment of waste that were not included under the activities listed in Section 194.22 (a)(2). EPA did not identify other containment apparatus or activities that require the establishment and execution of QA controls beyond those discussed above. EPA found that the QA programs of CAO, SNL, WID, and LANL provide adequate coverage within their organizations to identify any other possible items and activities important to the containment of TRU waste.

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4. Page 5-1, lines 29-31 -- The overall CAO assessment of SNL QA (May 1996) and WID QA (June 1997) previous to the publishing of the CCA found the SNL program to be marginal both for adequacy implementation, and the WID program marginally effective (see CCA p. 5-39, lines 6-13 for definitions of these terms). It is the later resolution of issues raised during the assessment by which the CAO determined SNL and WID QA to be adequate and effectively implemented (see Section 5.4.2, p. 5-45, and section 5.4.3, lines 24-29). (744)

Response to Comment 4.G.4:

EPA agrees and therefore, conducted audits of the SNL and WID QA programs. The SNL QA program was audited January 13-24, 1997. The SNL audit concluded that SNL has a QA program that implemented the requirements of Section 194.22. [Docket: A-93-02, Item II-A-44] The WID QA audit was conducted February 10-14, 1997. EPA concluded WID had a QA program that implemented the requirements of Section 194.22. [Docket: A-93-02, Item II-A-45]

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5. Page 5-14, lines 24-26 -- The process utilized for controlling drilling activities in the WIPP vicinity is an important activity for containment of waste with which the DOE has had problems in the past (see the "Passive Institutional Controls" section of EEG's March 14, 1997 letter to the EPA, in the WIPP docket for a pertinent example). QA oversight of this process could enhance the WIPP disposal system. (775)

Response to Comment 4.G.5:

EPA is aware of the concern associated with the drilling activities in the vicinity of the WIPP site. Therefore, DOE was required to implement institutional controls, both active and passive. The plan for Passive Institutional Control (PICs) was peer reviewed in accordance with NUREG 1297. The peer review panel determined the PICs plan to be technically adequate. EPA has evaluated the PICs plan and determined it to be compliant with the requirements of Section 194.43 -- subject to Condition 1 of the certification.

Issue H: Positive comments

1. The WIPP level of quality assurance, and the standard of excellence in operation . . . have been substantiated as both appropriate and correct. This substantiation includes numerous peer reviews by both U.S. and international experts, and it also has been recognized, through a long list of safety and quality awards. (200)

2. The SNL/WIPP assessment program is based on nuclear quality assurance requirements. We have been very active in support of experimental activities which have been identified by the DOE Carlsbad Area Office as critical to the WIPP project. In fiscal year 1997 alone we performed 12 audits and 25 surveillances of our contractors and of SNL work. Our lead auditors are trained to manage their audit teams so that each auditor reviews assigned work activities to assure that procedures, calibration test plans, scientific notebooks, and software meet NQA standards. As assessment task leader, it's my responsibility to ensure that we use our limited resources and funding as efficiently as possible, and because of our assessment program we have a high level of confidence that we are doing the most scientifically defensible work possible in support of the WIPP project. (182)

3. DOE's QA program for WIPP ensures that participants are in full compliance with QA requirements through an aggressive assessment program. In preparation for the CCA, DOE conducted extensive assessments of the WIPP participants to ensure they met the QA requirements of 40 CFR 194 and NQA-1, -2 and -3. In addition to data quality requirements, NQA criteria include, for example: controls on documents records; personnel qualification and training; design; procedures and drawings; nonconforming items; software; procurement; tests and inspections. (208)

4. Two separate teams, one technical and one quality assurance were at the SNL offices and records center almost the entire time for the last two years. The team made up of EPA staff and contractors had tremendous experience in environmental sciences and QA and degrees in high powered fields such as nuclear engineering and law. . . These teams reviewed hundreds of thousands of records, including data packages, parameter packages and analysis packages. They verified that our staff were qualified, our brine core samples were properly collected and handled, our gauges were properly calibrated and that our procedures and plans were properly reviewed and implemented. . . EPA left no stone unturned during their review of the WIPP. (235)

<u>Response to Comments 4.H.1 through 4.H.4:</u>

EPA verified the proper execution of QA programs via EPA audits. EPA conducted an audit of SNL's quality assurance program on January 13-24, 1997. EPA's audit team determined that SNL had properly executed a quality assurance program for the WIPP. [Docket: A-93-02, Item II-A-44] A records review was conducted at SNL on April 16-18, 1997 and May 12-16, 1997. The reviewers determined that data were traceable to their qualifying source. [Docket: A-93-02, Item II-A-48] An audit of SNL's process of establishing T=0 for their subcontractors, was conducted June 2-6, 1997. [CCA, Chapter 5, p.s 5-48 through 5-52 for discussion of T=0] The audit team determined compliance with the requirements of Section 194.22(b). [Docket: A-93-02, Item II-A-49]

EPA conducted an audit of DOE's CAO quality assurance program on December 9-13, 1996. [Docket: A-93-02, Item II-A-43] The audit determined that CAO adhered to a QA program that implements the requirements of 40 CFR 194.22(a)(1), including that CAO adhered to the requirements of NQA-1 element #18, entitled Audits , and its supplement. CAO performed audits of its lower-tier organizations to enforce the flow down of the NQA requirements.

Issue I: Response to comments

1. We have expressed some quality assurance concerns in the past to EPA, and we feel these have not been adequately responded to at this time. (489)

Response to Comment 4.I.1:

Specifically worded concerns related to quality assurance have been addressed as received.

Issue J: WID QA

1. Section 194.22(a)(1) -- CAO has established a program that meets the NQA standards, but WID's -- and to some extent, CAO's penchant for showing compliance with DOE's internal QA program rather than the NQA standards could be a point of contention.(86)

Response to Comment 4.J.1:

Section 192.22(a)(1) requires that WID comply with NQA. An audit of WID conducted in February 1997 verified that the WID QA program meets the NQA requirements. [Docket: A-93-02, Item II-A-45] [See CARD 22] EPA audited DOE's CAO quality assurance program on December 9-13, 1996. [Docket: A-93-02, Item II-A-43] The audit determined that CAO adhered to a QA program that implements the requirements of 40 CFR 194.22(a)(1), including that CAO adhered to the requirements of NQA-1 element #18, entitled Audits , and its supplement.

2. Page 5-14, line 17 -- Data and information collected by WID is used throughout the CCA. Several chapters in the CCA reference the Site Environmental Reports for 1990 and 1992-1995, for example. Many of the appendices to the CCA are totally based on WID or WID subcontractor data. (774)

Response to Comment 4.J.2:

EPA agrees that WID data was used in the CCA.

Issue K: Application of NQA requirements to QA programs after April, 1996, and qualification of data prior to application of NQA programs

1. Section 194.22(a)(2)(ii) -- DOE has been conducting an EM program since 1985, and data from 1991-95 was used in the CCA; the 1997 EPA audit did not cover this data. EMP's QA section is written to address DOE's internal QA requirements, not the NQA standards, and the two are not equivalent. (88)

2. Section 194.22(a)(2)(iii) -- Subsidence and disposal room monitoring are not the primary discussion of geologic factors in the CCA. SNL was responsible for much of the work related to geologic factors used in the CCA, and much of this work was performed after 1989. Neither DOE nor EPA has presented evidence that the NQA program was established and executed or geologic factors used in the CCA. Credit for the current WID QA program does not cover data for from WID's disposal room monitoring program, for which CCA Section 7.3 indicates data from pre-1991 was used. Section 7.3 also shows that data from the WID disposal room monitoring program is used as a part of the disposal monitoring program, and as such should be a part of the Section 194.22(a)(2)(ii) demonstration for monitoring of performance of the disposal system. (91)

3. Groundwater has been measured in the WIPP vicinity for years; one study cited in the CCA (INTRAVAL WIPP2) used sixty wells, and took place before WID's QA program was found by CAO to be adequate. (92)

4. The meteorologic information on pp. 2-178 to 2-180 clearly came from WID meteorological field measurements, and other parts of Chapter 2 also use meteorological characteristics that could not be geological data. . . WID's meteorological program should be analyzed for compliance with the NQA standards from 1991 to the present. (93)

5. Section 194.22(a)(2)(vi) -- Execution of the NQA standards for the design of the disposal system has not been demonstrated by either EPA or DOE. The 1989 SER found as-built design documents were not available for the WIPP facility; though these were reconstructed, no evidence is provided that NQA standards were applied. (97)

6. Page 5-6, lines 15 and 17 -- Section 5.4.2.2 discusses in very generalized terms the Qualification of Existing Data (QED) process (for data that was not collected under an NQA program) and includes no commentary specific to measurements of topographic characteristics. Reference to this section implies that a demonstration of adherence to NQA standards for topographic characteristics as required by Section 194.22(a)(2) cannot be performed. (759)

7. Section 194.22(b) -- Recommendation: The EPA should reconsider the use of data from peer-reviewed technical journals for site characterization activities as an acceptable method under this criterion. The EPA should review the CCA for data related to the Section 194.22(a)(2) criteria that precede adherence to the NQA standards, and determine if the programs cited under this

criterion have assessed and qualified that data. The conduct of this review should be recorded in the documentation of the final rule. (1292)

Response to Comments 4.K.1 through 4.K.7:

Several comments state that QA programs should be applied to data acquired prior to April 1996. Section 194.22(a)(2) states that any compliance application shall include information which demonstrates that the quality assurance program required by paragraph (a)(1) of this section has been established and executed for the eight areas listed. Section 194.22 (a)(1) requires that DOE shall adhere to a program that implements the requirements of NQA-1, NQA-2, part 2.7 and NQA-3 after April 9, 1996. Therefore, EPA did not require QA programs to be established before April 9, 1996.

Section 194.22(b) states that data collected prior to the implementation of Section 194.22(a)(1) must be qualified by an NQA equivalent program, peer review, corroborating data, or confirmatory testing. EPA conducted audits, including representative sampling, to verify the qualification of existing data important to the containment of waste. [Docket: A-93-02; Items II-A-43, II-A-44, II-A-45, II-A-46, II-A-47, II-A-48, and II-A-49] Due to the voluminous amount of data generated for the WIPP, it would be impracticable for EPA to verify the qualification of each data point. Based on the audits, including representative sampling, the QED process was deemed to comply with the requirements of Section 194.22(b).

SNL was responsible for assuring the data used in the PA were qualified. Several audits were conducted at SNL to verify execution of the requirements established by Section 194.22. An audit conducted in January 1997 concluded that SNL has a program which implements the requirements of Section 194.22(a)(1). [Docket: A-93-02, Item II-A-44] EPA conducted an audit of the T=0 process in June 1997 [Docket: A-93-02, Item II-A-49], and an audit of the Individual Review Team (IRT) process in September 1997. [Docket: A-93-02, Item II-A-48] See CCA, Chapter 5, pp. 5-48 through 5-52 for discussion of T=0 and IRT. The audits consisted of reviewing QED procedures for technical adequacy; and taking representative samples of the process to ensure implementation of the procedure. All audits of the QED process concluded that the an adequate process for qualifying existing data has been established and executed.

EPA conducted an audit of the Peer Review process in February 1997. [Docket: A-93-02, Item II-A-46] The audit team evaluated six peer reviews for compliance with the requirements of Sections 194.22(b), 194.27, and NUREG 1297. The audit results concluded the peer review process had been conducted in a manner that adhered to the requirements of the rule.

Section 194.22(a)(2)(ii) states that a quality assurance program will be established and executed for environmental monitoring, monitoring of the performance of the disposal system, and sampling and analysis activities. The disposal system is currently not in use. Therefore, environmental monitoring, monitoring of the performance of the disposal system, and sampling and analysis activities are not necessary at this time. Any environmental monitoring data generated prior to use of the disposal system will not be evaluated for compliance with the requirement. Baseline environmental values have not been selected. EPA will ensure that the data selected for comparison have been appropriately qualified.

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8. The WID WQSP program in operation since 1994 meets exactly the definition for 3 of the 11 operations cited in Appendix MON, Table 2 as the proposed disposal system performance monitoring program, and the results are reported in WID Annual Site Environmental Reports. EPA could assess this program and its data to demonstrate that this criterion has been met. (89)

Response to Comment 4.K.8:

The reference to Appendix MON, Table 2 for the Water Quality Sampling Program (WQSP) is misplaced. Appendix MON, Table 2 defines nine types of instrumentation used to support the geomechanical monitoring system, not water quality. The WQSP was not included in the QA audit because EPA examined whether or not the WID had a QA program in place according to the NQA requirements, and this QA program would qualify the WQSP which involves future monitoring. Moreover, the WQSP is intended to be used for RCRA monitoring.

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9. The sampling and analysis parameter was included in the environmental and disposal monitoring requirement to indicate that these were the areas of interest; WC and PA are not applicable evidence for these activities. DOE has performed both environmental and disposal monitoring, and QA on the sampling and analysis performed should be examined for compliance with the NQA standards. (90)

Response to Comment 4.K.9:

Sampling and analysis for waste characterization has not yet begun for the waste generator sites, but LANL was found to have a proper QA program. For future waste characterization, before any waste is shipped, EPA will verify the QA program for that waste generator site. The PA samples were qualified by peer reviews. For environmental and disposal system monitoring, monitoring of performance of the disposal system has not started, but EPA has no reason to believe that the QA process for this activity will not be similar to the QA process for existing monitoring activities. In addition, EPA will perform periodic audits, or inspections of CAO audits, of WID to verify proper maintenance of WID's QA program in the future. Monitoring of the performance of the disposal system and sampling and analysis activities will be implemented during the pre- and post-closure of the WIPP. EPA could not assess whether QA activities related to monitoring of the performance were properly implemented because implementation of pre-closure monitoring has not begun. However, EPA did review all QA procedures established for environmental monitoring activities to determine that the necessary QA procedures had been established to meet the requirements of Section 194.22(a)(2)(ii).

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10. No evidence is presented by either DOE or EPA to show that QED covered measurements of topography. Neither the IRT reviews shown in CCA Table 5-5 nor any of the peer review panel reports addressed topographic information. Topographic information required by Section 194.14(2)(h) was gathered in August of 1996 according to CCA Appendix DEL, Figure DEL-6; QA for this data should not have been part of the QED process. (94)

Response to Comment 4.K.10:

EPA agrees with the commenter in that DOE did not provide information in the CCA to show that measurements of topography had been qualified. However, the comment cites the CCA Appendix DEL [Figure DEL-6] for the lack of QA data through QED. Figure DEL-6 derives from comprehensive information found at the New Mexico Oil Conservation Division (NMOCD). This information was qualified by SNL Procedure 20-3, Section 3.11 which defines "existing data" as: Data developed prior to the implementation of a DOE approved NQA-1, 2.7, 3 QA program by SNL and its contractors, or data developed outside the SNL-WIPP program, such as by oil companies, national laboratories, universities, or data published in technical or scientific publications. Existing data does not include information that is accepted by the scientific and engineering community as established facts (e.g., engineering handbooks, density tables, gravitational laws, etc.)" [Definition derived from NUREG 1298 definition] EPA finds that this information was qualified through QED because it is data based on comprehensive well records on file at the NMOCD.

11. Section 194.22(a)(2)(vii) -- SNL used data in CCA which was not collected or analyzed by the DOE -- Chapter 2, for example, makes extensive use of USGS data. Neither the DOE or EPA documents indicate this data was assessed in terms of the NQA standards, or that NQA-3 paragraph 3.2 was addressed for this data, or even that the planning required by NQA-3 paragraph 2.1 for site characterization was established and executed. (98)

Response to Comment 4.K.11:

U.S. Geological Survey (USGS) data were qualified through the QED process as defined by SNL Procedure 20-3, Section 3.11 (and NUREG 1298) cited in the Response to Comment 94. Existing data, as defined above, include data published in technical or scientific publications. Therefore, EPA finds that the USGS data used in the CCA [Chapter 2] were qualified because the data were published in technical or scientific publications.

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12. Page 5-6, lines 6-13 -- The argument is ludicrous in a document written to show compliance with 40 CFR 194. A large part of site characterization data included in the CCA has been performed since 1989; the NMVP is concerned with disposal of chemical wastes, not the radiological component that is the Section 194 concern, and the major concern at WIPP (plutonium is not on the list of 40 CFR 268 hazardous components); QA approaches and

philosophies have changed in the intervening years; the regulation to be complied with is different for the CCA (40 CFR 191 and 194) than it was for the NMVP (40 CFR 268); and a demonstration of establishment and execution of a QA program that adheres to the NQA standards was not a requirement for the 1989 NMVP. (758)

Response to Comment 4.K.12:

P. 5-6, lines 6-13 of the CCA discusses data collected by DOE during site selection and the site characterization program. The section does not mention the No Migration Variance Petition (NMVP); therefore, EPA is unsure about the question being asked.

Section 194.22 requires DOE to implement a QA program that adheres to the requirement of NQA, as soon as practicable after April 1996. All data used in the CCA and important to the containment of waste were qualified in accordance with the requirements of Section 194.22(b). EPA conducted numerous verification activities the ensure that DOE complied with all of the requirements of Section 194.22. All of the verification activities are documented and available in Air Docket No. A-93-02.

13. Section 194.22(a)(2)(ii) -- Recommendation: NQA- 1 requires periodic assessment of programs by QA organizations, and the WID Environmental Monitoring Program has been in operation since 1985. The CAO, or the WID, QA departments should have assessed the program by now to ensure that NQA-1 requirements had been properly addressed in the program (that the program is adequate), and that the documentation from the program meets these requirements (that it has been effectively implemented). EPA should review reports from these assessments and cite them in the documentation of the final rule as a demonstration of establishment and execution of the NQA standards for environmental monitoring.

The CAO or the WID should also have assessed the WQSP (or the entire Groundwater Monitoring Program), and the Geotechnical Analysis Program. The EPA should review these reports, and cite them as a part of the demonstration of establishment and execution of the NQA standards for this criterion.

Sampling is an integral part of these programs, as are some analysis activities. However, the WQSP samples have been sent to contract laboratories for analysis, and radionuclide determinations from the Environmental Monitoring Program samples have also been performed by contract labs. The EPA should verify that contracts for these analyses include the proper QA requirements. (1286)

Response to Comment 4.K.13:

The Agency assumes that this comment provides three different recommendations. First, EPA should review previous assessments of the EMP; second, EPA should review the assessments of the WQSP; and third, EPA should verify that QA requirements were implemented for the laboratories analyzing the sample collected for the EMP and WQSP.

First, Section 194.22 (a)(1) requires the implementation of a QA program which adheres to the requirements of NQA as soon as practicable **after April 9, 1996**. Therefore, EPA's evaluation of assessments conducted prior to April 1996 are not required.

Second, WQSP has not been evaluated because EPA examined whether or not the WID had a QA program in place according to the NQA requirements, and this QA program would qualify the WQSP which involves future monitoring. Moreover, the WQSP is intended to be used for RCRA monitoring.

Third, EPA's audit of WID [Docket: A-93-02, Item II-A-45] included an evaluation of procurement [NQA-1, Req. 4], and control of purchased items and services. [NQA-1, Req.7] A random sample of contracts were reviewed to ensure that QA requirements were included in the contracts for purchase of items important to the containment of waste. The audit results did not identify any findings associated with procurement.

Issue L: Verification of computer programs

1. Section 194.22(a)(2)(iv) -- Computer programs at most generator sites haven't been checked by either DOE or EPA. Adequate passing down of requirements is not a demonstration of execution of the program. (95)

Response to Comment 4.L.1:

In the certification decision, EPA has certified that a compliant quality assurance program for waste characterization activities and assumptions has been established and executed at only one waste generator site, LANL. EPA has not certified the establishment and execution of quality assurance programs for waste characterization activities and assumptions for any other waste generator site. Therefore, the certification is conditioned on each waste generator site demonstrating compliance with Section 194.22(a)(2)(i) prior to such site shipping any transuranic waste for emplacement at WIPP. For additional information, refer to Condition 2 of the certification. EPA will audit, or inspect CAO audits of, all DOE sites to verify that the computer software is in accordance with NQA 2.7 requirements.

Computer programs used for waste characterization activities are reviewed at each site prior to that site shipping waste. This review includes both technical and quality assurance requirements. The review ensures that each program falling under the EPA purview is capable of performing its intended function, is properly used, and is controlled under all applicable quality assurance requirements. Since many generator sites use unique software for performing waste characterization, these programs must be reviewed individually at each site. The continual improvement and upgrading to both hardware systems and analytical software in the waste characterization program requires that reviews be performed when the site is close to implementing their waste characterization program. Accordingly, EPA performs inspections and audits at the generator sites in a timely manner, rather than attempting to review all computer programs prior to determining which waste characterization methods will be used. This schedule does not remove the requirement for the generator sites to have effective software QA programs, but only delays the verification of the software QA program until such time as the list of applicable software can be defined.

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2. Section 5.3.20 is a general description of computer software QA for the WIPP. It does not address computations (which are not always performed on a computer) and does not demonstrate the establishment and execution of a QA program which adheres to the requirements of the NQA standards for computer codes. It also does not describe the process for controlling the most important of computer codes for the CCA, those related to the PA. (763)

Response to Comment 4.L.2:

The quality assurance requirements for software provided in the CCA describe the basic framework for the WIPP software quality assurance program. This program, by definition, is only applicable to calculations and data manipulations performed on computing machines. The program includes not just large, formal computer programs, but also items such as spreadsheet calculations, databases, on-line forms, and other data formatting and manipulating routines. Computations performed by hand, or using devices such as hand calculators, are not subject to software quality assurance requirements, but rather are controlled by other quality assurance procedures. Individual software QA programs at CAO, SNL, WID, and the various generator sites are verified to be in compliance with NQA standards via audits. EPA has been aware that on-site audits are a much more effective method for verifying compliance with the NQA standards for software than is reviewing a description of the software QA program provided in the CCA, since the on-site audit includes implementation as well as programmatic reviews. The on-site audit of SNL performed by EPA in January 1997 included software quality assurance as applied to the codes used in the WIPP performance assessment. [Docket: A-93-02, Item II-A-44] This audit verified that SNL had implemented a software quality assurance system which met the requirements of NQA-2 Part 2.7 as required by 40 CFR 194.22.

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3. Page 5-7, lines 11-16 – The statement implies that all software supporting compliance is to be found in Table 5-1 (which lists only SNL's PA-related software). Other software (data acquisition, WWIS, facility design, NDA) are discussed later in this section (p. 5-9, lines 14-20), but these are not identified in Table 5-1, which is entitled "Computer Software and Codes." (764)

Response to Comment 4.L.3:

EPA agrees that Table 5-1 is not a complete list of all software programs that must be controlled under NQA-2 Part 2.7 as part of the WIPP project. EPA understands that a complete list of all codes and ancillary programs related to the WIPP project from all organizations and generator sites would be difficult to produce for the CCA, since the applicable programs are constantly changing. The audits and inspections performed by EPA at each organization are designed to determine if the organizations have identified the programs falling under the NQA software QA requirements, and whether or not the organizations are properly implementing their software quality assurance programs. This system does not allow those programs that are missing from Table 5-1 to escape the requirements of NQA 2.7, but rather ensures that the latest set of computer programs is being controlled by each organization. An example of this is the LANL certification inspection performed in August of 1997. The software QA review included programs, such as PC-FRAM, that were not on any list of WIPP QA software at the time the CCA was written.

4. Page 5-7, Lines 19-37 – QAP 9-2 requires, among other things, that the need and intended use of a parameter be documented; that the rationale for the parameter be documented; and that documentation of the parameter development be referenced or attached to the Form 464 (which is a form essential to tracing of parameters). These requirements are unique to QAP 9-2, and should be required of all parameters used. Assuming that the PA is considered a scientific investigation, the CAO QAPD Rev. 1 would seem to require use of QAP 9-2 for all but the excluded type 4b parameters under the dictates of section 5.1.B, 5.1.C, 5.1.D, 5.1.E, and 5.1.H (other sections may also apply). (765)

Response to Comment 4.L.4:

The QAP 9-2 requirement, and the CAO QAPD section 5.1 requirements, for data to be qualified according to its intended use, stem from NQA-3. The intent of the NQA-3 requirement is to ensure that data or parameters used in scientific analysis, and as input to computer models, be traceable as to source and qualified for use. Traceability provides an audit trail for the data, and ensures that data can be updated and managed without loss of continuity. Qualification provides assurance that the data or parameters have been reviewed for suitability. QAP 9-2 was not intended originally to require form 464 for each parameter, as legacy and placeholder parameters were originally not included under QAP 9-2. SNL has subsequently included form 464 sheets with each parameter in the PA database to improve traceability and enhance parameter management. The sample of parameters reviewed by EPA all had form 464 sheets, which significantly enhanced tracing the data sources for the parameter as well as the qualification method for that parameter. Thus, the parameters in the PA database now are documented for use, source, and qualification method, which meets the NQA-3 requirement.

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5. Finally, it seems useful to note that parameter data in the CCA (in Appendix PAR) is not necessarily the same values as was used in the running of the PA codes for the CCA. For example, Parameter # 3148, a concrete compressibility parameter, is listed in Appendix PAR as having a value of 1.2e-p/Pa, but is shown in the code listings for the CCA (not in the CCA; at SNL) as 2.64e-9/Pa. This difference is apparently due to Appendix PAR being taken from a later

database than the one used by the PA codes for the CCA. The information and data in the CCA should be the same data that was used to demonstrate compliance. (766)

Response to Comment 4.L.5:

EPA agrees and is aware that some differences exist between the listings in Appendix PAR and the parameter database. The COMP_RCK parameter used as an example here was found to be different during the EPA audit of SNL in January 1997 [Docket: A-93-02, Item II-A-44], and led to some further sampling of parameters for review during subsequent visits to SNL. DOE has supplied documentation of parameters that have differences between the Appendix PAR value and the value used in the CCA. The documentation of all changes is found in Form 464 located in the SNL WIPP Central Files.

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6. Page 5-7, line 39, to page 5-9, line 32 – No explanation as to the definition of "screening efforts" is supplied, and the terminology is rather obscure. The calculations and reasoned arguments are used to determine whether or not to include consideration of a feature, event, and process (FEP) in a model, but this is not explained in the text. The connection between screening efforts and the requirements of 40 CFR 194.22 or the NQA standards is not made clear in this section. As with the parameter categorizations, this is not a QA description but a description of an operational process. No screening efforts other than those for FEPs are identified. (767)

Response to Comment 4.L.6:

The description of the FEP screening process, including those FEPs that were considered and their status, is included in Appendix SCR. The FEP screening process determines which FEPs will be included in the repository models, and as such can be considered as a quality assurance-related activity subject to the requirements of 40 CFR 194.22. The description of the FEP process in CCA Chapter 5 mentions that the process was controlled under QAP 9-1, which brings the FEP process under the control of the quality assurance program. As expected for a chapter on quality assurance, CCA Chapter 5 mentions the control of the FEP process via QAP 9-1, and briefly describes the general method used in the FEP screening. The general description of the FEP screening method indirectly provides the link to 40 CFR 194.22 by indicating that the process was used to determine computations, computer codes, models and methods. [Section 194.22(a)(2)(iv)] It thus was required to be controlled under an appropriate Quality Assurance Procedure, and that procedure was required to be in conformance with the Quality Assurance Program requirements derived originally from 40 CFR 194.22 and passed down via the CAO QAPD.

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7. Page 5-10, lines 20-23 – This document was replaced by WP16-IT3117, Revision 0, which has the same title, on 9/26/96 (a month before publication of the CCA) (768)

Response to Comment 4.L.7:

The commenter is correct. EPA is aware that some documents have been revised or superseded since the various chapters of the CCA were authored. By imposing the NQA standards for document control and record keeping on the WIPP activities, EPA has effectively required that documents referenced or mentioned in the CCA, or in any other QA documents, be traceable forward to the current applicable document. The document in question here, WP 16-117, can be traced forward to the current document, WP 16-IT3117, via the WID Index to Controlled Documents, which is part of the NQA compliant record system used by WID.

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8. Page 5-37, lines 8-9 - No specific mention is made of software problem reports or other resolution mechanisms in section 5.3.20; the closest statement is (p 5-41 lines 25-26) "For released versions, software problems are documented, evaluated and, if appropriate, corrected." This seems far short of the "discussion" indicated. (789)

Response to Comment 4.L.8:

EPA agrees that section 5.3.20 of the CCA provides minimal detail as to the methods used by the various WIPP program participants for software problem reporting. The description of software quality assurance in section 5.3.20 of the CCA is taken directly from NQA-2 Part 2.7, and describes the general requirements for software quality assurance applicable to all WIPP program participants. The paragraph mentioned here, P 5-41, lines 25-26, continues beyond the statement quoted in the comment to state that "Evaluation of software problems includes the impact on previous use and any appropriate corrective action. Problems that significantly impact decisions based upon prior use or that require significant modification to the software are identified. Errors that qualify as a condition adverse to quality are controlled as described in Section 5.3.17." This describes the important requirements of any software problem reporting system; that the impact of errors or bugs discovered in software are evaluated for their potential effect on any previous runs of the program, and the impact of those effects on any decisions made based on those program runs are evaluated. The actual procedural method for implementing a problem reporting system varies widely between organizations. The EPA audit program for software quality assurance includes checks of the problem reporting system at each of the WIPP program participants to ensure that it includes the above requirements.

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9. Page 5-37, lines 9-10 -- The difference between a minor software problem, which may or may not be corrected, a condition adverse to quality in software, for which the corrective action process must be followed, is not explained. The term "condition adverse to quality" is not defined, though "significant conditions adverse to quality" is. (790)

Response to Comment 4.L.9:

Minor and major software problems are specifically defined by each organization in their software quality assurance program. Minor software problems are generally restricted to those with no impact upon the computationally important results of the program or on the program's ability to execute, such as output formatting, ancillary result reporting, header/footer settings, etc. At SNL, QAP 19-1 contains definitions for minor software problems as opposed to major software problems. These definitions were reviewed by EPA and found to be acceptable within the bounds of the SNL software QA program. The terms "condition adverse to quality" and "significant condition adverse to quality" are defined in CAO QAPD section 1.3.2.1, and have the same meaning for software applications as for other applications.

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10. Page 5-40, lines 10-12 – This description (however it may be interpreted) falls short of describing the necessary requirements phase documentation specified by NQA-2 Part 2.7 sections 3.1 and 6.2. (794)

Response to Comment 4.L.10:

EPA agrees that the section in question does not provide a full description of a software requirements phase document. Section 5.3.20 does state that all software will be placed under controls meeting the CAO QAPD, which requires that all controlled software meet the documentation requirements of NQA-2 Part 2.7. The requirements phase documentation for controlled software is available at the respective WIPP program participant sites, and the content of the documentation is determined by applicable site controlling procedures. In the case of SNL, QAP 19-1 defines Requirements Documents to include functionality, performance, design constraints, attributes, and external interfaces. Determining the presence and completeness of all necessary documentation for controlled software is part of the EPA software QA audit program.

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11. Page 5-40, lines 15-17 – NQA-2 Part 2.7 Section 10.1 states that not only will the supplier report software errors or failures to the purchaser, but "the purchaser shall report software errors to the supplier." No mention of determination of applicability by the purchaser is to be found in NQA-2 Part 2.7 – the reporting of software errors and failures to the supplier must always be performed. (795)

Response to Comment 4.L.11:

The CAO QAPD is the controlling document for software quality assurance and, as such, requires in section 6.9 that all affected organizations be notified of software errors. The list of affected organizations includes the software supplier. The term "if applicable" in the CCA is interpreted to differentiate software which was internally developed from software which was externally supplied. This does not change the actual QA requirement for suppliers to be notified of software errors since this requirement flows down from the CAO QAPD. The audits of SNL and other WIPP program participants by EPA to this date have observed that the notification requirement is properly flowing down to the implementing procedures.

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12. Section 194.22(a)(2)(iv) -- Recommendation: The EPA documentation should be more specific in its descriptions of EPA auditing activities for software. A demonstration of execution (an assessment) of the NQA standards for NDA at LANL, the WWIS, and the WID database system(s) should be cited in the documentation for this criterion. The documentation should also reference the DOE's audits the PA process, and of the PA software, as demonstrations of execution of the NQA standards for these computer codes and models. (1288)

Response to Comment 4.L.12:

The reports for each audit conducted by EPA include the criteria against which software were evaluated. These criteria include the checklists used in the audit, the documents reviewed, and any findings developed in the software topic. The checklists used in the software QA evaluations are developed from the requirements in NQA-2 Part 2.7. These software requirements are applied to all sites in the WIPP project, including generator sites. Documentation of how EPA evaluated software QA as applied to the PA codes is included in SNL audit report. [Docket Number A-93-02, Item II-A-44] Similarly, the application of QA requirements to the WWIS was reviewed at the WID audit. [Docket Number A-93-02, Item II-A-45] Application of NQA software standards to NDA software will be evaluated at each site during the certification audits for that site.

Issue M: Expert judgment (EJ)

1. Section 194.22(a)(2)(v) -- Criterion met for waste particle size expert judgment. There are other activities, however, which may or may not be "expert judgment" which are not addressed. (96)

Response to Comment 4.M.1:

All identified EJ elicitation has been reviewed, and the only EJ was for particle size. Refer to the responses to comments on Section 26, Expert Judgment for additional discussion of this issue.

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2. Section 194.22(a)(2)(v) -- Recommendation: The EPA should consider whether the Trauth, et al. report is an expert judgment elicitation, and whether other expert judgment elicitations are utilized in the CCA and analyze the QA applied to any that meet the criteria. (1289)

Response to Comment 4.M.2:

The Trauth report was part of the expert judgment elicitation conducted in May 1997. All identified EJ elicitation has been reviewed, and the only EJ was for particle size. See the response to Issue M and the Expert Elicitation Audit Report. [Docket: A-93-02, Item II-A-47]

Issue N: Clarification of the CCA

1. To state that, "the TWBIR was prepared in compliance with the CAO QAPD" (p. 5-3) implies that the data from the TWBIR used in the CCA (first published in December 1995) was prepared according to the requirements in Revision 1. It wasn't, and the distinction should have been clearly made. . . Versions of the WAC and TRU QAPP current at the time the CCA was submitted were written under Revision 0; the NDA (Non-Destructive Assay) software is, of course, currently controlled under Revision 1, but any NDA data used in the CCA would clearly predate the issuance of Revision 1. (738)

Response to Comment 4.N.1:

EPA finds that the CCA could have been written more clearly to identify the exact version of the QAPD that was applied to the Transuranic Waste Baseline Inventory Report (TWBIR).

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2. Page 5-1, lines 17-18 -- Table 1-5 lists only Appendices QAPP and ALJD, but other appendices are referenced in Chapter 5 (MON, p. 5-5 line 38; EMP, p. 5-6 line 20; SEAL, p. 5-12 line 24). These additional appendices should have been included in Table 1-5. (743)

Response to Comment 4.N.2:

The additional appendices mentioned in the comment (MON and EMP) do not necessarily support Chapter 5. Only Appendices QAPP and AUD (no Appendix ALJD exists) support Chapter 5. Therefore, Table 1-5 is correct in listing only the QAPP and AUD.

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3. Page 5-3, lines 38-39 -- The referenced sections are brief generalized statements which include no specific discussion of waste characterization data from the TWBIR. (751)

Response to Comment 4.N.3:

Chapter 4 of the CCA provides a detailed discussion of the TWBIR. The TWBIR is included in the CCA as Appendix BIR. Quality Assurance activities associated with waste characterization are discussed in Section 4.3.3 and Section 4.4, pp. 4-39 to 4-49.

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4. Page 5-4, lines 25-42 -- The list of documents does not include some that would seem to be applicable. For instance, documentation used in design of the TWBIR (which should have addressed QA), the TRU Waste Characterization QAPP, the WWIS Software Quality Assurance Plan, and Performance Demonstration Program documentation should be listed, as these activities are all mentioned in the preceding text. The "examples of subcontractors for the principal participants" does not include the subcontractor that assembled the TWBIR, which is the principal waste characterization activity that had taken place at the time the CCA was published. (754)

Response to Comment 4.N.4:

Due to the voluminous amount of information required by 40 CFR Part 194, it would have been impractical to include all information in the CCA that demonstrates the application of a QA program. The TWBIR is provided in the Appendix of the CCA. It is also discussed in detail in Chapter 4 of the CCA. A QA program was not applied to the TWBIR. The TWBIR was qualified through peer reviews. The CCA, on p. 5-4 (lines 32-37), includes the documented evidence of the establishment of a QA program (e.g., CAO QAPD), and not the technical reports and procedures on items and activities that affect the containment of waste. [WWIS Software and Performance Demonstration Program, PDP] The CCA, on p. 5-4 [lines 25-26], states that the following list identifies "...examples of subcontractors...." It was not meant as an exhaustive list.

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5. Page 5-42, lines 31-32 -- The problem of using scientific notebooks as a requirements document has cropped up at SNL in the past, when scientific investigations were in process (sometimes completed) before test plans or procedures governing the operation had finished the review and comment process. When QA assessments uncovered the deficiency the response has been that daily communications documented by entries in scientific notebooks were thought to be sufficient. If comments have yet to be resolved and approvals haven't been granted, how can the daily communications recorded in the notebooks reflect the yet-to-be-determined requirements? If the result of the CAO QAPD statement quoted above is to allow scientific notebooks to be used as described at SNL, the CAO QAPD may have failed to fulfill Basic Requirement 2 of NQA-1. This requirement states in part that the documented quality assurance program "shall provide for the planning and accomplishment of activities affecting quality under suitably controlled conditions. Controlled conditions include the use of appropriate equipment, suitable environmental conditions for accomplishing the activity, and assurance that prerequisites for the given activity have been satisfied." [emphasis added] (797)

Response to Comment 4.N.5:

The commenter confuses the use of the word "requirements" in the CCA section cited. The "requirements" in scientific notebooks refer to laboratory protocols and procedures, or "technical implementation documents." [CCA, p. 5-42, lines 31-32] These protocols and procedures in scientific notebooks are not legal requirements in the sense of NQA-1 and 40 CFR 194.22.

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6. Page 5-25, line 19-21 -- The EEG controlled copy of the WID QA procedures shows that this document was removed from the WID Quality Assurance Manual on September 27, 1996, a month before the CCA was issued. The controlled copy change notice does not indicate any replacement document. At the EPA audit of WID in February, 1997, WP 1 3.03 Revision 0, Quality and Regulatory Assurance Department Assessment Program, effective August 26, 1996, was identified as the current implementation of the WID grading process (Section 7.3.1, "Activity Grading Process"). (781)

Response to Comment 4.N.6:

EPA agrees that the document WP 13-QA3501 has been superseded by WP 13-1.

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7. Page 5-43, line 34 -- WID performs scientific investigations (under any rational definition of the term WID's environmental monitoring program qualifies), and undoubtedly has implementing documents in the form of plans and procedures which should have been listed here. (798)

Response to Comment 4.N.7:

EPA finds that the term “scientific investigation” can be interpreted in more than one way. The CCA states that “technical investigations and design-development data collection activities performed in support of this application are defined, controlled, verified, and documented.” [CCA, p. 5-42, lines 3-4] The WID monitors environmental conditions at the WIPP and documents the results. However, other WID activities such as Field Measurements of Geological Factors, may include “technical investigations.” EPA will note this observation in further dealings with DOE.

8. Page 5-3, lines 11-14 -- The first CAG expectation (p. 18) is that the DOE top tier QA documents be included in the application; the second is that the top tier QA documents of principle contractors also be included in the application. This first mention of these documents should also state where they can be found. CCA Appendix QAPP contains the CAO QAPD Rev. 1 and the WID QAPD Rev. 16, but the TRU QAPP, SNL's procedures, and QAPjPs from the generator sites are not included. (748)

9. Page 5-16, lines 20-42 -- QA documents that demonstrate this is being done should be referenced (the CAO QAPD in Appendix QAPD, Section 1.1.2.1 covers the majority of these requirements). (779)

10. Page 5-21, lines 10-11 – The source document(s) for this requirement should be properly referenced. (780)

Response to Comments 4.N.8 through 4.N.10:

The QA documents that demonstrate that the QA program requirements have been passed down to principal participants (SNL, WID, and the generator sites) with the directive that applicable requirements then be passed down to lower-tier organizations are referenced in the CCA as follows:

Section 5.0	p. 5-1	lines 16-31
Section 5.1	p. 5-3	lines 10-15
Section 5.1.1	pp. 5-4 to 5-5	
Section 5.1.3	p. 5-7	lines 3-8
Section 5.1.4	pp. 5-9 to 5-10	

Figure 5-1	p. 5-17	
Figure 5-2	p. 5-19	
Section 5.3.3	pp. 5-22 to 5-23	
Section 5.3.3.2	pp. 5-25 to 5-26	
Section 5.3.5	p. 5-27	lines 10-35
Section 5.3.13	pp. 5-32 to 5-33	
Section 5.3.18	pp. 5-36 to 5-37	
Section 5.3.19	pp. 5-37 to 5-38	
Section 5.3.20	pp. 5-38 to 5-40	
Section 5.3.21	p. 5-42	lines 17-37

The location of lower-tier documents are found in their respective field locations. For example, SNL's implementation procedures are found in the SNL office, Albuquerque, New Mexico. EPA will conduct maintenance audits of CAO to ensure that the current QA program adheres to the requirements of Section 194.22. EPA will also conduct periodic audits of SNL and WID to ensure adequate flow down of the CAO QA program.

11. Page 5-12, lines 24-34 -- References to the specific audits and surveillance should have been included. (773)

Response to Comment 4.N.11:

DOE audits of SNL are referenced in Table 5-4, p. 5-47, lines 29-38. The SNL audits and surveillance of their subcontractors are presented in Table 5-6 and Table 5-7 p. 5-53. Specific audits associated with the repository sealing system are as follows:

Audit No.	Contractor
IA 95-01	University of Nevada at Reno
EA 95-06	RE/SPEC Inc.
EA 95-10	Parsons-Brinkerhoff
EA 95-11	INTERA Inc.
SR 96-04	RE/SPEC Inc.
SR 96-05	INTERA Inc.

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12. Page 5-49, lines 8-16 -- In the Independent Review Team (IRT) process, the entire QA program did not need to be equivalent to one which satisfied the NQA requirements. Only those portions applicable to the data being qualified needed to be equivalent to NQA requirements. The difference is important, in that none of the data qualified by IRT processes was collected under a fully NQA equivalent program. (805)

Response to Comment 4.N.12:

EPA agrees with the comment.

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13. Page 5-2, line 41, to Page 5-3, line 8 -- 40 CFR 194.22(a)(1) specifically excludes those portions of NQA-3 (which addresses QA for site characterization data collection activities), that refer to the graded approach. Having raised the "graded approach" issue, Chapter 5 should provide evidence (even a single statement) that the site characterization data was not collected or processed using a graded approach to QA. (747)

Response to Comment 4.N.13:

The purpose of NQA-3 is to establish the collection of scientific and technical information for site characterization of high-level nuclear waste repositories. WIPP is proposed to be a **low-level** nuclear repository. Therefore, sections of NQA-3 are variable or not applicable to WIPP.

The "graded approach" supports the implementation of QA programs after April 9, 1996. The WIPP project began research more than 22 years ago. The requirements of Section 194.22 were required to be implemented after April 1996, and after the WIPP site had been characterized, selected, and built. Therefore, it is impracticable to evaluate site characterization data using a graded approach. However, all data important to the containment of waste, including site characterization data was peer reviewed in accordance with the requirements of NUREG 1297. EPA evaluated the QED process and the Peer Review process, to ensure that the requirements of Section 194.22 were met. [Docket: A-93-02; Items II-A-48 II-A-46, respectively]

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14. Page 5-50, lines 1-2 -- The DOE document establishing the qualification should be referenced. (806)

Response to Comment 4.N.14:

The data referenced in the comment refers to SNL data collected to support compliance. Specifically the data was collected after August 1, 1995 when the SNL QA program was qualified by DOE. SNL's QA program was audited and found to be adequate. [CAO Audit A-95-07] This audit is referenced on p. 5-4 in Table 5-4.

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15. Page 5-5 1, lines 13-14 -- Only those data sets used in the CCA were qualified. About 30 data packages failed the IRT process but were not sent to peer review. (807)

Response to Comment 4.N.15:

EPA agrees with the comment in that 30 data packages failed the IRT process but those packages were not included in the CCA. The data sets included in the CCA were qualified. The data sets not used do not need to be qualified.

16. Page 5-51, lines 30-31 -- Revision 0 of QAP 20-7 has an effective date of November 20, 1996, nearly a month after the CCA was published. The process used may be documented in the procedure, but an approved version of QAP 20-7 was obviously not available at the time the T=0 determinations for the subcontractors listed in Table 5-6 were made. The process of determining T=0 is a quality-affecting one, and should have been controlled by procedures or instructions as required by NQA-1, Basic Requirement 9 and Supplement 9S-1.2, and the CAO QAPD Section 2.1.A -- that is, the SNL document(s) that controlled and authorized the process at the time the subcontractor T=0 determinations were made should have been cited, not QAP 20-7. (808)

Response to Comment 4.N.16:

Prior to the approval of SNL QAP 20-7 in November 1996, the T=0 process was conducted in accordance with SNL WIPP Desk Instruction, Establishing T=0 for Subcontractor QA Programs. Therefore, the process was controlled by an instruction as required by NQA-1, Basic Requirement 9 and Supplement 9S-1.2. EPA conducted an audit of SNL's T=0 process in June 1997. [Docket: A-93-02, Item II-A-49] T=0 for three SNL subcontractors, including five contracts, were reviewed during this audit. The EPA audit team evaluated TerraTek, Inc.-Contract AD-3656, Rock Physics Associates/ Core Laboratories-Contract AF-3945 and Contract AI-3669, and INTERA, Inc.-Contract 63-5605 and Contract AG-4980. The audit team evaluated the T=0 process using both the Desk Instruction and QAP 20-7. The audit concluded the process for establishing T=0 addresses the requirements of Section 194.22(b).

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17. Page 5-6, lines 23-35 -- SNL was responsible for most of the measurements of geologic factors, including the "site selection and characterization program" mentioned in this section. To state that there were no SNL activities, QA documents, or subcontractors is ludicrous. (761)

Response to Comment 4.N.17:

The section in the CCA cited in the comment states that "In 1989, EPA reviewed and commented on much of the data collected by DOE during the site selection and site characterization program." [CCA, p. 5-6, lines 6-7] SNL's work in this area focused on pre-selection activities which occurred in 1989. EPA requires QA programs to be in place after April 9, 1996. Therefore, EPA finds that SNL may, in fact, not have any activities applicable to the Section 194.22 requirements at that time.

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18. Page 5-11, lines 13-22 -- A reference to the document which shows that Supplement 3S- 1 methods were used to verify the WIPP facility design should be referenced. (770)

19. Page 5-11, lines 26-31 -- The design documents and start-up testing documents should be referenced. The Section 194 requirement is to demonstrate that the activities described in these statements were performed, not to describe them. (771)

Response to Comments 4.N.18 and 4.N.19:

Section 5.1.6.2, p. 5-11, lines 29-31 state "Start-up testing is currently described in WID Implementing Procedures WP 03-001 through WP 03-006 and has been controlled since its inception by appropriate predecessor procedures. Lines 43-1 states:

> Design verification ensures compliance with identified [NQA-1, 3S-1] requirements. The WID Quality Assurance Program Description establishes actions and responsibilities to verify the adequacy of a design. Design controls specified in the WID Quality Assurance Program Description are in place to track and verify the design process.

Lines 4-5, p. 5-12 of the October 1996 CCA refers the reader to Section 5.3.2.8 for the location of applicable QA records.

EPA conducted an audit of WID in February 1996. [Docket: A-93-02, Item II-A-45] The audit concluded that WID had implemented a QA program in accordance with the requirements of Section 194.22. Design verification was reviewed during the audit; no findings associated with design verification were identified.

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20. Page 5-11, lines 33-38 -- In short, the original QA records for design were not collected, stored, or maintained as required by NQA-1 Supplement 3S-1.7, and had to be redone. Chapter 5 should reflect the true history of QA for the facility design. (772)

Response to Comment 4.N.20:

The QA history of the facility design is not a requirement of Section 194.22. Section 194.22 requires DOE to implement a QA program that adheres to the requirements of NQA, as soon as practicable after April 9, 1996. The WIPP project began research more than 22 years ago. It is impracticable to require 22 years of activities to comply with current standards and be documented in the CCA. However, all activities important to the containment of waste have been qualified in accordance with the requirements Section 194.22. EPA has conducted numerous verification activities to ensure DOE's compliance. The results of all verification activities associated with Section 194.22 are available in Air Docket: A-93-02 and the Federal Register.

21. Page 5-37, line 36 to Page 5-38, line 6 -- Classification of the many unique records generated by the WIPP has yet to be accomplished, as the DOE must submit suggestions to NARA (National Archives and Records Administration) on classification of WIPP records and await NARA's guidance. The NARA positions could take some years to obtain. The provisions are in

place, but many of the QA records have not been classified yet. This should have been explained in the CCA. (791)

Response to Comment 4.N.21:

EPA agrees, a more detailed explanation should have been provided in the CCA. However, the CCA is only required to show compliance with Section 194, including by reference NQA. NQA 17S-1.2.7 requires records to be classified as Lifetime or Nonpermanent. EPA has verified compliance with NQA requirements for QA records, through audits of CAO [Docket: A-93-02, Item II-A-43], SNL [Docket: A-93-02, Item II-A-44], and WID. [Docket: A-93-02, Item II-A-45]

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22. Page 5-38, lines 17-22 -- Essential records are still at several subcontractor sites other than those mentioned. For instance, records related to microbial degradation of the waste were at Brookhaven National Laboratories in early February 1997, four months after the CCA was published. (792)

Response to Comment 4.N.22:

The majority of the essential records are at subcontractor sites. NQA-1 Requirement 17 requires QA records to be retrievable and protected against damage, deterioration or loss. EPA conducted audits of CAO [Docket: A-93-02, Item II-A-43], SNL [Docket: A-93-02, Item II-A-44], and WID [Docket: A-93-02, Item II-A-45] to ensure essential records are retrievable and protected against damage, deterioration or loss. The audits concluded that DOE's QA record system complies with the requirements of Section 194.22.

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23. Page 5-26, lines 28-30 -- The CAO Manager had yet to perform an assessment of CAO at the time the CCA was published (one is scheduled for February 24-28, 1997). The NQA-1 requirement (Basic Requirement 2, last paragraph) is that management "...shall regularly assess the adequacy of the program for which they are responsible...... SNL's last WIPP Project Management Assessment (previous to the October 1996 publication of the CCA) was June 12, 1995. Corrective Action Reports on management assessments have been initiated at both CAO and SNL. (783)

Response to Comment 4.N.23:

The DOE CAO implemented procedure MP 9.1 to address the requirements NQA-1 Requirement 2. However, MP 9.1 did not include a provision for regular management assessments. The EPA audit of CAO conducted in December 1996 [Docket: A-93-02, Item II-A-43] issued a finding to this effect. MP 9.1 was under revision during the time of the audit and was corrected to address regular management assessment. During the maintenance audit of CAO conducted during January 1998, the management assessment was reviewed and determined to address the requirements of NQA-1 Requirement 2.

NQA-1 Requirement 2 does not specify a time limit for conducting management assessments. Therefore, SNL addressed the requirement of NQA-1 Requirement 2 with the management assessment conducted in April 1995. NQA-3 also requires management assessments. NQA-3, Requirement 2.4, states "Management assessments of the quality assurance program shall be conducted regularly and reported at least annually." SNL QAP 2.8 Revision 2 requires the SNL Project Management to initiate periodic management assessments. However, the last management assessment was performed in April 1995.

SNL noticed the deviation from NQA-3, Requirement 2.4 and SNL QAP 2.8 Revision 2, and instituted CAR W-97-013. EPA conducted an audit of SNL in January 1997 [Docket: A-93-02, Item II-A-44] and issued one finding and one observation related to this issue. Numerous EPA follow up audits at SNL confirmed that a management assessment was conducted in 1997, and it addressed the requirements of NQA-1 and NQA-3.

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24. Page 5-32, lines 6-22 -- The CAO QAPD, Rev. 1 requires that inspections be performed in accordance with approved implementing procedures (Section 2.4.1). This section implies that SNL does not have the procedure required by the CAO QAPD for conducting inspections. It further implies that there are no documents controlling SNL's inspection activities at all. (784)

<u>Response to Comment 4.N.24:</u>

EPA finds that SNL does not conduct inspections as described in the comment, and is not required to do so by NQA-1. Therefore, SNL would have no documents controlling inspection activities.

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25. Page 5-32, line 32 to Page 5-33, line 16 -- Apparently all SNL tests are considered to be scientific investigations, covered by the procedures listed in Section 5.3.21. This should have been made explicit in the text, as the sense of the text in this section is that SNL has no implementing documents for control of testing. (785)

<u>Response to Comment 4.N.25:</u>

EPA agrees that SNL performs no testing as the term is used in NQA-1. NQA-1 uses 'testing' to describe determining the capability of an item to meet specified requirements by subjecting the item to a set of operating conditions, and to demonstrate the satisfactory performance of that item. The emphasis is on testing *items* for their adherence to a set of requirements, not testing as is typically performed for research or investigative purposes. This interpretation is further amplified by Supplement 11-S1 to NQA-1 Requirement 11, which notes that required tests include, as appropriate, prototype qualification tests, production tests, pre-operational tests prior to installation, construction tests, pre-operational tests, and operating tests. All of these are typical of tests one would perform on a specific item or system. QA control of testing done as part of scientific investigations is noted in the first paragraph of section 5.3.12 as being described in section 5.3.21. The only type of testing which SNL performs that could be construed to fall under NQA-1 Requirement 11, Test Control, is software testing. NQA-1 Requirement 11, Supplement 11-S2 may be used to cover software testing if the software is not elected as being covered under NQA-2, part 2.7. SNL has elected to perform software testing for repeatedly executed codes under QAP 19-1, which is derived from NQA-2 part 2.7. Single use programs that are run as part of an analysis or calculation may be tested prior to use under QAP 9-1, which fulfills the testing requirements of NQA-1 Requirement 11, Supplement 11-S2 for software testing.

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26. Page 5-34, lines 21-37 -- NQA-1 Supplement 13S-1.2 requires that these processes are to be "conducted in accordance with established work and inspection instructions. . .or other pertinent documents or procedures specified for use in conducting the activity." This section implies that SNL has no such documents or procedures. (786)

Response to Comment 4.N.26:

The comment cites to the section entitled "Handling, Storage and Shipping." [CCA, Section 5.3.14] EPA finds that SNL does not conduct any activities involving handling, storage and shipping.

27. Page 5-35, lines 5-7 --The implication is that SNL has no internal documents requiring compliance with NQA-1 Basic Requirement 14, Inspection, Test, and Operating Status. (787)

Response to Comment 4.N.27:

The comment cites to the CCA statement: "The specific status indicators, their use, and the authority to apply or remove them are delineated in applicable QA plans or implementing procedures." [CCA, p. 5-35, lines 5-6] EPA finds that SNL does not produce any items that require "specific status indicators." Therefore, SNL would have no internal documents on this point.

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28. Page 5-35, line 30 to Page 36, line 13 -- In this section, neither SNL or DOE implementing documents are specified. SNL does have at least one procedure that would seem to apply to the discussion in this section (QAP 2-5, "Issuing and Lifting Stop Work Orders"); WID, too, has a "Stop Work" procedure that would also seem to apply (WP13-008). . . Procedures covering the discussion of nonconforming items should have been listed. (788)

Response to Comment 4.N.28:

NQA-1 Requirement 15 address nonconforming items. CAO does not conduct any activities which requires implementation of Requirement 15. SNL procedure QAP 12-2 WIPP Calibration QA Program, provides provisions for identifying, documenting, segregating and disposing of nonconforming calibration equipment. WID procedures WP 13-007 and WP 13-3003 address NQA-1 Requirement 15. EPA audits of SNL [Docket: A-93-02, Item II-A-44] and WID [Docket: A-93-02, Item II-A-45] concluded the requirements of Section 194.22, including NQA were adequately implemented.

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29. Page 5-6, lines 36-39 -- The title of this document since March 3, 1996 (eight months before the CCA was published) has been "Groundwater Surveillance Program Plan, Revision 3"; it is not a "Quality Assurance Plan", but five of the 25 pages (pp. 5-9) have brief sections addressing each of the 18 NQA-1 Basic Requirements. The QAPjP for collecting meteorological data described in Appendix EMT is not listed among the WID QA documents. (762)

Response to Comment 4.N.29:

EPA agrees with both parts of this comment. First, the document is incorrectly titled. The CCA lists WP 02-1 as the "WIPP Groundwater Monitoring Quality Assurance Plan." The correct title should be "Groundwater Surveillance Program Plan." The applicable NQA-1 requirements are addressed in the correctly titled document. Second, the QAPjP for collecting meteorological data described in Appendix EMT should be listed among the WID QA documents.

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30. Page 5-15, lines 1-19 -- The principle documents for the QA program(s) described, and the documents showing the changes, should be referenced. The DOE/AL Operations Manual should be included in the References/Bibliography at the end of the chapter. (776)

31. Page 5-15, lines 1-19 -- In 1989, it appears that reviewers did not find a WIPP QA program which met the requirements of the NQA standards. Chapter 5 should reflect a more accurate history of WIPP QA. (777)

32. Page 5-16, lines 12-18 -- The EM-342 documents describing the assessment and its conclusions should be referenced. (778)

Response to Comments 4.N.30 through 4.N.32:

The issues addressed by Comments 776 and 777 are found in the CCA section on "Program History." [Section 5.2] The particular lines cited in the comment for this section deal with QA historical information dating from 1977 to 1982. Likewise, Comment 778 deals with QA program adequacy from 1993 to 1994. DOE was required to provide, through the CCA and additionally requested information, objective evidence of a QA program after April 9, 1996. For data and information collected prior to this date, the data and information had to be qualified through one or more of the methods identified in 40 CFR 194.22(b). The methods, such as peer reviews, were conducted during audits and surveillances. The audits and surveillances are found in reports which are detailed in the following CCA sections: 5.4.2.1, 5.4.2.2, and 5.4.2.3. EPA finds that this data did not need to be referenced in the CCA because it is available in audit and surveillance reports. The information provided in the CCA demonstrates that this data was qualified, and references where the information can be found. To include all this information in the CCA would be difficult due to the voluminous amount of information.

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33. QA Program Documents (p. 5-25) -- This section does not include SNL QA program documents. The CAG expectation (p. 18) is that DOE principle contractor top tier QA documents would be included in the CCA, not merely listed. (782)

Response to Comment 4.N.33:

EPA conducted an audit of SNL in January 1997. [Docket: A-93-02, Item II-A-44] The audit concluded that SNL had established and implemented a QA program that adhered to the requirements of Section 194.22.

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34. Page 5-39, lines 15-16 -- The "implementing documents" sections for this section list procedures, but no QA plans are cited. (793)

Response to Comment 4.N.34:

The comment is accurate in that no QA plans are cited in the "Implementing Documents" section. However, the comment cites to the following sentence: "The management and control of audits and surveillances are documented in QA plans or implementing procedures." (Emphasis added). EPA finds that the audit and surveillance reports are included in the implementing procedures. Therefore, QA plans do not need to be cited.

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35. Page 5-42, line 4-6 -- The section referenced is "Control of Measuring and Test Equipment." Process variables other than equipment can affect scientific investigations. (796)

Response to Comment 4.N.35:

EPA agrees, process variables other than equipment can affect scientific investigations. Hence, EPA requires the implementation of a quality assurance program. An effective quality assurance program includes training, documented procedures, process controls, etc. EPA conducted audits of CAO [Docket: A-93-02, Item II-A-43], SNL [Docket: A-93-02, Item II-A-44], and the Westinghouse WID [Docket: A-93-02, Item II-A-45] to ensure that all process variables that can affect scientific investigations are controlled. Audit results concluded DOE has implemented an adequate quality assurance program.

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36. Page 5-45, lines 26-31 -- Reference to the documentation of the acceptance by the auditors that the program is now considered to be effectively implemented should be included. (804)

Response to Comment 4.N.36:

The documentation to support the implementation of the DOE program is referenced by audit report 96EM36-AU-01. [p. 5-45, line 26] It would have been impractical for DOE to include all referenced documentation in the CCA. Therefore, EPA verified the implementation of DOE's QA program by an audit conducted in December 1996. [Docket: A-93-02, Item II-A-43]

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37. Page 5-52, lines 36-40 -- The term "internal customer" is not a commonly understood term, and should have been defined. The transition from internal QA to external contractor QA between the second and third sentences is not explicit. (809)

Response to Comment 4.N.37:

In the CCA section cited in the comment, the term in question is "internal WID customers and external contractors" and not simply "internal customers" as cited in the comment. A rational reading of this sentence implies that the two customers exist: one inside WID and the other outside WID. Therefore, EPA finds that this term does not need to be further defined. The transition from internal QA to external contractor may be confusing, and thereby in need of grammatical review.

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38. Page 5-6, lines 20-21 -- The section of Appendix EMP concerning groundwater (Section 5.4.3, p. 5-12) does not include any QA information; the QA section of Appendix EMP does not discuss establishment and execution of NQA requirements. (760)

Response to Comment 4.N.38:

Section 6.0 of Appendix EMP discusses sampling and analysis associated with the environmental monitoring program. The introduction references the WID Quality Assurance Program Description as a source document for the program. The introduction also states that each laboratory is responsible for maintaining an approved quality assurance program discussed in Chapter 5 of the CCA.

Section 8.0 of Appendix EMP provides a discussion of quality assurance. Section 8.1-Introduction states "This section defines the policies and procedures that have been implemented at the WIPP to provide confidence in the quality of the environmental data that are generated.

QA practices that cover monitoring activities at the WIPP are consistent with applicable elements of the 10-element format in ANSI/ASME NQA-1."

WID will be responsible for environmental monitoring activities. EPA conducted an audit of WID in February 1997. [Docket: A-93-02, Item II-A-45] The audit concluded that WID had implemented a program in accordance with the requirements of Section 194.22, including by reference NQA.

Issue O: Interpreting Section 194.22 requirements

1. Section 194.22(a)(1) -- Recommendation: If the intent of the criterion was that the CAO's QA program only meet the requirements of the NQA standards for the 8 critical areas listed in Section Section 194.22(a)(2), then the EEG agrees that the criterion has been met. However, the documentation for the final rule should include a rationale for considering only those areas described in Section 194.22(a)(2) as falling under the Section 194.22(a)(1) criterion. (1284)

2. Section 194.22(a)(2)(vii) -- Recommendation: The EPA should review the CCA for data and information other than that covered by the other (a)(2) criteria which is important to compliance, and cite the review, and a demonstration of establishment and execution of the NQA standards, for any found not to be a part of the other (a)(2) criteria. The EPA should rewrite section 22.H of CARD 22, and revise the proposed rule, to remove the QA responsibility for all data in the CCA from SNL's shoulders. (1291)

Response to Comments 4.O.1 and 4.O.2:

The Section 194.22(a)(1) requirement is applied to the eight criteria in Section 194.22(a)(2) based on the language in Section 194.22(a)(2) which states, in part, "...that the quality assurance program required pursuant to paragraph (a)(1) of this section has been established and executed for: (I)...(viii)." The eight criteria encompass everything that Section 194.22(a)(1) is to be applied to.

The CAO QAPD was approved by DOE on April 22, 1996, but not necessarily implemented on that date. To fully implement the CAO QAPD requires more time, as in this case-four months, due to the voluminous amount of documents. The QAPD, a top-tier document, takes time to filter down to the WID and SNL implementing documents, and then to the sub-contractor implementing documents. [Figures 5-1, 5-2 of CARD 22]

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3. Page 5-44, lines 33-38 -- Section 194.22(a) covers the requirement for the QA program described; Section 194.22(c) seems clearly to be a requirement independent, and additional, to that established for the overall QA program. (803)

Response to Comment 4.O.3:

EPA agrees and therefore, evaluates the criteria of each Section 194.22 requirement separately. This is demonstrated by the format of the CARD; the justifications for each requirement provided in the proposed rule; and the variety of activities audited for compliance.

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4. Section 194.22(d) -- Recommendation: The EPA should review the CCA to establish a list of the data for which the application should demonstrate how it was qualified, and ensure that the documentation reflects the elements of this list. (1294)

Response to Comment 4.O.4:

EPA agrees that a list of all data and its associated qualification methods is a good idea. Such a listing is not required by Section 194.22. However, an EPA parameter database has been established and maintained at SNL. [WPO # 46761] This database contains a list of all parameters used as input in the PA, and their associated data sources and qualification methods. While this data may not be comprehensive to all data referenced in the CCA, it does contain data important to the containment of waste.

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5. Section 194.22(e) -- Recommendation: The EPA should review internal EPA documents relating to the promulgation to ensure that the underlying reasoning behind each Section Section 194.22 criterion has been adequately addressed for the information presented in the CCA. (1295)

Response to Comment 4.O.5:

EPA has conducted a comprehensive evaluation of whether the WIPP will comply with the radioactive waste disposal regulations, as required by Section 8 of the WIPP Land Withdrawal Act. In conducting this evaluation, EPA has determined whether the underlying reasons behind each of the Compliance criteria have been adequately addressed.

Issue P: Condition 2 should be stricken because it is duplicative, redundant, will delay the certification process, increase costs, and adds nothing to public health and safety, or the protection of the environment.

1. I believe that QA programs which are in place at the generator sites are consistent with Part 194, and that the Waste Acceptance Criteria are sufficiently specific for protection. I urge the EPA to avoid imposing further complicating and unnecessary procedural conditions on QA in the final rule. (474)

2. I would also like to note that the QA standard is identical to 10 CFR 50, Appendix 3, which is the QA standard invoked by the nuclear regulatory commission for every nuclear power plant in

this country. During the licensing phase of all of these 120 U.S. nuclear power plants, the Nuclear Regulatory Commission did not go out and inspect all of the 200 plus suppliers and compost manufacturers making nuclear reactors and power plants. They relied upon the quality assurance programs of the commercial nuclear power plants. The analogy is TRU waste sites are supplying waste to the WIPP Project. The DOE sets the requirements. My question is should the EPA be concerned about increases in costs that don't increase public safety. (279)

Response to Comments 4.P.1 and 4.P.2:

The WIPP LWA requires EPA to, among other things, develop, through informal rulemaking pursuant to Section 4 of the APA, criteria by which to certify whether the WIPP will comply with EPA's radioactive waste disposal regulations at 40 CFR Part 191 [LWA, Section 8(c)], and utilize such criteria to certify, through informal rulemaking pursuant to Section 4 of the APA, whether the WIPP will comply with such regulations. [LWA, Section 8(d)(2)] EPA duly promulgated the Compliance criteria [40 CFR Part 194] pursuant to the notice and comment obligations of the APA. [61 FR 5224] Therefore, EPA has a legal obligation to utilize these Criteria in its determination of whether the WIPP will comply with the 40 CFR Part 191 regulations. In other words, EPA has no legal authority to ignore or disregard the requirements of the Compliance criteria in making its determination. Thus, the quality assurance and waste characterization conditions (conditions 2 and 3) imposed on EPA's certification that the WIPP will comply with the Part 191 regulations reflect the fact that DOE did not demonstrate compliance with Sections 194.22(a)(2)(i), 194.24(c)(3), 194.24(c)(4), and 194.24(c)(5) of the Compliance criteria.

In making its certification decision, EPA cannot address such issues as to whether demonstration of compliance with these regulatory requirements will impact DOE's schedule for placing transuranic wastes in the WIPP, is "redundant," or constitutes a "needless duplication of effort." EPA is legally required to determine whether DOE has met the requirements of the Compliance criteria. As set forth in the rule, EPA has determined that DOE has only met the specific waste characterization and quality assurance requirements at issue for the identified waste streams at one waste generator site. Until such time as DOE demonstrates that it has met these requirements at other waste generator sites, EPA can do no more.

Issue Q: EPA should amend 40 CFR 194.22(a)(2).

1. In order to clarify that implementation of sites' quality assurance and waste characterization programs are an ongoing responsibility of both DOE and EPA, DOE suggests that Section 194.22(a)(2) be revised as follows:

> (2) Any compliance application shall include information which demonstrates that the quality assurance program required pursuant to paragraph (a)(l) of this section has been established and will be executed for:
>
> (I) Waste characterization activities and assumptions; . . .

This revision to 194.22(a)(2) would clarify that EPA's authority to verify execution of all quality assurance programs originates in 194.22(e) and that the appropriate means of verification is through surveillance, audits, and management systems reviews of DOE's process for authorizing sites to send waste to WIPP. (949)

Response to Comment 4.Q.1:

It is beyond the scope of this rulemaking to substantively revise the Compliance criteria of 40 CFR Part 194. In order to do so at this point, EPA is required to conduct a separate rulemaking. The Agency will take under advisement the question of whether it is appropriate to conduct such a rulemaking.

Section 5 Models and Codes -- Section 194.23

Comment Issue Page #

Issue A: Spallings

1. A spallings release, which occurs in the event of a drilling intrusion when pressurized gas propels waste toward the surface, is not adequately represented by the model used in PA, as has been noted by DOE's own peer review group. (139)

2. At the request of DOE, staff from Sandia subjected the spallings process to complete and vigorous evaluation during the months between December 1996 and April, 1997. This evaluation included assessment of the assumptions included in the CCA's design and implementation of experiments on waste forms and properties, consultation with oil industry professionals on gas blow-out processes, and development of computer codes and models to predict the outcome should an inadvertent intrusion occur. We spent more than 10,000 hours of time on this program, and demonstrated that releases due to spallings would, in fact, be quite small. (178)

3. The fact that our models assume an uncontrolled blowout doesn't mean that's what we expect. It is simply a means to bound the results. The waste forms start out as 55 gallon, steel drums. Simulation of heterogeneous, massive waste forms is very difficult. Hence, it was assumed that the waste consisted of particulates - not because we think it will look that way, but simply to bound the results. Even if the maximum degradation occurs and some of the waste exists as a particulate matter, it takes an extremely vivid imagination to come up with a means to transport a large volume of material through 1" drilling annulus more than 2000' to the surface. When one views the computed results with the complex reality, the inescapable conclusion is that *Spallings* releases will be small. This is true regardless of the type of drilling fluid used or the precise character of the waste or of the exact amount of gas generation or of creep closure or of any of a hundred other processes. (728)

4. Modeling of the volume of waste released due to spallings has been attempted numerous times and never achieved. No model of the spallings process -- not even the latest modeling contained in the Spallings Release Positions Paper (II-G-23) -- has been endorsed by the Conceptual Model Peer Review Panel. (1024)

<u>Response to Comments 5.A.1 through 5.A.4:</u>

EPA agrees that the spallings conceptual model contained in the CCA PA was found to be inadequate by the Conceptual Models Peer Review Panel (CMPRP). After the CMPRP found the spallings model implemented in the CCA to be inadequate, DOE conducted a significant computational and experimental program to develop a new spallings conceptual model, as stated in Comment 5.A.2 and as documented in the Spallings Release Positions Paper, Hansen, et al., 1997. [Docket: A-93-02, Item II-G-23] DOE did not ask the CMPRP to review the new spallings model against the criteria contained in 40 CFR Part 194, nor did the Department ask the Panel to reconsider its conclusion that the original spallings model was not adequate. Thus, Commenter 1024 is correct, the CMRP did not endorse any DOE spallings modeling. Instead, DOE asked the Panel to determine *whether* use of the spallings volumes derived from the inadequate spallings model and incorporated in the CCA was reasonable. [Docket: A-93-02, II-G-22, Conceptual Models Third Supplementary Peer Review Report, April 1997, p. 3] On the basis of the new modeling, the CMPRP determined that the spallings model used in the CCA resulted in the calculation of release volumes which are reasonable to use in the performance assessment, and may actually overestimate expected releases. [*ibid*., p. 12]

The new spallings modeling predicts extremely small spallings volumes for all gas pressures below lithostatic pressure. EPA has concluded that, since the spallings model in the CCA considers only particle dislodgement from the waste, not lofting of dislodged particles up the borehole, the approach taken by DOE is conservative. DOE assumes that all failed waste is transported to the surface when, in actuality, only a portion of the failed waste would be able to travel up the borehole, resulting in radioactive releases to the earth's surface. EPA agrees with Commenter 5.A.3 that larger particles dislodged from the surfaces of radial fractures in the waste will not be lifted 2,150 ft to the land surface. The maximum size of particle which could be transported (assuming that adequate fluid energy was available) is limited by the annular space between the drill collar and the borehole wall. This dimension is about 0.054m (2.1 inches). Using the particle size distribution based on the expert elicitation of waste particle sizes [Estimate WIPP Waste Particle Sizes Based on Expert Elicitation Results: Revision 1, Docket: A-93-02, II-G-36], it can be shown that about 30 % of the waste particles are larger than the annulus and could not be transported to the land surface. [Attachment 4 in Letter from G. Dials, DOE/CAO, to M. Kruger, EPA/ORIA dated January 26, 1998, Docket: A-93-02, IV-G-7] In addition, calculations show that at the time when the first borehole intrusion would occur[7], more than 40% of the steel would not yet be corroded and reduced to a particle size where transport is possible. [*ibid.*] However, the CCA model assumes that <u>all</u> failed waste reach the earth's surface, resulting in an overestimate of radioactive releases due to spallings. EPA agrees with Commenters 5.A.2 and 5.A.3 that spallings releases will be small.

DOE measured the tensile strength of saturated surrogates waste to be 0.074 megapascals (MPa) while that of dry waste was 0.15 MPa. [Hansen et al., 1997, Docket: A-93-02, IV-A-6, SAND97-1369, p. 1-3] These values are much greater than the value of 1 Pa (0.000001 MPa) used for the strength in the spallings model. Thus the tensile strength (i.e., cementation strength) in the spallings model was conservatively assumed to be several orders of magnitude lower than that determined by tensile strength tests on waste surrogates. Even though the original spallings model was unacceptable, the waste tensile strength used in that model was two orders of magnitude lower than that measured on surrogate waste, further supporting the contention that the results from the original model were conservative.

EPA does not agree with the comment that modeling of the volumes of waste released by spallings has never been achieved (Comment 5.A.4). EPA has carefully reviewed the material reported by DOE in Hansen, et al., 1997 [Docket: A-93-02, IV-A-6] and has determined that the modeling conducted there to estimate the volumes of waste which fail because the strength of the waste is exceeded is based on solid experimental data for waste strength and defensible numerical/analytical models to calculate failed waste quantities. To validate the models, the semi-analytic calculations were compared with analogs based on field experience. For example, Hansen, et al. 1997 [*ibid*., Docket: A-93-02, IV-A-6] cite work done in coal seams to intentionally develop cavities at the bottom of the boreholes. The coal bed numerical simulations showed that, with an instantaneous pressure drop of 8.97 MPa in a material with a cohesion of 0.1034 MPa or more, a cavity did not develop (i.e., spallings did not occur). The modeling involved coupled flow, deformation, and failure with progressive cavity evolution. The modeling predictions were validated with sonar caliper logs of actual cavities in coal seams. [*ibid*., p. 5-28] By comparison, WIPP waste has a higher cohesion of 0.13 MPa and the maximum instantaneous pressure drop is about 6.8 MPa (14.8 MPa maximum pore pressure minus 8 MPa bottomhole pressure in the drilling mud). Other key parameters in the coal seam simulations were similar to conditions at the WIPP. This analogy suggests that spallings should not occur under WIPP conditions and the

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[7] There is a 86.9% probability that the first borehole intrusion will occur within 4000 years. [Docket:A-93-02, IV-A-6, Appendix E, p. E-4] Subsequent intrusions are of less concern because the repository is depressurized during the first intrusion.

conclusion is supported by the calculations in Hansen, et al. 1997 [*ibid*., see, for example Table 3-3, Docket: A-93-02, IV-A-6] which demonstrated that the spalled volumes are small.

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5. Air drilling increases spallings releases from WIPP, especially at high repository pressures, because (a) the repository gas pressure need not overcome the hydrostatic weight of the mud column, and (b) at higher pressures the pressure difference between the borehole and the repository is larger than with mud drilling, causing larger waste failure zones (II-D-120 at 6). (1032)

Response to Comment 5.A.5:

EPA agrees with the comment that air drilling will increase spallings releases as compared to the case where the normal mud drilling practice is employed. However, as discussed in EPA's Analysis of Air Drilling at WIPP [Docket: A-93-02, V-B-29], the Agency has determined that air drilling is not representative of current practice for drilling through the Salado and Castile Formations in the Delaware Basin. Furthermore, the Agency has shown the releases expected from air drilling generally fall within the expected range of spallings volumes used in the CCA PA and in the PAVT (i.e., 0.5 to 4 m^3) where the drilling fluid was assumed to be mud. [*ibid*., Appendix A] Thus, spallings releases due to air drilling would not be significantly greater than spallings releases due to mud drilling.

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6. The modeling of human intrusion was completed by the code CUTTINGS_S. . . The calculations showed that the amount of waste brought to the surface would not change, but the number of realizations that possibly could result in a release would increase. The increase of a spalled events [sic] from a highly pressurized repository doubled from the CCA to the Castile simulation. (1082)

Response to Issue 5.A.6:

The comment is based on a sensitivity analysis of PA parameters conducted by EEG and reported in EEG-69. [Docket: A-93-02, IV-G-43] In its sensitivity analysis, EEG compared normalized releases to the accessible environment for the case where there was an 8% probability that the repository was underlain by a brine pocket in the Castile Formation (the CCA assumption) and the case where the probability was 100%. EEG found that "the Castile brine assumptions do not have a significant effect on the overall CCDF." [*ibid*., p. 80] EEG also showed a doubling in the number of PA realizations where spallings occurred. This result is consistent with the fact that brine availability can cause the pressure to be higher in more scenarios and hence to create conditions where spallings can occur (i.e., pressures >8MPa). Even though the fraction of the total realizations with spallings increased, the mean CCDF did not change appreciably from the mean CCDF in the CCA. As EEG observed, " The outcome showed that there is no significant change in releases due to the minor addition of releases from a spalled or brine release." This conclusion is consistent with the results described in the Supplemental Summary of EPA-

Mandated Performance Assessment Verification Test (All Replicates) [Docket: A-93-02, II-G-28] where the brine pocket probability had a small effect on spallings releases. EPA agrees with the commenter that the amount of waste brought to the surface in a realization would not change.

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7. Failure to include the effects of brine and particle size variation are critical omissions which render the spallings model inadequate. . . DOE must include time based scenarios such as the effects of rapid depressurization and varying waste strengths. DOE fails to analyze the influence of waste permeability on gas flow rate and how scale effects model projections are serious omissions. Moreover, DOE's failure to include RH-TRU waste in its spallings scenario further renders the conclusions inaccurate. (1206)

8. The EEG is satisfied that neglecting RH-TRU in spallings calculations and using a single waste stream to represent RH-TRU in the cuttings and cavings model are acceptable modeling approximations. The primary reasons for this assessment are that RH-TRU will be less that 1% by volume of the transuranic inventory of the repository and that the high activity levels in the RH-TRU waste are from fission products that will have significantly decayed in the first two hundred years of burial. While the present activity of RH-TRU waste varies many orders of magnitude, the transuranic content of the waste does not. (1310)

<u>Response to Comments 5.A.7 and 5.A.8:</u>

EPA does not agree that the failure to include the effects of brine and waste particle size is a serious omission from the spallings model. If the commenter is referring to the short term brine releases associated with a drilling intrusion, this process is taken into account in the direct brine release model. If the commenter is referring to the effect of brine on waste properties, this effect is taken into account as well. Most of the waste strength data in Hansen et al., 1997 are based on specimens containing large quantities of water. [Docket: A-93-02, IV-A-6, Table 2-10] In its modeling of spallings in the CCA, DOE did consider waste particle size. Parameter PARTDIA (Id #3246) was a sampled parameter in the CCA with a minimum value of 0.00004 m, a mean value of 0.0235 m, and a maximum value of 0.2 m. [Docket: A-93-02, II-G-1, Appendix PAR, p. PAR-115] Modeling by DOE subsequent to the CCA did not consider particle size since it was conservatively assumed in the Quasi-Static Model and the Cavity Growth Model that, if the waste failed, it would be transported to the surface. Since transport was not modeled, it was not necessary to know the waste particle size in this later work. [Hansen, et al., 1997, Docket:A-93-02, IV-A-6]

Hansen et al., 1997 [Docket: A-93-02, IV-A-6] includes consideration of such factors as rapid depressurization (see, for example, Figure 3-6), waste permeability (see, for example, Section 3.4.4.3), and varying waste tensile and shear strength (see, for example, Table 3-2) on spallings release. As noted elsewhere in this section under Comment 5.A.8, EEG does not believe that it is necessary to include RH-TRU in the spallings analysis. EEG's position is discussed in more detail in EEG-66. [Individual Radiation Doses from Transuranic Waste Brought to the Surface by Human Intrusion at the WIPP, J.K. Channell and R.H. Neill, February 1998, Section 3.0] Since the RH-TRU canisters are isolated from the waste rooms in the repository walls, there is little opportunity for the canisters to be exposed to significant quantities of mobile brine. Thus, the canisters will not corrode and the maximum volume of waste which could be released from the intersection of a drill bit with the canister would be 0.89 m^3 (i.e., the entire canister contents). This is well within the range assumed for CH-TRU waste (i.e., 4 m^3 max.). In addition, most of the fission products typical of RH-TRU waste will have decayed significantly within a few hundred years leaving residual radioactivity levels similar to the CH-TRU waste by the time that the PA predicts it most likely that a borehole will enter the repository. [EEG-66, Table 3-2] Thus, the Agency sees no need to model RH-TRU waste separately from CH-TRU because EPA expects that during a drilling event, the amount of radioactivity due to RH-TRU waste would be less than or equal to that from CH-TRU. Thus, excluding RH-TRU waste is more conservative than including it.

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9. EEG believes that releases in brine could be somewhat larger (perhaps more than 100%) than calculated in the CCA or PAVT if non-random loading on a room-size scale was assumed. We agree that the cuttings and cavings releases will be about 25% higher if there is non-random loading on stacks of drums. Also, spallings releases are likely to be 25-50% higher with waste stream sampling on random emplacement and higher yet with sampling on non-random emplacement.

EEG disagrees with the DOE position (and EPA concurrence) that since non-random considerations do not show that these three release mechanisms would lead to non-compliance they are unimportant and can be ignored. The effect of these three mechanisms combined could increase the total mean CCDF at .001 probability by 50% or more. This is still a long way from non-compliance. However, there are other assumptions in PA models and parameter values that EEG does not believe have been shown to be non-conservative, that can also affect the final CCDF curve.

EEG recommends that releases from cuttings and cavings and spallings be determined from waste stream sampling based on non-random emplacement. Direct brine release values should be based on non-random emplacement on a scale no larger than one waste room. (1282)

Response to Comment 5.A.9:

According to the requirements of Section 194.24(d), "The Department shall include a waste loading scheme in any compliance application, or else performance assessments conducted pursuant to Section 194.32 and compliance assessments conducted pursuant to Section 194.54 shall assume random placement of waste in the disposal system." In the CCA, DOE chose to assume a random loading scheme rather than provide a detailed waste loading scheme. In its review of the CCA, EPA required that DOE provide additional documentation on how it planned to achieve random waste loading and, if DOE could not achieve random loading, DOE needed to analyze the effects of non-random loading. [May 19, 1997 Letter from R. Trovato, EPA/ORIA to A. Alm DOE, Docket:A-93-02, II-I-17] DOE's response to this request is documented in a May 2, 1997 letter from G. Dials, DOE/CAO to R. Trovato, EPA/ORIA. [Docket:A-93-02, II-I-28] In its response, DOE analyzed the effects on actinide concentrations in the brine, on cuttings/cavings, and on spallings of a loading scheme in which large quantities of a single waste stream were shipped to the WIPP at the same time and emplaced in the same location in the repository.

In addressing actinide concentrations in the brine, DOE examined possible flow paths through the waste and determined that the flow paths were sufficiently long and tortuous that the brine would be well mixed and representative of a large volume of waste. In addressing the effect of non-random loading on cuttings and cavings, DOE compared a random loading scheme with a scheme where three drums from a single waste stream are stacked vertically. The CCDFs for the two cases were essentially identical. This new information was reviewed by the Conceptual Models Peer Review Panel during its examination of the cuttings/cavings conceptual model. The Panel concluded in it Supplementary Conceptual Models Peer Review Report [Docket:A-93-02, II-G-12] that the model remained adequate. In addressing spallings release, DOE examined the impact of the highest activity waste stream containing at least 810 drums. The probability of intersecting a waste stream with fewer than 810 drums would be less than 0.001 -- the lower limit of the EPA standard defined in Section 191.13(a). The selected waste stream meeting this criterion was Rocky Flats residues containing 20,100 drum equivalents with 0.0496 EPA units of radioactivity per drum equivalent at 100 years after disposal (0.092 EPA unit/m^3 of waste and backfill). Based on the maximum spallings volume of 4 m^3 from the CCA, this would result in a total release of 0.368 EPA units as compared to the standard of 10 EPA units at an exceedance probability of 0.001. Thus, the impact of non-random loading on spallings is also small compared to EPA's standard in Section 191.13(a).

In its compliance review, EPA determined that it did not matter to compliance how the drums were placed in the waste. Consequently, the assumption of random emplacement was acceptable to the Agency. [CARD 24, Section 24.J.5 and 24.J.6, Docket:A-93-02, V-B-2] Moreover, EPA concluded that no waste loading scheme need be implemented. As stated in the proposed rule, "Since EPA concurred with DOE that a final waste loading plan was unnecessary, DOE does not have to further comply with 194.24(f), requiring DOE to conform with the waste loading conditions." [62 FR 58815]

EEG argues that non-random emplacement of waste should be included in PA assessment since this would increase the mean CCDF by 50% or more at the 0.001 probability level. However, as EEG also notes, even if non-random sampling is added to the PA calculations, one is still a long way from non-compliance. In fact, inspection of Figure 6-40 in the CCA [Docket: A-93-02, II-G-1, Volume I, p. 6-227] shows that the summed normalized release at a probability of 0.001 is about 0.2 EPA units as compared to a standard of 10 EPA units. Increasing the releases by 50% would result in the releases being 0.3 EPA units. Releases of this magnitude are still more than an order of magnitude less than the standard. Even if the waste were not emplaced in a random manner, the impact on the mean CCDF is small.

EEG further argues that these small changes should, never-the-less, be included because there may be other PA assumptions which EEG believes may be non-conservative. EPA disagrees and observes that the objective of performance assessment is to provide a reasonable expectation that the requirements of Section 191.13(a) will be met. It is not the role of PA to treat each event and process in the most conservative manner.

Issue B: Cavings

1. DOE is aware of the inconsistency in the CCA regarding the median and distribution of the waste shear strength between Appendix CUTTINGS and Appendix PAR. Appendix CUTTINGS is a Users Manual that provides a general overview of the use of the code, and uses example parameter values for illustrative purposes only. It is not intended to be consistent with the specific application of the CUTTINGS code in the CCA. Appendix PAR describes the parameter values used in the CUTTINGS code for the performance assessment calculations of the CCA. Thus, there is no discrepancy involved. The values found in Appendix PAR quote the actual values used in the CCA, whereas the values in Appendix CUTTINGS quote the original values used in the 1992 PA. (110)

Response to Comment 5.B.1:

EPA agrees that the values in Appendix PAR are the values used in the CCA PA. Support for this conclusion is documented in the Technical Support Document for Section 194.23: Parameter Report. [Docket:A-93-02, V-B-12]

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2. The model of cavings and spallings was the subject of EEG's presentation to EPA on January 21, 1997 (II-E-34). As to cavings, it was pointed out that the model does not account for the erosive action of particles contained in the drilling fluid. Further, cavings from helical turbulent flow (e.g., return flow) are not considered. Cavings from the action of the drillbit itself, as it penetrates waste, are omitted. Brine ejected before spallings is not considered. (1038)

Response to Comment 5.B.2: EPA disagree*s* that the cavings model does not address turbulent helical flow. As discussed on pp. 46 and 47 of the CUTTINGS_S User's Manual [Docket:A-93-02, II-G-3, Vol. 4], analysis of turbulent flow generally requires recourse to empirical methods because of the complexity of the processes. To address this issue, DOE modified the equations for axial turbulent flow to approximate helical turbulent flow by applying a rotation correction factor to the axial flow velocity. This correction factor is obtained by adjusting the turbulent flow velocity until the eroded diameter for turbulent flow equals the eroded diameter for laminar flow at a Reynolds number of 2100. (Transition from laminar to turbulent flow is assumed to occur at this Reynolds number.) The laminar flow equations specifically address helical flow, so that use of the correction factor extends the helical flow regime into the turbulent flow regime. EPA believes that this is a reasonable approach to a complex problem. Borehole flow is generally turbulent and turbulent flow is not amenable to exact mathematical solutions. Consequently, in modeling turbulent flow, fluid mechanics generally relies on empirical methods. The use of a correction factor based on laminar flow equations, which explicitly include the rotational flow component, is a logical way to approach the modeling of turbulent flow. EPA does not share the commenter's concern that brine ejection before spallings release is not considered for two reasons: first, direct brine releases are modeled separately from spallings and are accounted for in the CCA PA; second, all of the radioactivity is assumed to remain in the waste in the spallings calculation, even though some of it potentially would have dissolved in the brine and would have been counted as radioactivity from direct brine release. Thus, the analytical approach taken by DOE is conservative, since direct brine releases and spallings releases are modeled separately, with each model including all the radioactivity.

The commenter is correct in stating that the model does not specifically account for the erosive action of particles contained in the drilling fluid. The Agency does not believe it is necessary to model the erosive action of particles in the drilling fluid to model releases appropriately or to develop a reasonable expectation that cumulative releases estimated from performance assessment will meet the disposal standards because of the insignificant impact of this process. As presented in Appendix PEER of the CCA , the Conceptual Models Peer Review Panel concluded that "The model is sufficiently developed and uncomplicated that no serious concerns were found. It appears capable of accurately representing the waste that might be removed during a drilling intrusion and is fully adequate for implementation in support of the WIPP performance assessment." [Docket: A-93-02, II-G-1, PEER 1, p. 3-88] Further, it can be shown that the shear stress acting on the borehole wall is proportional to the mud density raised to the 0.75 power ($\rho^{0.75}$) and the viscosity raised to the 0.25 power ($\mu^{0.25}$). [Bourgoyne, et al. 1991; see Docket: A-93-02, Item V-B-1] Using 5% as the maximum solids carrying capacity of the drilling mud as described in the CUTTING-S User's Manual [Docket:A-93-02, II-G-3, Vol. 4], these solids would increase the mud density by 7% (based on a mud density of 1210 kg/m^3 and a solids density of 2839 kg/m^3). This would, in turn, increase the shear stress by 5%. Similarly, an increase in the mud viscosity of 10% due to the presence of solids would increase the shear stress acting on the borehole wall by only 2%. Thus, the stresses exerted on the waste would increase by less than 10%. Since the shear strength of the waste (TAUFAIL) varies by more than two orders of magnitude (i.e., one-hundred fold), these small changes in shear stress (i.e., <10%) would not have a significant effect on the total cavings release in comparison to the range already being calculated.

References

Bourgoyne, Adam T, et al., 1991. *Applied Drilling Engineering*, Society of Petroleum Engineers, Richardson TX (see Docket: A-93-02, Item V-B-1)

Issue C: EPA spallings modeling

1. What was EPA's intent in preparing III-B-10 and III-B-11? (82)

Response to Comment 5.C.1:

EPA prepared its analysis of spallings documented in Technical Support Documents for Section 194.23: Spallings Evaluation and Supplemental Spallings Evaluation [Docket: A- 93-02, V-B-10 and V-B-11] in order to model transport of spallings releases up the borehole during blowout which was not included in the CCA. These documents were intended to discuss the simplified analysis of waste particles that could be lofted up the borehole and to evaluate the dynamics of particle lifting based on gas flow rates. EPA undertook these studies before the Conceptual Models Peer Review Panel had completed its review of the Spallings Conceptual Model. At that time, DOE had not published the Spallings Release Position Paper. [Docket: A-93-02, II-G-23] The work was not intended to evaluate an alternative conceptual model but rather to determine the importance of transport up the borehole -- a process not considered by DOE who presumed that all failed spalled material would be removed to the surface. The studies thus provided a measure of the amount of conservatism in the DOE approach. At the time the studies were undertaken it was not known that the DOE spallings model in the CCA would produce conservative results without considering the additional limitation of borehole transport on releases to the land surface. Although the EPA studies provided insight into the sizes of particles which could be lofted from the bottom of the borehole to the surface, this information was not used in the Agency's compliance decision.

These analyses investigated gas production rates, velocities, and particle sizes that would affect the volumes of materials transported from the bottom of the borehole to the surface. The EPA modeling did not consider the processes by which spalling could occur. The EPA studies are complementary to the DOE work, in that DOE considered the quantity of material spalled and EPA considered what fraction of that spalled material could be transported up the borehole. If not all of the spalled material is transported to the land surface, transport will be the limiting process in determining the consequences of spallings.

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2. The EPA spalling investigation cannot be used to assess surface release of spall predicted by Hansen et al. In addition, EPA's bounding model is not really bounding, particularly if it's based on "the old CCA model" (Berglund 1994). (40)

Response to Comment 5.C.2:

The EPA spallings investigation as described in the Technical Support Documents for Section 194.23: Spallings Evaluation and Supplemental Spallings Evaluation [Docket: A- 93-02, V-B-10 and V-B-11], was not used to assess the surface release of spall predicted by Hansen, et al. [Spalling Release Positions Paper, Docket: A-93-02, II-G-23] It was used to estimate the maximum particle size which could be lofted under blowout conditions as a function of such parameters as waste permeability, depth of drill bit penetration into the waste, and assumed waste cavity size. By comparing the maximum particle size which could be transported with the expected particle size distribution in the waste, one can obtain an estimate of the fraction of the failed waste potentially transportable to the surface. As noted under Comment 5.C.2, if not all of the waste is transportable to the surface, then transport of the failed waste will limit the consequences of spallings compared to the volume of waste which fails in tension or shear. EPA performed the spallings analyses to determine if the spallings model would yield conservative results that overestimate releases, even if the spallings conceptual model was inadequate. The EPA model is not related to "the old CCA model"; rather, it addresses waste transport up the borehole. Transport up the borehole was not considered in the CCA which assumed that, if waste particles were eroded from the waste matrix, the particles were released to the land surface. The commenter does not indicate why he believes that the EPA spallings model cannot be used to address surface release of spall predicted by Hansen, et al. in Docket: A-93-02, II-G-23. While EPA did not couple the Hansen work to estimate failed waste volumes with its own transport modeling, the Agency sees no reason why this approach could not be undertaken. The commenter states that the EPA model is not bounding if it based on the old CCA model. As noted above, the purpose of the model is to describe the range of particle sizes which might be transported to the surface. There is no connection between the old CCA model and the EPA model. EPA believes the assumptions used in the model are fairly conservative and can be used to develop a bounding analysis for transport of waste up the borehole.

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3. Did EPA explore the possibility of "top-to-bottom" penetration of the repository? (83)

Response to Comment 5.C.3:

Yes. EPA did examine "top-to-bottom" penetration of the repository in its spallings evaluation. The Agency found that the results were not changed after the first two feet of penetration. The graph in the Technical Support Document for Section 194.23: Spallings Evaluation [Docket: A-93-02, V-B-11, Figure 10, P. 5-12] show this effect.

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4. Did EPA consider that drillers may not always use blowout preventers? (84a)

Response to Comment 5.C.4:

Yes. In its spalling modeling, EPA assumed that drillers did not use blowout preventers at all. The modeling in Technical Support Documents for Section 194.23: Spallings Evaluation and Supplemental Spallings Evaluation [Docket: A-93-02, V-B-10 and V-B-11] involved analysis of particle size and lifting of waste particles. It was never intended to model all aspects of drilling. EPA believes that not considering the use of blowout preventers is a conservative assumption. Blowout preventers are included on rigs for deep drilling. If blowout preventers are promptly activated, as intended, they would limit the transfer of waste from the repository to the land surface and decrease ultimate releases to the surface. This safety factor was not included in any EPA analysis.

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5. Did the Agency try using time-dependent waste permeabilities?(84b)

Response to Comment 5.C.5:

No. However, as described below, EPA evaluated the use of time-dependent waste permeabilities in performance assessment modeling. Based on the results of its evaluation, the Agency did not require DOE to include time-dependent permeabilities in modeling. There are two general aspects to evaluating the effects of time-dependent waste permeabilities. These pertain to brine flow and spallings releases. With respect to brine flow, which is more important for long term releases through transmissive geologic strata, DOE assigned a conservatively high estimate of $1.7x10^{-13}$ m^2 to the waste permeability. At this permeability, brine containing mobilized radionuclides is rapidly transmitted through the wastes toward the accessible environment. EPA does not believe that an approach to varying permeability with time would significantly enhance the analysis, since the wastes reach their final, constant permeability approximately within the first 200 years of the 10,000 year simulation. [Appendix PORSURF, Docket: A- 93-02, II-G-1] Thus, the use of a constant permeability is reflective of 98% of the regulatory timeframe. The likelihood of an intrusion during the first 200 years is very small and is, in fact, zero for the first 100 years due to the use of active institutional controls. [CCA Chapter 6, p. 6-182 and 6-183, Docket: A-93-02, II-G-1] For the spallings release predictions, the Agency did not believe it was necessary to use time-dependent permeabilities because the time frames involved in the spall, blowout and gas release calculations are very short (on the order of minutes), and waste permeabilities would not appreciably change during such a short period of time.

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6. The EPA investigation determined that venting of the repository would not be energetic enough to bring spall material to the surface. . . The investigation's focus is on relatively long term transportation capability consistent with the CCA spallings model. It should be on the immediate transport of material from the formation of an explosive spall cavity, as in the most recent DOE model. (689)

7. The permeability reduction used in the EPA model is inappropriate to address removal of the initial spall material. The spallings model of Hansen et al. predicts that spalling will stop after a few seconds and that depressurization is negligible beyond roughly 1.5 meters at this time. (690)

8. The temporal and spatial discretization of the EPA investigation is far too coarse to investigate the potential for evacuation up the borehole of spall material created in the first few hundred seconds. For example, in the case of a two foot penetration with 0.25 m^3 spall cavity, the first element of the EPA analysis is 0.39 m thick. In the Hansen et al. model, the first element is 0.01 m thick. In the EPA investigation the first time step is 86 seconds compared to 0.001 seconds in the Hansen et al. model. These differences in both temporal and spatial discretization are an indication that the EPA modeling cannot predict gas velocities from local depressurization reliably. (691)

9. Hansen et el. also considered the issue of maximum particle size that could be transported up the borehole. Their results indicate that particles as large as 10,000 microns may be transported to the surface after the mud column has been expelled from the borehole, about 250 seconds after intrusion, and that transport of such large particles could occur for much more than 200 seconds. Two-hundred and fifty seconds is still very early in the EPA investigation (3 time steps). (692)

10. The EEG therefore recommends to the EPA to **not** use the results of simplified modeling contained in the draft rule attachments TSD III-B-10 and III-B-11 to confirm the validity of the CCA spallings model, or to limit the potential releases from air drilling. (693)

11. Dr. Bredehoeft is incorrect regarding his assertions about the DOE models. Neither the CCA spallings model (Appendix CUTTINGS_S) nor the Hansen et al. (1997) spallings analysis attempted to bound the size of a solids release by modeling particulate transport up the borehole. In both of these models, processes occurring within the region of failed waste itself (i.e., in the repository), and the process of mud ejection from the borehole by Hansen et al. (1997), were considered to be the limiting factors, and not the transport of particulates in the borehole. In Hansen et al. a discussion of borehole transport is presented, but this phenomena is discussed only to demonstrate that particulate transport is exceedingly unlikely during the time period between drillbit intrusion into a waste panel and ejection of the mud from the drill string. The conceptual model comprising wellbore dynamics, transient gas flow and mechanical response of the waste established that the CCA estimates of spall volume, 0.5 to 4.0 m^3 are conservative. (937)

12. EPA and DOE both attempted to estimate the maximum particle size of waste that would be carried to the surface in a spallings release. (II-G-23; TSD III-B-IO, III-B-11). However, the analyses differ markedly in their conclusions: DOE’s analysis found that the maximum particle size would be 30 mm (II-G-23, Fig. 4-22). EPA's analysis found that the maximum particle size would be usually less than 100 microns and, in any case, would not exceed 570 microns. Neither report considered the prospect of stuck pipe and the driller's response thereto. (1025)

13. EPA's analyses (TSD III-B-10 and TSD III-B-11) fail to address the dynamic problem of spallings, in that they use time steps far too large to model the transient spallings behavior. (1026)

14. EPA initially “concluded that only small particles and/or a limited volume of waste could be entrained during a spallings blow-out.” (CARD 33 at 33-8; see TSD III-B-10 and TSD III-B-11). Later, EPA correctly determined that its independent analysis was inadequate to estimate spallings releases (IV-A-I at 18). Moreover, the EPA analyses ask what solids will be entrained in flowing gas and brought to the surface, when the appropriate question is what particles will be brought to the wellbore, since drilling equipment clearly will bring any waste that reaches the borehole up to the surface. (1027)

15. For consideration of removal of spall created in the first few seconds of a drilling intrusion into the repository, the calculations of Hansen et al. (1997) are more accurate than those of the EPA investigation because of the use of a one-dimensional cylindrical geometry and coarse

discretization in the EPA model. The EPA investigation underestimates velocities during a spallings event. Based on the information supplied by Hansen et al. (1997), large enough gas velocities are likely to occur during a spallings event, for a long enough period, to transport large amounts of the spall material up the borehole. In conclusion, the calculations of Hansen et al. (1997) indicate that transport of spall material up the borehole will not limit the release of spall material to the surface. (1249)

Response to Comments 5.C.6 through 5.C.15:

EPA initiated the spallings work that is presented in Technical Support Documents for Section 194.23: Spallings Evaluation and Supplemental Spallings Evaluation [Docket: A-93-02, V-B-10 and V-B-11] before the work performed by Hansen et al. [1997, Spallings Release Positions Paper, Docket: A-93-02, II-G-23] was released. The intended purpose of EPA's TSD documents was to provide some calculations to assist in identifying the processes and parameters that had the most influence on particle lofting velocities (which affect the transport of spalled material the surface). As such, the EPA model was not designed to predict cavity growth or the amount of material that would initially spall within the first few seconds after the waste was penetrated by the drill bit (Comments 5.C.6 and 5.C.7). Furthermore, since these were primarily calculations to define the general scope of processes and parameters rather than detailed modeling calculations, the temporal and spatial discretization were left relatively coarse, as some commenters noted (Comments 5.C.8 and 5.C.9).

EPA never intended the calculations in TSDs V-B-10 and V-B-11 to form the sole basis for spallings release predictions. Instead, these calculations would merely allow for some type of independent check on the amount of conservatism inherent in DOE's spallings calculations once they were completed. The EPA calculations were never intended as a substitute for the work by Hansen et al., which is a much more rigorous treatment of the spallings issue, as suggested by the commenter. In addition, Hansen's work predicts volumes of spallings releases, the most relevant calculation for consequences on PA, whereas EPA's modeling is simply a bounding calculation that examines sizes of particles and not volumes of spallings releases. EPA relies primarily on Hansen's work for estimates of actual spalled volumes in making its final certification decision (Comment 5.C.10). [CARD 23--Models and Computer Codes, Section 2.4; Docket: A-93-02, Item V-B-2]

Several of the comments question the validity of EPA's modeling of transport up the borehole (Comments 5.C.12 and 5.C.14). The Agency agrees that its modeling would require refinement to conclusively demonstrate the fraction of the failed waste which is transported to the surface. However, the Agency emphasize*s* that modeling of transport to the surface was not included in the PA calculations used in the CCA and the PAVT. Rather, all waste subject to tensile failure was conservatively assumed to be released for purposes of developing CCDFs. The Agency believes that not all spalled waste will be transported to the surface*,* but this was not embodied in the PA calculations. EPA's compliance determination does not depend upon the spallings modeling performed in Technical Support Documents V-B-10 and V-B-11, nor does it depend upon knowing the fraction of waste that will be transported to the earth's surface.

The Agency agrees that EPA's spallings model does not explicitly address the "stuck pipe" scenario. See EPA's response to Comments 5.E.1 through 5.E.24 for a discussion of why EPA believes the stuck pipe scenario will not occur at the WIPP. Comment 5.C.12 notes that the DOE modeling and the EPA modeling calculated different sizes for the maximum particle lofted to the surface (0.000570 m for the EPA study and 0.03 m for the DOE study). In the EPA study, the gas velocity in three different regions of the borehole was calculated -- in the spalled cavity adjacent to the drill bit, in the annulus between the drill collar and the borehole wall, and in the annulus between the drill pipe and the borehole wall. The lowest gas velocity was calculated to occur in the bottomhole cavity. The lowest velocity limited the size of particles which can be lofted to the surface. If the velocity is insufficient to loft a particle from the cavity to the drill collar annulus, it is not possible for the particle to be transported to the surface. The cavity velocity associated with lofting a 0.00057 m particle is about 3 m/s. [EPA Supplemental Spallings Evaluation, Docket:A-93-02, II-B-11] In its modeling DOE did not include a spalled cavity and thus the minimum velocities were higher than in the EPA study, creating the possibility that larger particles could be lofted to the surface. The EPA modeling approach is more realistic because it includes the cavity effect, which is an integral part of the spallings process.

EPA does not agree with the comment that the drilling equipment will clearly bring any waste which reaches the borehole up to the surface. In the case of blowout, the quantity of waste brought the surface will depend primarily on the size of the waste fragments and the velocity of the gas in the borehole not on the drilling equipment. In the case of stuck pipe and gas erosion, since mud circulation is not lost, the transport situation is different but is still limited by particle size. (Comments 5.C.12, 5.C.13, 5.C.14 and 5.C.15) DOE has noted in Comment 5.C.11 that the purpose of its transport work was to show that transport was unlikely before mud was ejected from the borehole and was not intended as a detailed analysis of volumes which could be transported to the surface.

Issue D: SNL/DOE's spallings GASOUT computer code

1. Measuring failed volume as a function of waste permeability, the GASOUT code generates some unexplained fluctuations in failed volume. Thus the GASOUT code may be unstable, especially when used as a tool to evaluate whether CCA spallings were conservative. (43a)

2. In addition, the conceptual model peer review accepted the conceptual model of GASOUT, but not the code itself. (43b)

3. Using the code GASOUT to estimate spallings releases with air drilling, and with waste permeability modeled to reflect porosity, releases range from several hundred to several thousand cubic meters of waste. (131)

4. [T]he author of the GASOUT code, the computer code that calculates releases due to spallings said it was never intended to be used for the purpose for which Dr. Bredehoeft used it, and, in fact, the author of that code called it an inappropriate and misleading use of the codes. In

summary, the Attorney General's letter and attached analysis are misleading, inappropriate, inaccurate, and incomplete.(212)

5. In an air drilling intrusion, about 50 to 2000m^3 of waste fails (i.e., breaks loose). The intrusion would cause “stuck pipe,” followed by a cleanout procedure, releasing 300 m^3 per day and possibly the entire failed volume. (712)

6. According to Dr. John Schatz, author of the GASOUT code, the analysis referred to by the Attorney General is *“an inappropriate and misleading use”* of the code. Dr. Bredehoeft’s report itself presents convincing objections to use of the code for the air drilling problem, a fact not mentioned in the Attorney General’s letter. . . GASOUT was devised and successfully used as one part of an extensive scientific exercise demonstrating that spallings releases presented in the CCA were, indeed, reasonable. A review of the expected conditions clearly shows that fundamental physical phenomenon present during an air drilling operation which (hypothetically) penetrates the WIPP are absent from the GASOUT code. Any results obtained from the code for this scenario are, therefore, meaningless. (725)

7. Our review of the report found that Mr. Bredehoeft’s modeling methods included the use of a computer code that is not applicable to an air-drilling scenario. Any results obtained from this code are meaningless, because the fundamental physical conditions present during an air-drilling operation are absent from this code. The report’s conclusions about the consequences of air drilling into the WIPP are overstated. (833)

8. An analysis of permeability with GASOUT showed that the code can only be applied to a small range of parameter values. For the most extreme case, using an initial pressure of 14.8 MPA and waste strength of 10 psi, the range is 1.7×10^{-13} to 2.0×10^{-13} m^2. . . The small range of permeabilities prohibits the use of the code under varying repository conditions. . . The code also underwent a sensitivity to the gas viscosity. . . It is reasonable to assume that the viscosity will be higher than the ideal value for Hydrogen at standard temperature and pressure. It will also be higher if other gas constituents are added to the repository. Yet, as the viscosity increases to values that are reasonable and defensible, the code calculates a very high failed volume due to the cascading effect noticed from low permeabilities.

Lastly, a sensitivity of the mud column density showed that the code does not promote a strong confidence in the results obtained from GASOUT. The analysis varied the parameter over a range of expected values at the WIPP, and found the code to behave erratically to small changes in values. . . The maximum reported spalled volume in Hansen et al. (1997) is only the maximum for a narrow set of repository conditions, and the code is shown to fail otherwise. (1087)

9. It is shown that the GASOUT code responds erratically to small changes in the input assumptions, and sometimes gives misleading results. GASOUT was the main code examined, due to its ability to remove material during failure, and for being the major code of spallings verifications for CCA values. EEG recommends that the code be examined more closely, before

judging the results of Hansen et al. (1997) as the maximum amount of failed material that will reach the surface, and the spalled volumes calculated in the CCA as reasonable. (1247)

Response to Comments 5.D.1 through 5.D.9:

Based upon the information provided in various comments (e.g. Comments 5.D.1, 5.D.8, and 5.D.9), it appears that the GASOUT code may not be stable under some conditions. This is not unexpected since the code was not designed to model air drilling or to model the blowout process beyond the first 5 to 10 seconds after intrusion as described in Summary of GASOUT Code Meeting, Docket: A-93-02, II-E-9. (Comment 5.D.1) GASOUT becomes unstable after mud is ejected from the borehole. Neither was the GASOUT code designed to simulate situations where the waste has near-zero tensile strength or where the permeability of the waste is less than about 10^{-14} m^2 as also discussed in the Summary of GASOUT Code Meeting. [*ibid.*] Over the range of conditions employed in the Spalling Release Positions Paper [Docket: A-93-02, II-G-23, Section 3.0], the code performs adequately as demonstrated by the comparisons with other modeling approaches documented in that report, such as the quasi-static spreadsheet model. [Docket: A-93-02, II-G-23, Section 5]

One commenter notes that the conceptual model underlying GASOUT was accepted by the Conceptual Model Peer Review Panel, but not the code itself. The role of the CMPRP was not to review specific codes; rather it was to review the conceptual models that the codes were designed to simulate. (Comment 5.D.1) The Agency has done its own testing with GASOUT and agrees with the DOE view that the code is stable only within a limited range of conditions. The Agency does not believe that attempts to use the code outside this narrow range are appropriate and relevant because the code is not stable beyond the specified range. Within its range of applicability, GASOUT produces results that are consistent with results obtained by other modeling approaches such as the Quasi-Static Model and the coupled numerical model. [Hansen, et al., 1997, Docket: A-93-02, IV-A-6]

Another commenter used the GASOUT computer code to estimate spallings releases that would result from air drilling and found much higher releases than those calculated in the CCA [Chapter 6.5] or in the Performance Assessment Verification Test. [Supplemental Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison with the Compliance Certification Application Calculations, Docket: A-93-02, Item II-G-28]

The Agency evaluated the adequacy of GASOUT for modeling air drilling and finds that the modeling mentioned by the commenter is inappropriate for this application (Comments 5.D.3 through 5.D.6). According to the consultant for Sandia National Laboratories who wrote the code (J. Schatz), GASOUT was developed to provide a physical description of repository behavior during the first few seconds after the repository is penetrated and gas from the repository is flowing into a mud-filled borehole (Comments 5.D.4 and 5.D.6). [Summary of GASOUT Code Meeting, Docket: A-93-02, IV-E-9, p. 2] The GASOUT code was not designed to model drilling using compressible fluids such as air, nor was it intended for low-permeability sensitivity studies (Comment 833). [Summary of GASOUT Code Meeting, Docket: A-93-02, Item IV-E-9, p. 2]

This code is appropriate for use in a relative narrow range of waste permeabilities from 10^{-13} to 10^{-14} m^2 and is not appropriate in the range found in the commenter's report. Additional information regarding GASOUT and its application may be found in Analysis of Air Drilling into WIPP by Dr. John Bredehoeft, M.K. Knowles, T.W. Thompson and J.F. Schatz SNL January 21, 1997 [Docket: A-93-02, IV-A-01. Attachment 2], and Responses to Air Drilling Letter from R.H. Neill, EEG to F. Marcinowski EPA, 12/31/97, P. Vaughn, D G. O'Brien and T. Hadgu January 15, 1998. [Docket: A-93-02, IV-A-01, Attachment 6] A good overview of DOE's approach to predicting spalling releases during air drilling is presented in Estimates of Maximum Spalling Releases from Air Drilling of Intrusion Boreholes January 21, 1998. [Docket: A-93-0, IV-A-01, Attachment 4]

The Agency has conducted its own modeling of spallings due to air drilling. [Section 6 and Appendix A of EPA's Analysis of Air Drilling at WIPP, Docket: A-93-02, Item V-B-29] This work used the Quasi-Static Model developed by DOE as a mechanistic model of spallings. This approach provides greater modeling flexibility than with the GASOUT code. EPA approximated flow of a compressible fluid, air, using the average density of the air column over the borehole length in order to adapt the Quasi-Static Model for air drilling. The Quasi-Static Model is conservative because it predicts the total volume of waste that is available for transport, which will be greater than the actual amount of waste transported to the surface. In addition, as shown in Hansen et al., 1997 , the Quasi-Static Model generally predicts larger spalled volumes than the Cavity Growth Model as implemented in the GASOUT code. [Docket: A-93-02, IV-A-6, Table 3-3] In its modeling of air drilling, EPA estimated failed volumes to be on the order of 1.4 m^3 (at an initial pore pressure of 14.5 MPa) which is within the range of spallings values predicted by the CCA and used in the PAVT evaluation (i.e., 0.5 to 4 m^3). [Docket: A-93-02, V-B-29, Section and Appendix A] Therefore, EPA concluded that releases calculated by the CCA and the PAVT are still appropriate and no further performance assessment calculations are necessary specifically to examine the impact of air drilling upon compliance with the containment requirements.

Comment 5.D.5 asserts that, when air drilling, about 50 to 2000 m^3 of waste will fail, which would cause stuck pipe. This comment also states that, during the cleanout procedure to free the stuck pipe by manipulating the drill string, 300 m^3/day*,* and possibly the entire failed volume*,* would be released to the surface. EPA disagrees. As discussed above, these failed volumes are based on incorrect use of the GASOUT code and are not relevant. Additionally, there is no information in Docket: A-93-02, IV-D-14 (the source of the comment) to support the conjecture that any quantity of failed waste would cause stuck pipe. Finally, the estimated cleanout rate is based on the supposition that, even with stuck pipe, it would be possible to increase the drilling rate to 600 ft/minute. This is far beyond the limits of air drilling capabilities when operating under normal conditions. [GRI 1995, as referenced in EPA's Analysis of Air Drilling at WIPP, Docket: A-93-02, V-B-29] Any waste pressed against the drill string with sufficient force to cause a stuck pipe condition would substantially reduce transport to the surface.

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10. DOE has also presented "Estimates of Maximum Spallings Releases from Air Drilling of Intrusion Boreholes (Letter, Dials to Kruger, Jan. 26, 1998, Att. 4)(IV-G-7). . .

(a) The argument based on waste heterogeneity asserts that, since 40% - 50% of the steel in the waste inventory will be uncorroded at the time of intrusion, the "drum remnants" will limit gas and particulate movement and will prevent release of more than nine drums of waste. . . Since no data support the assertion, EPA cannot accept it. . . DOE also asserts that 30% of the waste will be larger that the borehole annulus and will not be transported (at 7), but such claim ignores that such particles will actually stick the pipe, fragment, and be released.

(b) The argument based on particulate transport (fluidized bed theory) assumes that steady-state ("spreadsheet") calculations correctly model the gas velocities available to transport particles (at 16). But EPA has already noted that the spreadsheet calculations do not reflect the transients occurring in the highly dynamic circumstances of intrusion (IV-E-9 at 2). Therefore, they cannot "bound the response of the system during a hypothetical drilling intrusion." (Letter, Dials to Kruger, Jan. 26, 1998, Att. 4 at 16)(IV-G-7). Neither would the fluidized bed model incorporate transport by saltation (See IV-D-14 at 14).

(c) DOE asserts that a blowout with air drilling is preceded by "precursors," and it asserts that the driller would shut in the well in five minutes, but such assertions have no factual support and cannot be assumed. (1033)

Response to Comment 5.D.10:

EPA disagree*s* with the statement that there are no data to support the DOE arguments regarding waste heterogeneity. Heterogeneity of the emplaced waste has been clearly established*,* as documented in the Baseline Inventory Reports. [Docket: A-93-02, II-G-1, Appendix BIR] Further, DOE has shown in the CCA that the amount of iron remaining in the repository after 10,000 years is 40% to 98% based on CCA parameters and 28% to 98% based on PAVT parameters. [Docket: A-93-02, II-G-26, Appendix A, p. A-4] In a single waste panel the comparable figures are 0% to 98% for both the CCA and the PAVT. In Hansen et al., 1997 DOE shows that waste heterogeneity has a significant impact on spallings potential. [Docket: A-93-02, IV-A-6, Section 4.3] Hansen et al.'s modeling of waste with varying permeability (from 10^{-12} to 10^{-16} m^2) randomly distributed throughout a disposal room demonstrates that gas does not readily flow within the waste because of the absence of large interconnected zones of high permeability. In effect, the waste behaves much like homogeneous waste with a permeability of 10^{-15} m^2. At this permeability, DOE has shown that blowout will not occur in waste with uniform permeability. [*ibid*., Section 3.4.4.3] Thus, it is likely that blowout will not occur in randomly distributed waste with permeabilities varying from 10^{-12} to 10^{-16} m^2. .DOE also examined waste where the permeability varies throughout a sequence of horizontal layers. In waste that becomes layered due to varying amounts of brine influx, which reduces permeability near the bottom of the waste, DOE has shown that the pressure pulse associated with an intruding borehole will not move along the uppermost low-permeability layer (10^{-12} m^2) and cause extensive spalling of that layer. [Docket: A-93-02, IV-A-6, Section 3.4.4.3]

EPA acknowledges that the quasi-static spreadsheet model is based on the evaluation of a series of steady-state solutions made over a succession of small time steps*,* while the GASOUT code specifically models the transient case. However, EPA does not agree with the assertion that the spreadsheet approach cannot be used to provide bounding calculations. The excellent agreement between the Quasi-Static Model and the Cavity Growth Model, as implemented in the GASOUT code, was clearly demonstrated in Figures 3-19 through 3-25 in Hansen, et al., 1997. *[ibid*., Docket: A-93-02, IV-A-6]

DOE compared the two models with the function in the GASOUT code which provides for material removal from the cavity deactivated since, as discussed elsewhere in this section, the Quasi-Static Model does not incorporate material removal. EPA has extended the comparison to include use of GASOUT[8] with the material removal function activated. Similar, although not identical, results are included in Table 3-3 of Hansen et al 1997. [Docket: A-93-02, IV-A-6] The Agency's calculations show that, with comparable parameters, the tensile failure radius (i.e., the maximum radius into the waste due to the borehole where the radial tensile stresses exceed the tensile strength of the waste) for the Quasi-Static Model is 0.36 m. [Analysis Package for the Semi-Analytical Calculations Conducted in Support of an Alternative Spallings Model: Method II - the Quasi-Static Model, WPO# 47388, p. 172] In comparison, for GASOUT with material removal, the radius is 0.34 m, and for GASOUT without material removal, the failure radius is 0.17 m. This comparison supports the EPA position that calculations based on the Quasi-Static Model are reasonable and conservative since the failed volume predicted by the Quasi-Static Model is model is larger than for the Cavity Growth Model with or without failed material removal.

EPA does not agree with the assertion that the Quasi-Static Model cannot be used to bound the response of the system. The basis for the EPA position is included in the Response to Comment 5.E.29 (see comments for **Stuck Pipe, Gas Erosion, and Related Waste Permeability**). The commenter also suggests that the gas velocities used by DOE to estimate transport velocities are flawed. Further, as shown in Attachment 4 to the January 26, 1998 letter from G. Dials (DOE/CAO) to M. Kruger (EPA/ORIA) [Docket: A-93-02, IV-G-7], pore velocities exceeding 0.5 m/s are not expected (except for a very thin layer at the cavity surface) when the spalled cavity reaches 1 m in radius. At this expected pore velocity, only particles less than about 0.001 m in diameter will be lofted from a bed of particles. Based on data presented in the Estimate WIPP Particle Sizes on Expert Elicitation [Docket: A-93-02, II-G-36], only about half the particles are expected to be of a size that would be lofted from the particle bed. The process is expected to be self-limiting since, as the cavity size increases, the pore velocity, and hence the lofting capability, decreases.

EPA has not used any assertions by DOE that air drilling is preceded by "precursors" in its decision-making process. The Agency has frequently alluded to the fact that the PA calculations in the CCA and the PAVT do not consider transport of waste up the borehole during a spallings

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[9] GASOUT default parameters were used except for the initial pressure and the far field pressure. In this work, these pressure values were both set at 14.5 E+07 MPa rather than the default value of 14.8E+07 MPa.

event. If the waste fails due to tensile stresses, that failed volume is assumed to be transported, *in toto*, to the surface for purposes of calculating compliance with the standards. EPA believes that this is conservative and over-estimates the actual releases. As discussed in the preceding paragraph, the Agency also believes that, in a blowout event, not all of the waste will actually be transported to the land surface and released.

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11. GASOUT along with several other codes were used to prove that the spalled volume calculated in the Compliance Certification Application (CCA) were reasonable, because the GASOUT calculated a much smaller spalled volume. The volume of spalled material calculated in the CCA ranged from 0.5 to 4.0 m^3. It is believed that the analysis of Hansen et al. (1997) may be slightly misleading. For example, the simulated blowout in the GASOUT experiments only lasted for five seconds. Blowout usually takes several minutes to control, and it is believed that much higher volumes of failed material would be derived if the simulations were run for longer periods of time. (1086)

Response to Comment 5.D.11:

EPA agrees that the blowout process may take several minutes to control. In addition, it has been estimated with the Quasi-Static Model that about 84 seconds are required to drive the mud column from the borehole when the pore pressure is 14.5 MPA and the waste permeability is $1.7x10^{-13}$ m^2. [Analysis Package for the Semi-Analytical Calculations Conducted in Support of an Alternative Spallings Model: Method II - The Quasi-Static Model, WPO# 47388, p. 44] However, data show that the maximum tensile failure occurs after only 0.5 s [ibid., Figure 7] Similarly, DOE has shown that the radius for tensile failure reaches its maximum value in about 1 s when running the GASOUT code under similar conditions to the Quasi-Static Model (except that material removal from the spalled cavity is included in the process), demonstrating good agreement between the two models. [Hansen et al. 1997, Docket:A-93-02, IV-A-6, p. 3-17] Thus, regardless of the time required to blow the drilling mud from the borehole and the time required to bring the blowout under control, no additional waste material will fail and be available for transport to the surface after the first few seconds.

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12. It is also recommended that a new spallings code be developed, that incorporates all the aspects of failure correctly. The GASOUT code seems to have difficulty with redistributing the pore pressures once waste has been removed. Also, the code only addressed the concern of tensile failure. In a hemispherical geometry, tangential forces will cause the material to be in compression, and the material could fail in shear. The GASOUT ignores shear failure as a possible mode of failure, although it is calculated. The strength of the waste is nominal in compression (measured values in Hansen et al., (1997) show a typical value of approximately 100 psi), and the pressures exerted from the overburden rock could cause the material to yield. (1248)

Response to Comment 5.D.12:

As discussed elsewhere in this section (see Response to 43a, 43b, 131 etc.), the range of applicability of GASOUT is limited. While it would be desirable that the code had broader applicability, this is not necessary for a compliance decision. In characterizing the spallings process, DOE used other analytical tools including the Quasi-Static Model and a fully coupled numerical model. The three approaches all supported the conclusions of the Conceptual Models Peer Review Panel on the spallings process. It is incorrect to say that the code only addressed concern for tensile failure, and not shear failure; as noted by the commenter, GASOUT calculates shear failure volumes using an appropriate failure criterion. Shear failure is also calculated in the Quasi-Static Model. DOE notes in Hansen et al., 1997 that, " in general, the extent of the shear zone is either similar to or less than that of the tensile failure zone for these calculations." [Docket: A-93-02, IV-A-6, p.3-10] In tests with GASOUT, EPA noted that, at an initial pore pressure of 14.5 MPa with the failed material option activated, that the tensile failed radius was 0.34 m and the shear failed radius was 0.16 m. This is consistent with the quoted DOE observation. While shear failure is possible, its consequences are likely to be less than for tensile failure, based upon data such as these. If shear failure occurs before tensile failure, the shearing process will act as a stress relief mechanism, reducing tensile stresses and minimizing tensile failure. Additionally, shear failure is likely to produce a few cracks in the waste but leave the bulk of the material within the cracked region essentially intact. EPA bases this conclusion upon extensive modeling and field testing done on methods to stimulate gas (methane) production from coal seams. Rock properties and stress levels are similar to those expected in WIPP wastes. [*ibid*., Table 5-26] The modeling and field testing results show that a cavity forms in that portion of the coal seam subjected to differential pressures sufficient to cause spallings and that a large volume of coal beyond the cavity perimeter is plastically deformed by shear stresses but is not removed during repeated pressure cycling. [Cavity Completions for Enhanced Coalbed Methane Recovery, Khodaverian, et al., Gas Research Institute, June 1996] Thus, the material will not be reduced to particles which can readily be transported up the borehole. Shearing will increase the permeability of the waste, which will reduce pressure gradients and stabilize the borehole. [Hansen, et al., 1997, Docket: A-93-02, IV-A-6, p. 5-9]

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13. EPA's assumption that the new spallings model is adequate to answer all spallings concerns does not address EEGs' concerns. EEG believes that relying solely on the results from the new spallings model may be underestimating the importance of the issue. For example, the new spallings model cannot simulate all expected repository conditions. Locally varying waste permeability or different gas viscosities cause the code to produce erroneous results. It is therefore suggested that the EPA look more closely at the newer model before dismissing any comment on spallings. (1311)

<u>Response to Comment 5.D.13:</u>

From the context of the comment, the Agency presumes that the commenter is referring to the GASOUT computer code used to implement the Cavity Growth Model in DOE's revised spallings analysis as presented in Hansen, et al., 1997. [Docket: A-93-02, IV-A-6] The Agency agrees that the GASOUT code is not the answer to all spallings concerns. EPA has characterized the shortcomings of the GASOUT code with its own studies. The Agency also has carefully considered every comment on spallings issues. The Agency has recognized that GASOUT is only one part of a three-pronged approach in analyzing spallings releases and has considered all three approaches in its decision-making process. When used within defined limits, results from GASOUT are consistent with results from the Quasi-Static Model and the fully coupled numerical model. [*ibid*.] Under some conditions of permeability or viscosity outside the range utilized in Hansen et al. 1997, [*ibid*.] the code may produce erroneous results. EPA believes that it has carefully considered several models for predicting spallings and that data from these models show that the results of the spallings model used in performance assessment are conservative.

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14. The Quasi-Static model uses a Runge-Kutta method for solving the analytical equations for 1-D flow of gas through porous media and the blowout of the drilling fluid. In addition, it solves the analytic expression for radial and tangential stresses in the waste near the wellbore. The model is a simplistic analysis, in that it solves a series of steady-state approximations to flow.

The EPA's analysis showed that under expected repository conditions, the release from an air drilling scenario would not be greater than 1.4 m^3, and hence much less than the predicted releases of the CCA and PAVT. . .

Several conceptual flaws can be seen from the analysis in U.S. EPA (1998). First, the code was not designed for failure. It was only designed to calculate the stresses in the waste, assuming no waste failure and subsequent removal occurs. Waste removal will have significant impact on the actual pore pressures that may exist. Second, the code was not designed to handle a compressible fluid as the drilling medium. The code assumes that water (or some other incompressible fluid) will be ejected from the borehole upon blowout. In reality, the gas from air drilling will expand, causing the weight of the drilling fluid to be over predicted in the model. The over prediction will cause the flow of the gas from the repository to be less, and time for complete blowout to be longer.

The code also only approximates the pore pressures in the repository by assuming steady flow. . . This characteristic, when combined with total stress of the overburden rock, produces oddly varying effective stresses in the waste. This shows that the code produces unreliable results for an air drilling scenario. . . Beyond the first couple of time steps, the code starts to be less accurate, and pore pressures begin to decrease in waste that should have been removed.

The analysis of air drilling by EPA also only showed one particular view of repository conditions. For example, the repository pressures can be above the assumed 14.5 MPa, and may be as high as 14.8 MPa, . . . When the Quasi-Static model was increased to 14.8 MPa, the code predicted stresses that would lead one to interpret a failure of 19.1 m^3. This is over ten times the predicted value stated in the EPA analysis. (1255)

Response to Comment 5.D.14:

The commenter asserts that there are several conceptual flaws in EPA's approach to the modeling of air drilling. EPA has described in considerable detail in its Response to 5.C.10 above the reasons why it believes the Quasi-Static Model is an appropriate analytical tools for analyzing spallings releases. As noted, results from the Quasi-Static Model are similar to but slightly more conservative than those obtained with the Cavity Growth Model. In EPA's Analysis of Air Drilling at WIPP, the Agency accounted for the fact that the drilling fluid was compressible by using an average density for the air column. EPA showed that varying this density by ±50% did not appreciably affect the results. [Docket: A-93-02, V-B-29] EPA also compared its modeling approach with a more rigorous treatment of fluid compressibility based on the methodology described in Analysis Package for the Semi-Analytical Calculations Conducted in Support of a Spallings Model for an Air Drilling Intrusion. [WPO# 48057] The Agency found that the calculated spalled volumes from the more rigorous method were in good agreement with those calculated using an average density for the air column in the borehole. [Docket: A-93-02, V-B-29, Appendix A] As discussed in Appendix A [*ibid*.], the maximum failed volume when instantaneously decreasing the bottomhole pressure from 14 MPa was 0.47 m^3 (in 0.2 s) using the more rigorous DOE approach and 0.36 m^3 (in 0.5s) using the simplified EPA approach. Based on this work*,* EPA disagree*s* that the spreadsheet model produces unreliable results.

The commenter states that, at a pressure of 14.8 MPa, the stresses predicted by the Quasi-Static Model suggest a failure volume of 19.1 m^3. The Agency's calculations do not support such a value. Using the methodology described in Appendix A of EPA's Analysis of Air Drilling at WIPP [Docket: A-93-02, V-B-29], the Agency calculates that the uncompacted volume of waste which failed in tension is 9.9 m^3 (at a pressure of 14.8 MPa and a waste permeability of 2.4 x 10^{-13} m^2). EPA notes that, based on the mean pressure CCDF (i.e., the arithmetic average CCDF for the pressure at the time of the first intrusion based on 100 realizations from replicate 1 of the CCA) for the repository presented in Appendix E of Hansen, et al., 1997 [Docket: A-93-02, IV-A-6], the probability of the pressure equaling or exceeding 14.8 MPa is about 3 x 10^{-3}. In addition, as described in EPA's Analysis of Air Drilling at WIPP [*op. cit*.], the probability of a borehole being drilled through the salt section with air rather than mud is less than 2%. Thus, the probability of an air drilled hole intersecting the repository pressurized to 14.8 MPa is about 6 x 10^{-5}. This probability is less than the exclusion limit of 10^{-4} specified in Section 194.32(d). From a consequence perspective, it can be shown, using the methodology described in Section 6 of EPA's Analysis of Air Drilling at WIPP, that the average spallings release volume would increase from 2.25 to 2.40 m^3 -- a change of about 7%. Inspection of Figure 6-41 in the CCA [Chapter 6, Docket:A-93-02, II-G-1] shows that, at a probability of 0.1, the spallings consequence is about 0.03 EPA units as compared to the standard of one EPA unit. Thus, a 7% increase in this consequence estimate will not significantly impact the results of PA. From both probability and consequence perspectives, the impact of a spallings release of about 10 m^3 is negligible. Even if such an event occurred and caused 9.9 m^3 of waste to fail in tension, the pore velocity in the failed waste would not be sufficient to loft all of the waste from the particle bed and transport it to the surface (see Response to 5.C.10 above). As described in EPA's Analysis of Air Drilling at WIPP [*op. cit*.], from a regulatory perspective, the Agency believes that PA does not need to include air drilling.

Issue E: Stuck Pipe, Gas Erosion, and Related Waste Permeability

1. DOE has also stated (responding on March 13, 1997 to NMAG comments) that the CCA permeability value is the same as that in the 1991 PA. . .The 1991 PA median values plainly come from Butcher (1990). The 1991 PA explains that the range of combustible values is based on the transient and end-state values for material #2 in Butcher (1990). The values for metals are as proposed by Butcher (1990). The 1991 PA does not explain the origin of the range for sludges, which does not go as low as Butcher (1990)'s minimum. (121)

Response to Comment 5.E.1:

The Engineered Systems Data Qualification peer review panel noted that the median combustible value is the mean of two tests on material #4 in Butcher, 1990 (which includes metals and cement, as well as plastics, wood and cloth). [See Engineered Systems Data Qualification Peer Review Report, CCA Appendix. PEER-5, pp. 5-12 through 5-19] It also noted that the median value for metals or glass is the highest value reported in the tests in Butcher, 1990. (In fact, the permeability value of 5×10^{-13} m^2 fell to 4×10^{-15} m^2 in 24 hours during the experiments). The panel also noted that the sludge values in Butcher, 1990 are from literature sources for cement. The low end value of 1.6×10^{-19} m^2 was based on ordinary Portland cement (CSA Type 10) cured for 130 days and the high end permeability of 1.7×10^{-16} m^2 was based on high alumina cement with fly ash. Butcher chose a median value of sludge permeability near the high end of the range. As the commenter notes, the low end of the range of sludge permeabilities in the 1991 PA (which formed the basis for the CCA) was set at 1.1×10^{-17} m^2 but the median sludge permeability remained unchanged at 1.2×10^{-16} m^2. This change between Butcher, 1990 and the 1991 PA has no effect on the waste permeability used in the CCA since the overall waste permeability of 1.7×10^{-13} m^2 was derived from the median permeabilities of the three waste components (i.e., combustibles, metals/glass, and sludges).

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2. The waste permeability used in the CCA was too high because it failed to consider the presence of MgO in the repository. In addition, the threshold permeability (10^{-16} m^2) for stuck pipe and gas erosion is faulty, because it was based on an estimate from outdated spallings code. Moreover, since blowout has been shown to cease between 10^{-14} and 10^{-15} m^2 (Hansen et al., 1997), stuck pipe and gas erosion should be considered in spallings releases. (42)

3. The fixed value used in the Compliance Certification Application for waste permeability -- 1.7×10^{-13} m^2 effectively eliminates from consideration two scenarios which involve large releases of waste: gas erosion and stuck pipe. The CCA treatment of waste permeability as an unsampled variable is not justified. The permeability of sludge wastes, in particular, is low enough to cause gas erosion or stuck pipe, and such wastes are expected to form a substantial quantity of the waste inventory. Moreover, available data suggests that other wastes may also have a permeability low enough to cause gas erosion or stuck pipe. (118)

4. DOE has asserted that gas erosion and stuck pipe can only occur if the waste permeability is lower than 10^{-16} m^2. In the CCA DOE has used a fixed value for waste permeability of 1.7 x 10^{-13} m^2. What underlies these figures? (119)

5. The CCA refers to values reported in Luker et al. (1991). (DOE, responding on March 13, 1997 to NMAG comments, stated specifically that the data supporting the permeability values was published in Luker et al. (1991)). The CCA states that Luker et al. (1991) showed permeabilities from 10^{-12} m^2 to 10^{-16} m^2 under lithostatic load. Of the materials examined in Luker et al., only two of eight samples included any backfill, and that backfill was crushed salt. None of the samples included any sludges. Luker et al. also say that permeability values were "quite variable between different samples of the same materials." Further, "the various granular materials had large grain sizes to intentionally represent worst case scenarios with respect to permeability." That is to say, there was a bias in favor of high permeability. (120)

6. The CCA states that "[u]se of a constant value rather than a variable has been found acceptable (Vaughn et al. 1995)." (CCA at 6-100). However, the only comparison of use of a variable permeability value with the use of a fixed value has involved varying the waste permeability with room porosity; i.e., the permeability assigned to the entire waste body was varied to reflect the effects of room closure. (See Vaughn et al. (1995) at 33-35, 69). The Vaughn et al. memo does not consider the effect of using a range of permeability values reflecting the characteristics of different waste types on projected blowout/gas erosion/stuck pipe releases. (122)

7. The peer review report points out that (as stated in Lappin et al. (1989)) average permeability of waste in a room depends on whether flow paths through different types of material are parallel or in series. It notes that in Lappin et al. (1989) flow paths were “conservatively" assumed to be parallel -- thus again resulting in use of the highest available permeability estimate. . .Under such assumption, the permeability value for the most permeable waste type will, in effect, be assigned to the entirety of the waste and be the "controlling permeability."

However, in considering a borehole intrusion, parallel flow paths cannot be assumed, since flow will occur to a point (the borehole), and as flow approaches the borehole, alternative flow paths are excluded. Thus, a borehole may penetrate a point where several drums of sludge are stored. The behavior of gas and waste at that point will be determined by the permeability of sludge, regardless of the presence of other waste types in the room. Series flow is the appropriate model, and the permeability of the least permeable waste type -- the sludge -- should be assigned to the waste. Therefore, it is important to consider the variety of waste types present in the room and their different permeabilities. (123)

8. The peer review panel noted the uncertainties as to placement of waste, collapse rate of drums, and use of backfill and stated that such uncertainties could cause the permeability to vary by up to an order of magnitude (a figure whose origin is entirely unexplained) but found that variation immaterial. (Appendix. PEER-5 at 5-17). So saying, the panel gave no thought to spallings releases, gas erosion, or stuck pipe and considered exclusively underground releases. (124)

9. Additional test data on waste permeability appears in the Spallings Release Positions Paper, Knowles et al. (1997). Surrogate waste samples were made and tested for strength and other characteristics. None of the samples tested for permeability had MgO backfill in the recipe. Also, most were compacted at 5 MPA, rather than full lithostatic pressure. "Experimental work emphasized conservative potential states, i.e., dominantly saturated conditions without MgO." (at 2-1) Again, conservatism was associated with high permeability. Testing was usually performed on brine-saturated samples. Permeability to brine was obviously tested in saturated conditions. Two tests were run on specimens S14 and S24, giving permeability values of 5.3×10^{-15} m^2 and 2.1×10^{-15} m^2 (at 2-17, 2-18). Specimen S14 included iron, glass, crushed concrete, crushed gypsum, crushed salt, and soil. Specimen S24 included such ingredients and various cellulosics. Plainly, these values are near the extreme low end of the range estimated in the 1991 PA and are well below the fixed value of 1.7×10^{-13} m^2 used in the CCA. Sludge was not tested, nor was waste with MgO. (125)

10. Moreover, as stated above, in considering gas erosion/stuck pipe, the relevant permeability is that in the specific area around a borehole. Certain wastes (i.e., sludges) plainly do have permeability within the range that will cause stuck pipe/gas erosion. How the addition of MgO to the waste will enhance local permeability of other waste types is not known. But in determining whether to (for instance) apply a sampled range to the permeability value or to assume a lower permeability, the gas erosion/stuck pipe scenarios have not been considered. As a result, the CCA entirely omits to consider the risks of gas erosion/stuck pipe. (126)

11. Previous calculations of the response of the WIPP waste form during a spalling event have represented the waste as a uniform, granular medium. However, recent work on waste degradation, brine inflow, and drum corrosion indicate that the waste form will be highly heterogeneous. It will also be relatively compartmentalized by partly corroded drums during the first intrusion, making it impossible to transport large volumes of waste to the surface in either an air or mud drilling scenario. (657)

12. It shows that the mechanical strength parameters used by DOE are conservative estimates of the weakest materials possible in the underground, and that bulk waste permeability and porosity used in the system performance assessment for disturbed and undisturbed scenarios are appropriate for the CCA calculations. These arguments obviate the critics concern about the possibility of the “stuck pipe” scenario. (658)

13. The EEG continues to believe that the “stuck pipe” is a plausible scenario because the threshold of 1×10^{-16} m^2 for stuck pipe and gas erosion may be faulty. This value resulted from the CCA Spallings model (as part of CUTTINGS_S), which was found to be conceptually flawed. (694a)

14. The new spallings model, GASOUT (Hansen et al., 1997), shows that blowout will cease when permeability is between 10^{-14} and 10^{-15} m^2. Berglund (1994) has shown that when blowout stops, the stuck pipe and gas erosion mechanisms of spall take over because the failed waste will be introduced into the borehole cavity and will not be blown out. Thus, the permeability

threshold for the stuck pipe and the gas erosion scenarios appears to be 10^{-14} to 10^{-15}, rather than 10^{-16}. In any case, because of the stuck pipe and the gas erosion scenarios coming into play when the blowout ceases, release to the surface will occur even when the conditions for blowout of the mud column cease. We therefore recommend that it should be assumed that all of the calculated spall material will reach the surface. (694b)

15. Furthermore, the permeability of the waste in the WIPP repository is quite likely to be lower than that anticipated by the DOE. None of the waste surrogates for permeability testing included MgO as a backfill material. . . Since the permeability of the waste is such a key parameter in assessing compliance with the standards, additional permeability measurements on surrogate waste that includes magnesium chloride cement should be carried out. Until this is done, the calculations may sample on the 10-12 to 10-16 range. (695)

16. [T]he assumed waste permeability value directly affects the projected release of the waste to the surface if a future driller inadvertently drills into the repository. The determination of the future permeability of the waste in the repository is highly speculative due to the inhomogeneous nature of the waste and the uncertain synergistic effect of a host of factors such as, precipitation from the magnesium oxide backfill and compaction due to salt creep. Yet, the DOE and the EPA argument for not considering all of the potential processes as part of the *spalling* scenario is essentially that the waste permeability may be as low as 10^{-15} m^2 but will not be 10^{-16} m^2, the assumed threshold of permeability for the excluded processes to come into play! Newer data indicates, in fact, that these processes may operate at the permeability equal to or more than 10^{-15} m^2. (719)

17. Bredehoeft perpetuates a model of the waste as a granular cohesionless material as assumed in the CCA for the cavings model. The compacted waste inventory will not remotely resemble cohesionless, particulate material. In fact, the physical and mechanical properties will include:

- ♦ blocky character,
- ♦ cohesive (possessing tensile and compressive strength);
- ♦ high porosity; and,
- ♦ spatially variable permeability

By contrast, experience with stuck pipe in the petroleum industry necessitates:

- ♦ sedimentary formations, especially weakly consolidated sandstones and shales;
- ♦ little or no cohesion between particles;
- ♦ low permeability; and,
- ♦ high pore pressure.

The physical and mechanical contrast between materials that could give rise to stuck pipe and the cohesive, bulky, compacted, waste suggests that conditions applicable to stuck pipe, as experienced in the petroleum industry, will not occur. (938)

18. The FEP discussion eliminates from consideration the physical properties of backfill, and specifically, the effect of MgO backfill in reducing the permeability of the waste disposal rooms. (969)

19. EPA states that originally DOE used a value for waste permeability of 1.7 x 10^{-13} m^2, and "[m]ore recently, DOE measured the permeability of surrogate waste mixtures based on current understanding of waste mixtures and degraded waste characteristics and determined the permeability of waste surrogates to be 2.1 x 10^{-15} to 5.3 x 10^{-15} m^2 on two samples (Docket: A-93-02, II-G-23, page 2-18). Based on the available waste permeability information, EPA concluded that the gas erosion and stuck pipe processes should not occur because permeabilities will be greater than the 1 x 10^{-16} m^2 threshold." (CARD 23 at 108). EPA accepted DOE's use of the permeability values of 1.7 x 10^{-13} m^2 and 2.4 x 10^{-13} m^2 (as corrected) without applying any sensitivity analysis that considered possible spallings, air drilling, stuck pipe, or gas erosion scenarios.(1028)

20. In its proposed decision EPA did not use realistic permeabilities based on actual experimental data, which do not exist because DOE and Sandia have not completed such experimentation. (1134)

21. A strict calculation of permeability can be a dual-edged sword. The assumption that flow will be parallel to the artificial layers in each drum may be conservative for the calculation of maximum flow of gas and brine in the repository, yet nonconservative when considering the damaging effects of stuck pipe (and/or gas erosion) from a lower permeability. A lower permeability can be calculated if flow is assumed to be perpendicular to the waste layers. In this assumption, the lowest permeability layer will contribute largely to an effective permeability of the waste. With a perpendicular flow assumption, the effective permeability could be as low as 5.9 x10^{-16} m^2. Therefore, the parallel flow is arbitrary, and could be seen as a nonconservative calculation. (1242)

22. Calculations of waste permeability from discrete layers of different waste material in the drums is inherently incorrect. In reality, the waste in the drums emplaced at the WIPP will be heterogeneously mixed, not in distinct layers, and the test specimens from Butcher (1990), and Luker et al. (1991) should have included a mixture of all waste types. A new set of permeability measurements from Hansen et al. (1997) report that the permeability of waste could be as low as 2.1 x 10^{-15} m^2 with a typical value of 4 x 10^{-15} m^2, using heterogeneously mixed waste.(1243)

23. In addition to lower permeability, the effects of MgO will increase waste strength in some localized areas. Permeability and strength are inversely correlated. Yet, if permeability and strength measurements taken on waste surrogate specimens with MgO are to be ignored based on conservatism, it must be remembered that the waste strength of specimens which varied between 5 to 15 psi in Hansen et al. (1997) also had permeability values on the order of 4 x 10^{-15} m^2. So, if a permeability, lower than that used in the CCA (and consequently in the PAVT), is used in a model as more representative repository conditions measured values from Hansen et al. (1997), the waste tensile strength from the same report should also be used. (1244)

24. It is essential that the sensitivity of the Hansen et al., (1997) spallings model to waste permeability be investigated before the EPA can conclude that the spallings model used in the performance assessment is indeed conservative as stated in the proposed rule. Unless further additional measurements on surrogate waste that includes magnesium chloride cement are available, the range of 10^{-12} to 10^{-16} m^2 is a reasonable range to investigate the sensitivity of the spellings model to permeability variation. If it is found that the model predicts greater spall volumes in this range than calculated in the performance assessment then the measurements of surrogate waste with magnesium chloride cement should be conducted to define the range more closely. (1245)

25. Conditions that do not lead to blowout of the mud column do not indicate that releases to the surface will not occur. Unless it can be shown that entrainment of spall into the drilling mud, "gas erosion", or re-drilling by the operator, "stuck pipe", will be limited, it should be assumed that all of the calculated spall material will reach the surface. (1246)

Response to Comments 5.E.2 through 5.E.25:

Various commenters questioned the value of the waste permeability used in the CCA. For example, several commenters (Comments 5.E.2, 5.E.10, 5.E.15, and 5.E.16*)* suggest that the waste permeability is inappropriate because it did not consider the presence of MgO in the repository. The impact of MgO on waste permeability is not pronounced*,* as will be described by the following argument.

Example of impact of MgO on waste permeability

During the first few hundred years after repository closure, the open space, or porosity,[9] in a waste disposal room of the repository will tend to be reduced by the inward creep of the surrounding halite in response to lithostatic pressure (i.e., pressure from overlying rock layers). Concurrently, brine from the Salado Formation will begin to seep into the repository and react with iron or organic materials to generate gas. The gas will create a back stress which opposes the creep closure process. Eventually, the opposing processes will reach equilibrium. At equilibrium, the room will have a porosity controlled by the amount of gas generation. The relationships between gas-induced pressurization and the lithostatic pressure exerted by the

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9 "Porosity" is the fraction of space present that is open and can store gases or liquids, as opposed to space filled by solid matter. Open space, or "pores," in a waste disposal room in the repository are spaces unoccupied by drums containing waste or by solid magnesium oxide (MgO). Open spaces in the repository room can then be filled by gases generated from the waste or by brine entering the repository. At the time of closure, a disposal room in the repository will typically contain 55-gallon drums comprised of waste and pore space, porous packages of MgO between and on top of the drums and head space between waste and the roof of the disposal room. All of this void or pore space constitutes the initial porosity in the disposal room. After the repository is closed the porosity will change in response to the competition between various physical (e.g., creep closure) and chemical (e.g., gas generation) processes.

overburden are used to developed the porosity surface[10] as described in Appendix PORSURF. [Docket: A-93-02, II-G-1, Volume XVI] As shown in Figure PORSURF-3 [*ibid*.], the minimum porosity of about 0.23 occurs at 10,000 years with no gas generation. It is assumed in the Salado Interbeds Conceptual Model that the pressure will not rise above lithostatic (i.e. 14.8 MPa) because the brittle anhydrite marker beds will fracture when the threshold stress is exceeded, creating a pressure relief mechanism. [Technical Support Document for Section 194.23 - Models and Computer Codes, V-B-6, Section 1.3.23] If the repository pressure is limited to about 14.8 MPa by this relief mechanism, then the fractional gas generation rate is about 0.45 times the nominal rate of 1600 moles of gas per drum. [*ibid*., Figure PORSURF-4] This, in turn, sets an upper limit on the waste porosity of about 0.58 for this fractional generation rate. [*ibid*., Figure PORSURF-3] The ideal gas law defines the relationship between pressure and volume (i.e., porosity) for a given amount of gas generation. This porosity then determines the permeability of the waste. A quantitative relationship between porosity and permeability can be established with the Kozeny-Carmen equation as described in Appendix D to MASS Attachment 16-3. [Docket: A-93-02, II-G-1, Volume X, discussed in greater detail, *infra*]

Having established a relationship between pressure, porosity and permeability, one can demonstrate that the volume of the precipitated salts will not significantly affect the porosity and permeability. In this example, EPA will compare porosity in four stages: 1) initial waste porosity as drums of waste are put in the repository; 2) room porosity considering emplaced waste and solid MgO; 3) room porosity as brine first enters the repository before brine and MgO react; and 4) room porosity based upon waste, brine, and compounds in reactions between brine, gases generated from waste, and MgO that create salts from magnesium ions.

Consider a room with an initial volume of 3644 m^3 containing 6804 drums each having a volume of 0.2539 m^3. [SAND92-0700, vol. 3, Docket: A-93-02, II-G-1, Ref. 563] The initial waste volume, including open space in the drums, is 1728 m^3 (0.2539 m^3 per drum x 6804 drums). The initial waste density is 757.6 kg/m^3 [per BIR, Rev. 2, Docket: A-02-03, II-G-1, Vol. III] and the average solids bulk density (i.e., the density of pore-free solid material) for this waste mixture is 2839 kg/m^3. The initial waste porosity is 0.73 (i.e., 1- {(initial waste density)/(average solids bulk density)}, or 1-757.6 kg/m^3 /2839 kg/m^3) and the waste solids volume is 467 m^3 (initial waste volume times the waste's solid volume fraction in the container, or 1728 x (1-0.73)).

Further, the repository contains 77,640 metric tons (mt) of MgO [Docket: A-93-02, II-G-1, CCA, Chapter 3] and the excavated volume of the repository is 436,000 m^3 (SAND92-0700, vol. 3, op. cit.). The effective repository-wide MgO density is 178 kg/m^3 (mass of MgO divided by volume of repository, or 77640 mt x 1000 kg/mt/436,000 m^3) and the amount of MgO in a room is 649,000 kg (effective MgO density times room volume, or 178 kg/m^3 x 3644 m^3). Using 3580 kg/m^3 for the particle density of MgO [Handbook of Chemistry and Physics], the MgO solids volume in a room is 181 m^3 (mass of MgO in room divided by MgO particle density, or 649,000

[10] The "porosity surface" is a mathematical representation of how porosity and the pressure within the pores changes over time and is obtained by calculating the impacts of salt creep, which closes empty space, and gas generation, which holds open or expands open space.

kg/3580 kg/m^3). Thus, the initial room porosity is 0.82 (i.e., 1 - ([467 m^3 waste solids +181 m^3 MgO solids]/3644 m^3 room volume)).

At some time, t_1, after closure, 466 m^3 of brine has flowed into the room[11] and reacted with the waste to generate H_2, CO_2, CH_4, etc. Assume that the room volume does not decrease from its initial value of 3644 m^3 due to creep closure. The pressure in the room will have increased due to the amount of gas generation which has occurred between t_0, the time of repository closure, and t_1, and the amount of void volume reduction associated with the brine inflow. At t_1 the room porosity would be 0.69 (i.e., 1-([181 m^3 MgO solids+467 m^3 waste solids+466 m^3 brine]/3644 m^3 room volume)) if the MgO were to remain unreacted. However, the MgO will react with brine and CO_2 to produce hydrated magnesium carbonates such as hydromagnesite ($3Mg(CO_3)\bullet Mg(OH)_2\bullet 3H_20$). Hydrated magnesium carbonates can precipitate from solution, thereby affecting the porosity and permeability. This process can be represented by the net reaction[12]:

$$4\ MgO + 3\ CO_2 + 4\ H_20 = 3MgCO_3\bullet Mg(OH)_2\bullet 3H_2O$$

The maximum amount of gas generated from microbial degradation of the waste is 4.7 x 10^8 moles [Docket: A-93-02, II-G-07, Helton and Jow 1996, Fig. 2.2.3, p. 2-13] of which about half is CO_2 and the balance is methane. [Appendix MASS, Attachment 8-1 and CCA Chapter 6, p. 6-102] This sets the total quantity of CO_2 at 2.35 x 10^8 moles. This can be pro-rated to the volume of a single room based on the relative excavated volumes of a room and the repository, resulting in 1.96 x 10^6 moles of CO_2 per room (2.35 x 10^8 moles CO_2 in the repository x 3644 m^3 in room /436,000 m^3 in the repository).

From the net reaction presented above, it can be seen that three moles of CO_2 reacts with four moles of MgO and four moles of water to produce one mole of hydromagnesite. Thus, in a repository room, the reaction with brine consumes a maximum of 2.61 x 10^6 moles of MgO, 1.96 x 10^6 moles of CO_2 and 2.61 x 10^6 moles of water and produces 0.65 moles of hydromagnesite. The equivalent volume changes for the various species are 30 m^3 MgO (2.61 x 10^6 moles MgO x 40.32 g/mole MgO/(3580 kg/m^3 for MgO x 1000 g/kg)), 47 m^3 of H_2O (2.61 x 10^6 moles H_2O x 18.02 g/mole H_2O/1000 kg/m^3 for H_2O x 1000 g/kg), and 110 m^3 of hydromagnesite (0.65 x10^6 moles hydromagnesite x 365.31 g/mole hydromagnesite/2160 kg/m^3 for hydromagnesite x 1000 g/kg). For this case, the room porosity will be reduced to 0.68 (i.e., 1-([181 m^3 solid MgO-30 m^3 MgO in solution+466 m^3 brine-47 m^3 H_2O+110 m^3 hydromagnesite+467 m^3 waste solids]/3644 m^3

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11 This brine volume was based on a realization from the CCA PA, Replicate 1 where the brine volume in a panel was 5900 m^3 and the pressure was 11.6 MPa at 10,000 y. This was selected as being representative of repository pressure conditions under which gas erosion/stuck pipe releases might occur. In only three of the 100 realizations was the brine volume in a panel greater than this. When this volume is pro-rated for a waste room rather than a panel the volume is 466 m^3 (5900 x 3644/46100). The magnitude of the porosity change is not sensitive to this assumption.

12 As discussed in Docket: A-93-2, II-A-39, alternative stoichiometries have been proposed for hydromagnesite including $4MgCO_3\bullet Mg(OH)_2\bullet 4H_2O$ but disagreement exists in the scientific community as to which stoichiometry is appropriate.

in room)). Note that the room porosity of 0.68 in the case of precipitated salts has decreased by only 1.4 percent from the room porosity of 0.69 in the case where brine enters the repository but has not yet reacted. This calculation is conservative since it ignores any reduction in waste volume due to the microbial degradation.

The Kozeny-Carmen equation characterizes the relationship between porosity, ϕ, and permeability, k, as follows [Docket: A-93-02, II-G-1, Appendix MASS, MASS Attachment 16-3, Appendix D, p. D-2]:

At a fixed particle size, $k_1/k_2 = 1.07$, where k_1 is the permeability at a porosity of 0.69 and k_2 is the permeability at a porosity of 0.68. Thus, for the maximum CO_2 generation case (which is also the maximum hydromagnesite production case), the permeability reduction is only about 7%. As long as both brine and cellulosics are available, gas generation will continue. Since the porosity, and thus, the volume for gases to fill, has been slightly reduced (from 0.69 to 0.68), the pressure upon a given amount of generated gas will be higher. The above discussion has been limited to the situation where creep closure does not occur. Since gas pressure acts in opposition to lithostatic pressure, the creep closure process will be somewhat slowed because the gas pressure will increase faster than was the case when the volume of precipitates was ignored, i.e. the case where brine has entered the repository but has not yet reacted with MgO. This slower creep closure will tend to maintain higher porosity (and permeability).

Comment 5.E.22 states that, in addition to lowering permeability, MgO will locally increase waste strength and concluded that permeability and waste strength are inversely correlated. EPA does not agree with this logic. While permeability and waste strength may have an inverse relationship, this is an over-simplification. Waste strength is also a function of the state of stress surrounding the waste, the extent of cementation between particles, and the degree of waste saturation. In its mechanistically-based conceptual model for spall, DOE used the waste strength based on saturated specimens, generally compacted at stresses less than lithostatic pressure for all assumed permeabilities. [Hansen, et al., 1997, Docket: A-93-02, IV-A-6] Due to the low compacting pressure, high saturation, and lack of cementation, these test specimens of surrogate waste are conservatively biased toward low strength. This approach is conservative because at high pressures, where spalling can occur, the wastes will be drier and hence stronger. Hansen et al., 1997 [*ibid*., p. 2-20, Docket: A-93-02, IV-A-6] have shown that drying increases the tensile strength by a factor of two compared to saturated specimens. In addition, using the strength of saturated waste samples does not consider cementation effects, which would increase waste strength.

<u>Waste permeability and probability of stuck pipe/gas erosion</u>

Numerous comments pertain to waste permeability relationships and are addressed by the following discussion (Comments 5.E.3, 5.E.4, 5.E.5, 5.E.7, 5.E.8, 5.E.9, 5.E.14, 5.E.15, 5.E.18, 5.E.19, 5.E.21, 5.E.24). One commenter correctly notes that blowout has been shown to cease at permeabilities between 10^{-14} and 10^{-15} m^2 as is demonstrated in Hansen, et al., 1997. [Docket: A-93-02, IV-A-6] Thus, if the waste permeability were lower than this range, spallings would not occur. However, the commenter suggests that stuck pipe[13] and gas erosion[14] mechanisms should be considered at lower waste permeabilities. Stuck pipe and gas erosion are mechanisms postulated by DOE to occur if the waste permeability is less than 10^{-16} m^2 and if the pressure exceeds 8 MPa for gas erosion and 10 MPa for stuck pipe. In these mechanisms, it is assumed that gas flow from the pressurized waste to the intruding borehole may cause waste failure adjacent to the borehole. [Docket: A-93-02, II-G-3, Volume 4, CUTTINGS_S User's Manual, p. 64] If the pressure is less than 8 MPa, there will be no driving force to move gas outward against the hydrostatic pressure head associated with a 655 m column of drilling mud. In the CCA DOE assigned a value of 1.7×10^{-13} m^2 for the permeability of the waste based on the permeabilities of the waste components. The source of this value is described in detail in Appendix PEER of the CCA. [Docket:A-93-02, II-G-1, PEER-5, Section 5.4] Since this value is greater than the maximum permeability that would cause gas erosion or stuck pipe, DOE did not model these processes in the CCA PA. After the CCA became available for review, it became apparent that long term releases of radionuclides to the accessible environment involving flow and transport through transmissive geologic strata were an insignificant fraction of total releases. This was true even though the relatively high value for waste permeability used in the CCA was conservative in the sense that it would enhance flow and transport of mobilized radionuclides from the waste. The CCA results showed that total releases were dominated by short term releases associated with inadvertent drilling intrusions into the waste and the focus of attention shifted to a critical examination of these mechanisms. Thus, the selection of what was originally considered to be a conservative assumption for waste permeability needed to be re-examined and the validity of the DOE assumption not to include stuck pipe and gas erosion mechanisms in the CCA PA needed to be justifiable. EPA analysis of the validity of the decision not to include these processes in the CCA is presented in the following paragraphs.

DOE has shown that the minimum expected porosity in the repository is about 0.2 and this condition occurs when there is <u>no</u> gas generation. [CCA, Docket: A-03-02, II-G-1, Appendix PORSURF, Figure PORSURF-3] DOE measured the permeability of a surrogate waste sample (S-24) designed to simulate 50% corrosion and 50% degradation of the organics. The measured permeability of this sample was 2.1×10^{-15} m^2. [Hansen, et al., 1997, Docket: A- 93-02, IV-A-6, p. 2-18] Although the porosity of this sample is not known, the porosity of 6 companion samples prepared using the same recipe was measured and averaged 0.209. [Docket: A-93-02, IV-A-6] It can be seen from Figures PORSURF-3 and -4 that a porosity of about 0.5 is consistent with a gas pressure of 8 MPa - the threshold pressure for gas erosion. At this pressure one can estimate from

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13 "Stuck pipe" means a situation where high gas pressures in the repository would break off radioactive waste and press it against a drill string hard enough to stop or greatly reduce drilling. In order to continue drilling, a drill operator would raise and lower the drill string and, in the process, allow waste to be transported to the surface.

14 "Gas erosion" means a situation where radioactive waste breaks off slowly due to high gas pressures in the repository, enters drilling mud surrounding the drill, and is transported to the earth's surface in the mud.

the Kozeny-Carmen equation above that the permeability for a porosity of 0.5 is about $7x10^{-14}$ m^2. At higher gas pressures the porosity is higher.

From this information it can be concluded that, at a porosity required to exceed a pressure of 8 MPa (the pressure threshold for gas erosion), the permeability is about two orders of magnitude above the permeability threshold for gas erosion assumed in the CCA and an order of magnitude above the threshold value deduced from the data presented in Hansen, et al., 1997. [Docket: A-93-02, IV-A-6] Thus, simultaneously meeting both the pressure and permeability thresholds for gas erosion is extremely unlikely. At this permeability, blowout rather than stuck pipe or gas erosion would be the expected release mechanism.

There will probably be localized areas of low permeability in the waste. However, the repository pressure, and hence the tendency for gas erosion/stuck pipe, will be determined by the average porosity, not the localized permeability or porosity since the pressure is constant throughout the undisturbed repository. All CCA and PAVT modeling assumes that the pore spaces within a waste panel are interconnected; thus, gas pressure throughout the panel will equilibrate to a constant value. This assumption is consistent with EPA's understanding of the physical state of the waste after disposal (Docket: A-93-02, V-B-5, Section 4.3).

Another factor mitigating against the occurrence of stuck pipe/gas erosion process is the fact that the waste will probably be horizontally stratified in the repository with the less permeable material located at the bottom where it was subjected to brine interactions. [Hansen, et al. 1997, *op. cit*., p. 4-36, Docket: A-93-02, IV-A-6] Where material is immersed in brine, anoxic corrosion and microbial degradation reactions will occur to the maximum extent. Brine is unlikely to immerse the drums of waste at higher elevations in the waste panel because modeling shows that only a limited amount of brine would enter the panel, and the brine would tend to pool at lower elevations. For example, Helton and Jow 1996 [Docket:A-93-02, II-G-7, Fig. 2.4.4] show that in most realizations the amount of brine in a lower waste panel is less than 4,000 m^3. Brine saturations associated with these brine volumes are typically less than 0.5. [*ibid*. Fig. 2.4.5] Consequently, without brine surrounding the waste, waste degradation will be reduced. Substantial amounts of uncorroded iron remain in most realizations after 10,000 years. [*ibid*., Fig. 3.2.7] An intruding drill bit would first encounter higher permeability waste near the top of the panel and, if the pressure was sufficient (i.e., >8MPa), spallings release would occur, depressurizing the repository and precluding stuck pipe or gas erosion.

While DOE used a single value for waste permeability in the CCA ($1.7x10^{-13}$ m^2) and EPA required the use of a slightly higher single value in the PAVT ($2.4x10^{-13}$ m^2)[15], the impact of permeability on spallings releases was discussed in Hansen, et al., 1997. [op. cit., Docket: A-93-

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15 EPA required DOE to use a higher permeability value of 2.4×10^{-13} m^2 in the Performance Assessment Verification Test (PAVT) as recommended by the Engineered Systems Data Qualification Peer Review Panel (see CCA Docket: A-93-02, II-G-1, Volume XII, AppendixPEER p. 5-14). This parameter value is based on a recalculation of the weighted sum of the permeabilities of the individual waste components using the expected value of a piecewise-linear cumulative distribution rather than a uniform distribution).

02, IV-A-6, Section 4.0] In that study DOE considered permeabilities ranging from 10^{-15} to 10^{-12} m^2 and showed that blowout and hence, spallings release, did not occur at permeabilities of 10^{-15} or less. At a permeability of 10^{-12} m^2, the blowout event is completed in a shorter time and with a higher bottomhole pressure than at the base case permeability of 1.7×10^{-13} m^2. In addition, DOE considered the impact of variable waste permeability -- both horizontally stratified and randomly distributed. In the case of horizontal stratification, where lower permeability waste would be located at the bottom of the waste room, DOE concluded that the stratified model produced more conservative results than the homogeneous model used for base case calculations involving a constant permeability. [*ibid*., p. 4-42] In the case of the random permeability model, pressure decay was similar to low permeability waste where blowout did not occur. Based on these calculations, DOE judged the random permeability model to be more conservative than the homogeneous permeability model, resulting in lower or negligible spalled volumes. [*ibid*., p. 4-45]

DOE observes in Comment 5.E.17 that the conditions required for stuck pipe as experienced by the petroleum industry are significantly different from those which are expected at the WIPP. DOE provides no specific references in their submittal to support the statements regarding petroleum industry experience. EPA's analysis that stuck pipe is unlikely to occur under conditions prevalent at the WIPP is based on the Agency's analysis of permeability relationships described in the preceding paragraphs.

The Agency also notes that DOE's Engineered Systems Data Qualification Peer Review Panel found the corrected waste permeability (used in the PAVT) to be reasonable when compared with permeabilities of compacted waste in municipal landfills. [Docket: A-93-02, II-G-1, Volume XII, Appendix PEER p. 5-18] Also, although that Panel estimated that uncertainties could cause the waste permeability to vary by up to an order of magnitude [Docket: A-93-02, II-G-1, Volume XII, Appendix PEER Attachment PEER-5 p. 5-17], the Agency concluded that because the waste permeability is already more than two orders of magnitude higher than the permeability of any other geologic or seal component, flow through the waste would be relatively fast and long term releases to the accessible environment would be fairly insensitive to changes in waste permeability within an order of magnitude. Additional information on waste properties can be found in a memorandum from M.K. Knowles, F.D. Hansen and T.W. Thompson entitled Clarification on Waste Properties, SNL, January 21, 1998. [Docket: A-93-02, IV-A-01, Attachment 5]

<u>Permeability of sludges</u>

Comment 5.E.5 discusses permeability based on the experimental work of Luker, et al., 1991 and notes that sludges were not included in any of the samples. [CCA Reference 411, Docket: A-93-02, Item II-G-1] Although sludges were not included in any of the test samples, the CCA permeability of 1.7×10^{-13} m^2 did include a contribution from sludges, as described by EEG [Evaluation of the WIPP Project's Compliance with the EPA Radiation Protection Standards for Disposal of Transuranic Waste, EEG-68, Docket: A-93-02, IV-G-43, p. 61]:

the constant value of $1.7x10^{-13}$ m^2 used for waste permeability in the CCA was based on an investigation of waste materials by Luker, Thompson, and Butcher (1991) in which a single value, homogeneous waste was needed for code calculations with BRAGFLO. The calculation of the permeability assumed that 40% of the waste volume was comprised of combustibles (45% Material 1, 37% Material 2, 9% 1-inch metal parts, 9% dry Portland cement), 40% metals and glass (50% 1-inch metal parts, 50% magnetite), and 20% sludge (assumed to be ordinary Portland cement cured for 130 days). The mean values used for the separate waste types are $1.7x10^{-14}$ m^2, $5.0x10^{-14}$ m^2, and $1.2x10^{-16}$ m^2 for combustibles, metals, and sludges, respectively. The mean values inherently assume a range of permeability values, and these ranges can be seen in Table 1. Table 1 reports minimum, median, and maximum from each waste type assumed in the calculation of the permeability value in the CCA as reported in Butcher (1990).

Permeability Values Used to Calculate Waste Permeability in the CCA (EEG-68)

	Min	Med	Max
Combustibles (m^2)	2.00E-15	1.70E-14	2.00E-13
Metals (m^2)	4.00E-15	5.00E-13	1.20E-12
Sludge (m^2)	1.10E-17	1.20E-16	1.70E-16

From this discussion it can be seen that the permeability used in the CCA is a composite value based on the relative quantities of three different types of materials (combustible, metals/glass, and sludges) each with an inherent range of permeabilities.

Parallel vs. series flow models

Comments 5.E.7 and 5.E.20 question the merits of using a parallel flow model for gas or brine (where the flow is horizontal along stratified layers in the waste) instead of a series flow model (where, because of waste heterogeneity, flow is more vertical) to calculate waste permeability. These comments argue that the series flow model results in lower permeabilities and therefore, by inference, should be used, since this will increase stuck pipe/gas erosion releases. One commenter states that "the behavior of gas and waste at that point will be determined by the permeability of sludge, regardless of the presence of other waste types in the room." EPA does not agree with that statement. As explained above in the discussion of threshold conditions for stuck pipe/gas erosion, the behavior of the gas (i.e., pressure) are not determined by the local waste permeability. Rather, the gas pressure in the entire repository determines the average porosity. In addition, if the series flow model is selected and the waste permeability of the least permeable waste type -- the sludge -- is assigned to the waste, the permeability would be sufficiently low that blowout would not occur. Furthermore, as discussed above, the contemporaneous occurrence for stuck pipe/gas erosion is extremely unlikely. Consequently, the short term releases would be limited to cuttings/cavings, which is less conservative than also including spallings.

Peer review panel conclusions

EPA agrees with Comment 5.E.8 but notes that the panel's conclusion [CCA, Appendix PEER, PEER 5, p. 5-19, Docket: A-93-02, II-G-1] -- "permeabilities of about $2.4x10^{-13}$ m^2 for the waste do not appear to be unreasonable" -- was not based on the intrusive processes to which the waste might be subjected but rather on whether the values used in the CCA were reasonable. EPA believes it is appropriate to make a judgment on the value of a parameter, which characterizes an intrinsic property of a material, without considering how the parameter is used in PA because such an approach does not bias parameter selection.

Heterogeneity of waste

Comment 5.E.11 notes that the waste will be heterogeneous and compartmentalized, reducing its ability to fail and be transported to the land surface. EPA agrees with this comment based on the work of Hansen, et al. 1997. [Docket: A-93-02, IV-A-6] The Agency observes that the approach taken in the CCA is conservative because it does not take into account the favorable effects of heterogeneity. Hansen, et al. 1997 [*op. cit*., Sections 4.3.1 and 4.3.2] considered the effects of heterogeneity on spallings and showed, in the random permeability model, that gas does not readily flow due to the absence of large connected zones of high permeability. The gas flow behavior in the random permeability model was similar to that for homogeneous waste with a permeability of 10^{-15} m^2. Other related studies in Hansen, et al, 1997 had shown that blowout does not occur at this low permeability with homogeneous waste. DOE, therefore, reasoned, by analogy, that, since random permeability waste exhibited behavior similar to homogeneous waste of low permeability and since the homogeneous waste of this low permeability did not experience blowout, random permeability would reduce calculated spallings volumes. EPA finds this line of argument reasonable and concurs with the DOE analysis.

Threshold permeability

EPA agrees with the notion in Comments 5.E.13 and 5.E.14 that the threshold permeability for stuck pipe/gas erosion may not be 10^{-16} m^2. Rather, based on information in Hansen, et al. 1997 [*ibid*., Docket: A-93-02, IV-A-6], it can be inferred that, since spallings does not occur below about 10^{-15} m^2, this permeability represents the upper threshold for stuck pipe/gas erosion. However, EPA believes that the distinction between 10^{-15} and 10^{-16} as the permeability threshold is not important because, as argued above, the contemporaneous occurrence of the pressure and permeability thresholds for stuck pipe/gas erosion is extremely unlikely at either permeability.

EPA agrees with several of the points made in Comment 5.E.12 including those regarding mechanical strength parameters and porosity and permeability parameters. However, EPA does not agree that accepting these parameters, *a priori*, obviates concern for stuck pipe. It does not automatically follow, without further discussion that such is the case. Such discussion is included above where EPA provides arguments as to why stuck pipe will not occur.

Waste permeability and spallings

Some commenters have suggested that by accepting the CCA permeability value of 1.7 x 10^{-13} m^2, EPA did not consider the impact of permeability on spallings release (e.g., Comments 5.E.18 and 5.E.23. As shown in Hansen et al., 1997 [*op. cit.*, Docket: A-93-02, IV-A-6], the blowout process is slow at $1x10^{-14}$ and does not occur at $1x10^{-15}$ m^2. EPA used the Quasi-Static Model to study the spallings release at a permeability of 1 x 10^{-14} m^2 and an initial pore pressure of 14.8 MPa. Under these conditions, the uncompacted failed volume of waste was 3.76 m^3. Similarly, EPA calculated the releases at a permeability of 1 x 10^{-12} m^2 and found that the uncompacted failed tensile volume of waste was 0.39 m^3. These releases are within the range used in the CCA and PAVT performance assessments (i.e., 0.5 to 4 m^3).

On the basis of all this information, EPA is satisfied that the use of a single permeability value will not bias the CCA results in a non-conservative manner.

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25. The range of releases from gas erosion and stuck pipe is large and would clearly violate the disposal regulations. The releases from gas erosion range from 44 to 356 m^3 of waste, varying with assumptions as to mud flow rate, drill bit diameter, and penetration rate. The releases from stuck pipe range from 43 to 238 m^3 of waste, varying with assumptions as to mud flow rate and clean out time. (127)

26. Stuck pipe and gas erosion, were not considered in the CCA performance assessment calculations. The importance of these two neglected mechanisms lead me to my next exhibit, which show that spalling releases were increased to include values that range from eight cubic meters to 54 cubic meters CCDF codes violate standards established by the EPA. A 1994 memo by J.W. Berglund of Sandia stated that releases due to these mechanism could be as high as 356 cubic meters, 8 to 64 cubic meters are entirely plausible values. (367)

27. We have also submitted a paper showing that even when drilling with mud, if WIPP is intercepted, first a large volume of waste would be fragmented and next gas pressure would push waste against the drill string and cause it to stick. This is the scenario of stuck pipe. When the driller tries to free a stuck pipe, he brings a large volume of waste to the surface. DOE's compliance application does not include stuck pipe. We have shown that stuck pipe can cause the release of hundreds of cubic meters of waste. Why didn't EPA pursue this issue?. . . EEG has shown another thing. They have shown that releases of the size that would be caused by air drilling or stuck pipe or direct brine release would violate the disposal standards. EEG found that if releases caused by drilling intrusions vary from 8 to 64 cubic meters, the release limits under the disposal regulations are violated. The releases from air drilling or stuck pipe or direct brine release are much larger than that. (405)

28. In a mud drilling intrusion at high repository pressures (12 to 14.8 MPa), about 3 to 800 m^3 of waste fails. The intrusion would cause "stuck pipe," followed by cleanout, releasing 43 to 238 m^3 per day and possibly the entire failed volume. (713)

Response to Comments 5.E.25 through 5.E.28:

The commenters state that releases for stuck pipe and gas erosion could be sufficient to breach EPA's standard. The Agency disagrees with this assertion. These estimates were based on early modeling work reported in Berglund 1994. [As referenced in the CUTTINGS_S User's Manual, WPO# 37765, p. 81] The Berglund estimates assumed that the waste had no strength and that these large volumes of solids could move up the borehole without choking off the flow in the annulus between the borehole wall and the drill collar. EPA believes that neither of these assumptions are realistic. As shown in the spallings report by Hansen, et al., 1997 [Docket: A-93-02, IV-A-6], the waste has significant tensile strength. This tensile strength will be increased under the low levels of residual brine saturation expected at the higher repository pressures required for stuck pipe and gas erosion. [*ibid*., p.2-19 and 2-20] As the tensile strength increases, the amount of waste which fractures and becomes potentially available for transport to the surface decreases.

With high tensile strength, it is unlikely that even high gas pressures will break loose significant volumes of waste, a necessary condition for the gas erosion and stuck pipe mechanisms. If some waste does fracture, all of it will not be of a particle size for transport up the borehole (see Response to 5.A.1, 5.A.2, and 5.A.3). In addition, it is likely that the waste strength will be further enhanced by precipitation of mineral salts as the brine in a panel is reduced through chemical reaction and pressure-driven outflow. Such precipitation will occur when the volume of brine is reduced and the solubility limit of various ionic species in the brine is exceeded or as brine constituents react with carbon dioxide. (See Response to 5.E.2 through 5.E.24 for additional discussion regarding the formation of hydrated magnesium carbonates.).

If the waste does fail, a significant fraction cannot move up the borehole since the annulus between the drill collar and the borehole wall is only about 0.05 m (2 in). At least 30% of the waste has an equivalent diameter greater than 0.05 m. [Attachment 4 to letter from G. Dials, DOE, to M. Kruger, EPA, dated January 26, 1998, Docket: A-93-02, IV-G-7] In addition, as discussed in the Response to 5.E.2 through 5.E.24, EPA believes it unlikely that the pressure and permeability thresholds for stuck pipe/gas erosion can exist contemporaneously.

With regard to Comment 5.E.26, see also EPA's Response to 5.E.31.

The Agency concludes that it is not necessary to include stuck pipe and gas erosion mechanisms in the CCA performance assessment because of the low likelihood of these events occurring.

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29. EPA's latest modeling of air drilling (IV-A-I at 17-20) has erroneous premises and fails to place bounds on the releases caused by this method. First, EPA estimated the mean volume of a

spallings release, assuming that air drilling occurred. EPA asserted that the maximum credible release volume would be 50 m^3 (at 18). However, the report, Drilling with Mud and Air into WIPP -- Revisited (IV-D-14) shows that failed volumes can range into the thousands of cubic meters (Fig. 3 at II), and stuck pipe releases can reach 238 m^3 based on a 24 hour cleanout period (id. 15). EPA's calculation is invalid. Next, EPA uses the quasi-static model to estimate the release volume from air drilling (which EPA asserts is 1.4 m^3), but in doing so EPA ignores the limitations of that steady-state model, which EPA has noted cannot effectively represent the transient conditions of spallings releases (IV-E-9 at 2). Moreover, the quasi-static model incorporates a spherical geometry that is inappropriate; the geometry of intrusion is more nearly radial. (1035)

Response to Comment 5.E.29:

EPA did not assert that 50 m^3 is the maximum credible release volume. In fact, on p. 18 of EPA's Analysis of Air Drilling at WIPP, EPA had cited 50 m^3 as a value asserted by some public commenters, rather than by the Agency. [EPA's Analysis of Air Drilling at WIPP*,* Docket: A-93-02, V-B-29, p. 18] EPA's use of the 50 m^3 was to provide a bounding calculation showing that, even with non-realistic assumptions, the spallings volume, adjusted for a 2% probability that air drilling would be used to create the borehole, was still within the limits of the 0.5 to 4.0 m^3 range used in the CCA. In Appendix A of that document*,* EPA presented an analysis showing that the expected spallings releases due to air drilling were about 1.4 m^3. As discussed elsewhere in the section called "SNL/DOE's Spallings GASOUT computer code,*"* the use of GASOUT for conditions outside those included in Hansen, et al., 1997 [*op. cit*., Docket: A-93-02, IV-A-6] is inappropriate. [See also Summary of GASOUT Code Meeting, Docket: A-93-02, IV-E-9] Failed volumes of thousands of cubic meters result from use of the code outside its designated design range of operation. Also, as discussed elsewhere under the section of responses addressing Stuck Pipe, Gas Erosion and Related Waste Permeability comments, EPA does not agree that the stuck pipe mechanism will occur or release significant quantities of waste to the land surface.

As described in Summary of GASOUT Code Meeting [Docket: A-93-02, IV-E-9], John Schatz of DOE*,* observed that the Quasi-Static Model did not handle early transience [transients]. EPA agrees that the Quasi-Static Model does not explicitly handle transients. The Quasi-Static Model uses a series of steady-state solutions calculated over a large number of closely-spaced time steps to model changes over time. Hansen, et al., 1997 shows that this approach provides good agreement with the full transient calculation, where time-dependent effects are treated with mathematical rigor rather than approximated with a series of steady-state solutions. [Docket: A-93-02, IV-A-6, Figures 3-17 through 3-25] Therefore, the Quasi-Static Model is a reasonable approximation of the transient Cavity Growth Model and can be used in its stead. (The Cavity Growth Model was the primary model used by DOE to demonstrate that the CCA spallings model was conservative.) In using the Quasi-Static Model to estimate air drilling releases, EPA has not ignored the limitations of the steady-state model. EPA has considered these limitations and has concluded, based on the information summarized here, that use of this model is appropriate since it provides results which are similar to, and generally more conservative than, those obtained with the Cavity Growth Model.

The commenter also questions the use of hemispherical rather than cylindrical geometry in modeling. Typical drilling rates in the Delaware Basin are 50 to 100 ft/h or 0.004 to 0.008 m/s. [CUTTINGS_S User's Manual, Docket: A-93-02, II-G-3, Volume 4, p. 65] At the time of intrusion the compacted waste height likely would be about 2 m based on an initial uncompacted porosity of 0.848 and compacted porosity of 0.7 (Hansen et al., 1997, *op. cit.*, p. 3-22). Thus, in one second, less than ½%of the total thickness of the waste will have been penetrated and in less than one second the maximum tensile failure radius will have been reached, as is shown in the Analysis Package for the Semi-Analytical Calculations Conducted in Support of an Alternative Spallings Model: Method II - The Quasi-Static Model. [WPO# 47388, Figure 3-10] Since the waste is not penetrated to any significant depth, it is a logical assumption that gas flows into the circular area defined by the drill bit as it initially contacts the waste surface from a hemispherical region in the waste beneath the drill bit. If the drill bit had penetrated a substantial fraction of the waste thickness prior to waste failure reaching its maximum extent, then consideration of gas flow from a cylindrical volume would be the more appropriate geometry to model.

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30. The original spallings model is totally inadequate, which is not the same as being conservative. The original model doesn't adequately deal with many scenarios, including direct brine release, stuck pipe, and gas erosion. DOE is now using a different spallings model, an additional implicit recognition of the problems with the original model. EPA should reject DOE's spallings models and require the development of a new and better model that can adequately calculate releases from direct air and mud drilling, including stuck pipe and gas erosion. (1159)

<u>Response to Comment 5.E.30:</u>

EPA agrees that the original spallings conceptual model was inadequate. [CARD 23--Models and Computer Codes, Section 7.0, requirement Section 194.23(a)(3)(v); Docket: A-93-02, Item V-B-2] Although the model was inadequate, it was never intended to include direct brine release. This process was addressed with a separate conceptual model. The mechanistically based conceptual model for spall described in Hansen et al., 1997 [*op. cit*., Docket: A-93-02, IV-A-6] was designed to consider spallings releases. It was not designed to consider air drilling, stuck pipe *or* gas erosion. The model has been modified to include air drilling as described in Analysis Package for the Semi-Analytical Calculations Conducted in Support of a Spallings Model for an Air Drilling Intrusion. [WPO# 48057] As discussed above in the Response to 5.E.2 through 5.E.24, stuck pipe and gas erosion need not be addressed in the spallings model because it is extremely unlikely that the necessary conditions would ever occur.. Therefore, EPA sees no need for another new spallings model to make its compliance determination. The Conceptual Models Peer Review Panel was satisfied that the spallings release volumes calculated by the conceptual model used in the CCA are reasonable and may overestimate waste volumes released by the spallings process. [Conceptual Models Third Supplementary Peer Review Report, Docket:A-93-02, II-G-22]

31. [T]he EEG conducted calculations to investigate the amount of spallings release through either the stuck pipe or the gas erosion process that would violate the EPA standard. . .[I]f between 8 m^3 and 64 m^3 of spalled material is assumed to reach the surface, the standard is violated at 10^{-1} probability. (696)

32. EEG has shown that spallings releases ranging from 8 to 64 m^3 violate Section 191.13. Thus, releases in the ranges shown almost certainly violate Section 191.13. (714)

33. The EEG is conveniently imprecise in its calculational method and claims about the sensitivity of compliance with the containment requirements to the magnitude of spalling release. First, the EEG ignores the probability aspect of releases - it has not attempted to determine the likelihood of a stuck pipe or gas erosion occurrence (note that the DOE believes stuck pipe and gas erosion are properly excluded from the calculations because they are not relevant to the future state of the waste). By omitting consideration of probabilities, the EEG has ignored an essential component for the construction of the CCDF (see section 6.1 of the CCA for a discussion of CCDF construction). Its treatment of the probability of the occurrence of stuck pipe/gas erosion is not discussed and is without basis. Without assessing the likelihood of stuck pipe occurring, the EEG's CCDF and sensitivity analysis are essentially meaningless. Second, in its sensitivity analysis the EEG multiplies releases used for the EPA-mandated PAVT. There is no physical basis to support this scaling of releases. (916)

Response to Comments 5.E.31 through 5.E.33:

EPA does not agree that there is violation of the containment requirement at 10^{-1} probability when the volume of spallings released is between 8 m^3 and 64 m^3. The commenter's analysis shows that the standard is just breached at a probability of 0.1 only when spallings releases are 64 $m^{3,}$, as shown in Figure 1 of Enclosure 3 to the 12/31/97 letter from R. Neill, EEG to F. Marcinowski submitting supplemental information from the December 10, 1997 EPA/EEG meeting. [Docket: A-93-02, IV-D-12] According to the commenter's earlier analysis, the standard is not breached at release volumes below 64 m^3.

Furthermore, EPA does not believe that spallings release volumes between 8 m^3 and 64 m^3 will occur, based upon the volume of spallings calculated in the CCA PA and in Hansen, et al. 1997. [*op. cit*., Docket: A-93-02, IV-A-6] In the CCA PA (and PAVT), the volume of spallings releases ranged between 0.5 and 4.0 m^3. [Helton and Jow, 1996, Docket: A-93-02, II-G-07] This range of spallings release volumes contributed to the total radioactive releases calculated in the CCA PA and PAVT, which had a mean result that was an order of magnitude less than the containment requirements of 40 CFR 191.13. [CARD 34, requirement (b), p. 34-13; Docket: A-93-02, V-B-2] Additionally, as discussed above in the Response to 5.E.2 through 5.E.24, EPA believes that stuck pipe and gas erosion will not occur because the threshold pressure and permeability conditions for these processes will not occur contemporaneously.

DOE points out in Comment 5.E.33 that the basis for the calculations referred to in Comment 5.E.31 was to multiply the PAVT spallings values by factors ranging from 2 to 16. [December 31, 1997, letter from R. Neill, EEG to F. Marcinowski submitting supplemental information from the December 10, 1997 EPA/EEG meeting, Docket: A-93-02, IV-D-12] DOE points out that such an approach fails to consider that release consequences must be probability adjusted. The probability of a release being 2 to 16 times that in the PAVT is different from the probability of a release in the PAVT. Construction of revised CCDFs based on higher spallings volumes requires recognition of both the increased consequence and the reduced probability of these higher values. The probability of these higher values is reduced because the underlying assumptions would have to be extremely conservative and would be less likely to occur. DOE also points out that there is no connection between spallings releases upon which the EEG calculations were based and stuck pipe/gas erosion. EPA agrees with the*se* DOE observations. The Agency notes that hypothetical calculations of the magnitude of releases which would breach the standard are irrelevant to a compliance decision, which must be based upon performance assessment computations.

Issue F: Gas generation model

1. Certain values for corrosion rates and gas generation have changed from those used in past performance assessments (e.g., the 1992 PA) for two reasons. First, the program of long-term corrosion testing is now complete so that more complete data on long-term corrosion rates are now available. Second, changes in repository design, the most important of which is the inclusion of large quantities of MgO in the backfill, will significantly affect long-term gas pressure increases, because CO_2 gas is absorbed by reacting with MgO. (105)

2. Aluminum corrosion does appear to be accelerated by the presence of iron based alloys, but due to the large quantity of steel and the small quantity of aluminum present in the waste in the repository, the overall impact on long-term corrosion rates and gas generation will be limited. (106)

Response to Comments 5.F.1 and 5.F.2:

EPA concurs with the comments. Substantially more corrosion data than were available at the time of the 1992 PA have been completed and reported in Telander and Westerman 1997. [Docket: A-93-02, Item II-A-36] In addition, the design of the repository which affects the corrosion rate has been significantly altered by the use of MgO backfill. EPA also notes that while the aluminum corrosion rate is increased by the presence of iron, which will certainly be the case in the repository, this will not have a significant affect on PA. This is true since gas generation is limited not by the inventory of iron (and aluminum) present, but rather by the availability of brine to react with the iron (and aluminum). As shown in Fig. 2.2.9 of Helton and Jow 1996 [Docket:A-93-02, II-G-7], substantial amounts of iron remain unreacted in the undisturbed repository.

3. These drums rust, generate hydrogen gas under high pressure. That gas pressure creates most of the problems in an air drilling or direct brine release scenario because the gas pressure fractures the waste. The gas pressure is one of the major causes of fracturing of interbeds. (407)

Response to Comment 5.F.3:

EPA agrees with the commenter's assertions that waste drums will rust, generating hydrogen gas and that, in some cases, the gas pressure is sufficient to fracture the waste and/or the anhydrite marker beds. However, EPA disagrees with the assertion that fracturing of the waste creates most of the problems with the direct brine release scenario. This scenario deals with the transport of contaminated brine to the surface. This process is independent of the state of the waste, since equilibrium between solids and brine is assumed for actinide solubility calculations in the CCA. The equilibrium assumption ensures that the maximum actinide concentration in the brine is used in release calculations because the actinides will be most soluble at equilibrium. Both EPA and the Conceptual Models Peer Review Panel have reviewed the model used to simulate fracturing of the interbeds and both have judged the model to be acceptable. [Section 1.3.23 of EPA's Technical Support Document for Section 194.23: Models and Computer Codes, Docket: A-93-02, Item V-B-6] EPA has also carefully reviewed the effects of repository pressure on releases associated with air drilling as described in EPA's Analysis of Air Drilling at WIPP. [Docket: A-93-02, V-B-29] In its analysis, EPA found that spallings releases associated with air drilling are in the same range as spallings releases due to mud drilling in the CCA calculations.

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4. The CCA value for an inundated corrosion rate is based on long-term tests, thus disregarding rates observed in shorter-term tests; assumes a pH of about 10; and has a minimum rate of 0, on the apparent assumption that salt crystallization may prevent corrosion. See MASS Att. 8-2, at 4-5. None of these assumptions is well-founded; in particular, the probabilities assigned lack support, and the overall result is to bias the corrosion rate on the low side. (970)

5. Telander and Westerman (1997) report that decreasing pH will significantly enhance corrosion rates. At pH 3 the average rate was 7900 µm/yr. (id. 6-33). Although MgO will tend to control pH, there must be some uncertainty in the matter, and there will be individual areas where MgO is not effective. Thus, some consideration of low pH should be included in the gas generation rate.

Also, direct contact with salt and backfill enhances the rate (id. 6-41), and such will often or usually be the case. Thus, this should also be accounted for in the rate. The backfill-immersed specimens showed a corrosion rate of 4.58 µm/yr. in the bottom-most tier, which may be regarded as reflective of the repository after closure. It should be noted that the backfill in the experiments contained 30% bentonite and 70% salt. There has been no explanation of why these results should be disregarded. (971)

6. Telander and Westerman (1997) also state that aluminum corrosion is a significant factor, approximately equal to the corrosion rate for steel (II-A-36 at ES-3). The rate of aluminum corrosion increased dramatically in the presence of CO_2 and in the presence of iron, which must be regarded as ever-present. (See 6-53 through 6-68). (972)

7. Based on the ongoing Telander and Westerman studies, in 1993 Larry Brush wrote that the demonstrated corrosion rate of 1µm/yr. should be increased by a factor of 50 to account for the

possibility of low pH (Brush to Tiemey, June 18, 1993, at E-10, E-11)(II-G-1, Ref. 92). He also determined to increase the maximum rate by a factor of four to account for high N_2 partial pressure (id. E-12). There was a further increase by a factor of 1.23 based on temperature (id. E-13). The resulting maximum corrosion rate was 200µm/yr (id. E-23). Brush's "best estimate" was 1 µm/yr. (id.). (973)

8. DOE seems to have proceeded on the premise that the observed data shall be used to fix the upper limit of a uniform distribution of corrosion rates (see MASS Att. 8-2 at 5, 6) -- a practice which would systematically understate the corrosion rate. (975)

<u>Response to Comments 5.F.4 through 5.F.8:</u>

DOE conducted steel corrosion experiments under both humid and inundated corrosion conditions since it was expected that, depending on the extent of brine inflow into the repository, some specimens would be immersed in the brine and some would be exposed to vapor from the brine. The corrosion rate under humid conditions was found to be negligible based on lack of both corrosion product formation and hydrogen generation, so the humid corrosion rate was set at zero as described in Appendix WCA, Attachment WCA.8.17, p. 5. [Docket:A-93-02, II-G-1, Vol. XIX] The inundated corrosion rate was based on experiments conducted by Pacific Northwest Laboratories (PNL) with low carbon steel specimens (ASTM Grades A366 and A570) in brines similar to Salado brines (*e.g.*, Brine A,[16] pH = 7.4) at 30ºC. Tests were conducted for 3, 6, 12, and 24 months as documented by Telander and Westerman, 1993. [Docket:A-93-02, II-G-1, Ref. 622] The measured hydrogen generation rate over the period from 12 to 24 months was used to develop a corrosion rate for the steel as follows:

> Measured hydrogen generation rate (0.10 mole H_2/m^2 steel-yr) x 1 mole of Fe corroded per mole H_2 generated ÷ 0.141 moles Fe corroded/m^2 steel-yr per µm/yr[17] = 0.71 µm/yr.

The corrosion rate of 0.71 µm/y was based on measurements of hydrogen gas evolution. If DOE had used data based on weight loss from the test specimens. the corrosion rate would have been 0.7 µm/y. [*ibid.*] A long term scaling factor of 70% was applied to this rate for the CCA PA. This long-term scaling factor was based on a test (container 36) of 38.5 months duration reported in Telander and Westerman, 1995 to which a small amount of CO_2 had been added, in contrast to the tests used to develop the basic 0.71 µm/y corrosion rate. The authors state that the agreement between this test and the tests without CO_2 additions are excellent for the period between 12 and 24 months and use this experimental information to support the contention that the use of the test with low CO_2 is appropriate in extending the previous corrosion results. The following quotation from Telander and Westerman, 1995 describes the issue:

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16 Brine A is a Salado brine simulant characterized as a high Mg, K, Na chloride-sulfate brine (Telander and Westerman, 1995).

17 Penetration rate conversion factor, Telander and Westerman, 1993, Table 6-2, p. 6-10.

> If the slope of the container 36 curve between one and two years is determined, excellent agreement is found with the 12-to-24 month reaction rate of Figure 6-1 [i.e, the figure used to develop the 0.71 μm/y rate]. If the final year of the 3.2-year container 36 test is examined similarly, it is found that the reaction rate is ~70% that of the 1-to-2 year rate.

DOE set the maximum corrosion rate at 0.5 μm/y based on the following :

0.71 μm/yr x 0.7 long term scaling factor = 0.5 μm/yr

The fundamental corrosion rate was obtained in brine with an initial pH of 7.4, which increased to 8.4 after 24 months. [Telander and Westerman, 1993] Since the corrosion rate was shown to decrease with increasing pH and since the expected repository pH is about 10 (see discussion of expected repository pH below), the corrosion rate of 0.5 μm/yr was assumed to be the upper limit. Telander and Westerman, 1993 estimated that increasing the pH from 7 to 10 would reduce the corrosion rate by one to two orders of magnitude. In a subsequent report, Telander and Westerman [1995], presented the results of laboratory tests to measure the corrosion rate as a function of pH. [See Docket: A-93-02, Item V-B-1] The following results were reported for tests of six months duration in an "ERDA-6 brine:"[18]

pH	Average Corrosion Rate (μm/y)
4.8	89
7.0	51
8.6	2
10.6	3.6

A corrosion rate of 1.72 μm/y was obtained in a test of the same duration in Brine A at a final pH of 8.3 indicative of close agreement between results in Brine A and ERDA-6 brine. PNL was uncertain as to whether the increase in corrosion rate between pH 9 and pH 11 was real or an experimental artifact.

DOE set the minimum inundated corrosion rate at zero based on the assumption that the corrosion rate could be extrapolated to be as low as 0.005 μm/y at a pH of 10, coupled with the observation from the Source Term Test Program at Los Alamos that salt films may prevent steel corrosion. [SCA Attachment SCA.8.17] Corrosion rates in the absence of CO_2 were assumed to be uniformly distributed between 0 and 0.5 μm/yr. [Parameter CORRMCO2 in m/s, Appendix PAR, p. PAR-16]

EPA does not agree with the comments that the assumptions of long-term rates, pH, and minimum corrosion rate are not well-founded. DOE conducted an extensive corrosion testing program at PNL for about seven years and used the results from this program as the basis for

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[18] The "ERDA-6 brine" had a high NaCl content and no Mg (Telander and Westerman, 1995). A low Mg brine was needed for constant pH tests to insure that $Mg(OH)_2$ would not precipitate out at higher values of pH and cause problems in interpreting the test results.

establishing the range of corrosion rates for steel under anoxic conditions. Since the results of the corrosion testing are used to develop a long-term (i.e., hundreds of years) hydrogen gas generation rate for the repository, DOE developed the rate based on hydrogen generation over a period from 12 to 24 months after the tests had been initiated rather than for shorter durations. [Docket: A-93-02, II-G-1, Ref. 622, p. 6-14] DOE did not include the higher gas generation rates which occurred initially in the corrosion tests. This is appropriate since some time is required before the test conditions stabilize. This is demonstrated by the fact that during the early phases of the test (i.e., less than 6 month*s*) the moles of iron reacted as determined by gravimetric techniques was not consistent with the moles of hydrogen as determined by pressure measurements. Based on the corrosion reaction:

$$Fe + 2H^{+} = Fe^{2+} + H_2$$

the molar quantities should be equivalent. After about six months of operation, the test system stabilized and good agreement between iron reacted and hydrogen produced was observed. DOE has observed that if the environment remained static and unrefreshed, the corrosion rate should continue to decrease over long periods of time. [*ibid.*]

The assumption of a pH of about 10 is consistent with the use of an MgO backfill. Calculations presented in Appendix SOTERM, Figures SOTERM-4 and SOTERM-5 [Docket: A-93-02, II-G-1] indicate that when more than about 1 mole $Mg(OH)_2$ is added per kg of H_2O, the pH will be about 9.3 with brines from the Salado Formation and about 9.9 with brines from the Castile Formation. DOE plans to add 77,640 metric tons of MgO to the repository as stated in Chapter 3 of the CCA. [Docket: A-93-02, II-G-1, Vol. 1] When this MgO reacts with brine, a total of $1.92x10^9$ moles of $Mg(OH)_2$ can be produced. Since the maximum amount of brine expected to flow into the undisturbed repository is about 85,000 m^3 as shown in Figure 2.1.1 of the Preliminary Summary of Uncertainty and Sensitivity Analysis Results, Helton and Jow, 1996 [Docket:A-93-02, II-G-7], adequate MgO is available to insure that the high pH level is maintained.

DOE has assumed that the minimum inundated corrosion rate is zero, based both on the consideration that salt films may prevent corrosion and the observation that in high pH brines the corrosion rate may be a low as 0.005 µm/y -- a near zero value. DOE assumed that the inundated corrosion rates were uniformly distributed from zero to 0.5 µm/y. The use of a uniform distribution is consistent with the basic assumption used throughout the CCA for parameters where only the range is known. [Appendix PAR, p. PAR-3 in Docket:A-93-02, II-G-1] EPA believes that sources of the parameter assumptions are adequately documented and the use of the particular parameter distribution is consistent with demonstrating the concept of reasonable expectation for the H_2 gas generation rates used in the CCA. However, EPA was concerned that the maximum corrosion rate value selected by DOE did not fully reflect other uncertainties such as the effect of hydrogen over-pressure and accelerated corrosion due to interactions with other materials such a backfill and aluminum. Consequently, in the PAVT, EPA required that the upper limit be doubled to assure that these other uncertainties were more fully reflected. [Technical Support Document for Section 194.23: Parameter Justification Report, Docket: A-93-02, V-B-14, Section 5.15 for STEEL-CORRMCO2 parameter] Despite this, and other changes made in the PAVT, the repository remained in compliance with the standards.

EPA agrees with the comment that low pH will dramatically increase the corrosion rate. However, as discussed above, adequate MgO is present to insure that the pH will be the in 9-10 range. Even, if the MgO were not fully effective and the pH were to drop to 7-8, the enhanced corrosion rate is reflected in the distribution for inundated corrosion rate parameter. EPA believes that a drop in pH to this level is highly unlikely since the quantity of MgO is far in excess of the quantity required for reaction with all the CO_2 and since MgO is uniformly distributed throughout the repository. This position is supported by the Conceptual Models Peer Review Panel. Initially, the Panel expressed concerns that reaction rims might form around the MgO pellets and "inhibit the ability of the MgO to react completely and rapidly with the CO_2 to buffer the chemical system ..." [Conceptual Models Third Supplementary Peer Review Report, Docket: A-93-02, II-G-22, p. 13] Based on experimental evidence documented by DOE in Chemical Conditions Model: Results of the MgO Backfill Efficacy Investigation [Docket: A-93-02, II-A-39], the Panel determined that reaction rims would not "hinder the ability of CO_2 to react with various forms of hydrated MgO pellets" [ibid., p.14] and concluded that "the MgO backfill will function as assumed in the CCA and this model is adequate to represent the future states of the repository." [ibid., p. 18]

The commenter notes that in a six-month test, the corrosion rate of specimens imbedded in a simulated backfill of 30% bentonite and 70% salt showed corrosion rates about twice those of similar duration immersion tests with no backfill. On the other hand, PNL also showed that, when the steel specimens were imbedded in salt backfill for three months, the corrosion rates were similar to those expected for specimens inundated in Brine A. Some of the steel in the repository could become imbedded in salt as creep closure proceeds but could not be in a salt/bentonite mixture. The Agency does not believe the results of the tests with salt/bentonite backfill need to be included in developing the corrosion rate since the test conditions are not relevant to the current WIPP design, which does not require a salt/bentonite backfill. The test results are not reflective of expected repository conditions after closure.

The commenter notes that CO_2 and iron will enhance the corrosion of aluminum. Although this assertion is correct, the Agency believes it is not relevant to performance assessment. First, as described above, CO_2 will be removed from the repository by reaction with MgO so that it will not be available to reduce the brine pH and enhance corrosion. Second, accelerated corrosion of aluminum in the presence of iron is not a significant factor in repository performance since the repository pressure is limited by the availability of brine and not by the inventory of iron and aluminum. DOE has shown that, in virtually all instances, ferrous metals in the repository are not totally consumed. For example, the Preliminary Summary of Sensitivity and Uncertainty Analysis [Docket:A-93-02, II-G-7, Fig. 2.2.9], shows that, in the undisturbed case, based on 100 vectors in replicate 1, for only one vector was the steel inventory in a waste panel depleted (after about 6,500 years). For all the other vectors at least 20% of the steel remained in the panel. For the repository as a whole, the minimum inventory was about 40%. For additional discussion see, for example, Appendix A of the Summary of the EPA-Mandated Performance Assessment Verification Test (Replicate 1). [Docket: A-93-02, II-G-26, pp. A-3 and A-4]

The commenter describes some analysis by Brush in 1993 where an average corrosion rate of 1 μm/y is proposed, as well as, a maximum rate of 200 μm/y. This analysis was based on the SNL investigator's judgment at the time. It does not reflect that DOE had not yet considered MgO backfill at the time, that longer term tests used to set the final corrosion rate were not yet available, and that higher pressure tests were also incomplete. For example, the factor of 50 for low pH is not appropriate since the pH will be held near 10 by the buffering of the MgO backfill. In addition, later tests, which extended to the test time to 38 months, indicated that the gas generation rate between 26 and 38 months was 70% of the rate between 12 and 24 months. Additional testing with nitrogen showed the corrosion rate at a nitrogen over-pressure of 127 atm was the same as at 73 atm and, more importantly, the corrosion rate with a hydrogen over-pressure of 127 atm was less than under the conditions used to set the basic corrosion rate of 0.71 μm/y suggesting an element of conservatism in PA.

The commenter correctly notes that the DOE corrosion data were used to set the upper limit of a uniform distribution of corrosion. However, EPA does not agree that this practice would systematically understate the corrosion rate. The experimental rate was obtained under pH conditions substantially lower than those expected in the repository (i.e., 7.4 to 8.4 versus 9.2 to 9.9). The corrosion rate is expected to be at least an order of magnitude lower at the higher pH. In addition, as noted above, EPA required that the maximum corrosion rate be doubled in the PAVT to account for uncertainties in this parameter. [Technical Support Document for Section 194.23: Parameter Justification Report, Docket: A-93-02, V-B-14, Section 5.15 for STEEL-CORRMCO2 parameter]

References

Telander, M.R. and R.E. Westerman, 1995. "Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments," Final Report (Draft), Sandia National Laboratories. (Docket: A-93-02, Item V-B-1)

Telander, M.R. and R.E. Westerman, 1997. "Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments," SAND96-2538, Sandia National Laboratories, March 1997. (Docket: A-93-02, Item II-A-36)

Issue G: Permeability of borehole plugs

1. In conclusion, the DOE has undertaken a survey of drilling practices and technology in the Delaware Basin, and combined this with a mechanistic approach to determine that the rate at which natural processes affect borehole plugs leads to an estimated lifetime of roughly 200 years for these plugs. A longer lifetime would not significantly affect PA results. (116)

2. EPA investigated DOE's [borehole plug] permeability values and found that they are too high. But, having found that DOE's values were too high, EPA proceeded to undermine its own conclusion by allowing DOE's exaggerated values to remain in the PA on an entirely speculative basis. . . EPA says, without data reference, that the upper bound of the BH_SAND parameter was left unchanged because "further reduction in this value would result in lower gas pressures and lower long-term releases." (TSD III-B-14 at 21). Thus, EPA expanded the range of values to include low permeabilities that EPA deemed realistic but left the unsupported DOE high values in the sampled range. EPA adopted a uniform distribution because (it said without any data support) "the Agency believes that all values across the range of several orders of magnitude are equally likely." (TSD III-B-14 at 21). EPA mandated a range for the CONC_PLG parameter that runs even higher than the fixed value that DOE had selected, explaining only that it is "based on the high end of the range of values from laboratory measurements, as adjusted upward to account for uncertainties in field placement techniques and minor concrete deterioration." Such "adjustments" are arbitrary. (1041)

3. [In its proposed rule EPA did not use:]

* realistic shaft, borehole, and panel seal performance estimates; (1143)

4. The CCA fails to model the build-up of gas which would result from impermeable borehole plugs. (1208)

<u>Response to Comments 5.G.1 through 5.G.4:</u>

In the CCA, DOE assumes that boreholes are initially plugged in one of three ways [Appendix PAR, p. PAR-112]:

- ♦ A continuous concrete plug through the Salado and Castile Formations, which is assigned a probability of 0.02;

- ♦ A two-plug configuration, which is assigned a probability of 0.68, with lower plug lying between the Castile brine reservoirs and the underlying Bell Canyon Formation and the upper plug in the Rustler Formation above the Rustler/Salado contact; and

- ♦ A three-plug configuration, which is assigned a probability of 0.30, with the upper and lower plugs located as in the two-plug configuration and the intermediate plug located between the Castile brine reservoir and the repository horizon.

The probabilities assigned to the three plugging configurations were developed from a survey of 188 boreholes presented in the CCA, Appendix MASS Attachment 16-1.

The concrete plugs are initially assigned a permeability of 5 x 10^{-17} m^2 based on field measurements on test plugs in the Bell Canyon Formation. [Appendix DEL, Attachment 7, p. 13, Docket:A-93-02, II-G-1] The continuous plug is assumed not to degrade and will retain this permeability over the entire regulatory period. In the other two scenarios, the upper plug is assumed to degrade after 200 years, increasing the permeability. The permeability of the borehole from the repository horizon to the surface is then assumed to range from 10^{-11} to 10^{-14} m^2 with a log uniform distribution based on literature values for silty sand. [Appendix PAR, Parameter 30 - PRMX-LOG, PRMY-LOG, PMMZ_LOG] Silty sand is assumed to be representative of debris which will fill the borehole. This is a logical assumption because blowing sand from the surface will be a major borehole fill material. DOE expects the lower plug between the Bell Canyon and the Castile to remain intact with a permeability of 5×10^{-17} m^2 for 10,000 years[19]. The intermediate plug in the three-plug configuration is also expected to have a permeability of 5×10^{-17} m^2 for 10,000 years. For the two- and three-plug configurations, DOE expects the plugs to each be 40 m in length. [Appendix MASS, Attachment 16-3, p. 36]

In the PAVT, EPA required that two changes be made regarding the permeability of the borehole plugs. First, the Agency required that the permeability of the intact plugs be treated as a variable rather than a fixed parameter. Thus, instead of using a constant permeability of 5×10^{-17} m^2 as was the case for the CCA, the PAVT assigned a permeability range from 1×10^{-19} to 1×10^{-17} m^2. This range lies within the bounds of values found in the literature and in available data. [CARD 33, Section 33.G, Docket: A-93-02, V-B-2]

The Agency also required that the permeability of the degraded borehole be changed from a range of 10^{-14} to 10^{-11} m^2 with a median value of 3×10^{-13} m^2 in the CCA to a range from 5×10^{-17} to 1×10^{-11} m^2 with a median value of 2.24×10^{-14} m^2 for the PAVT*,* as noted in EPA's Overview of Major Performance Assessment Issues. [Docket: A-93-02, V-B-5, p.37] Thus, the upper end of the range was the same as used in the CCA but the lower end of the range was reduced by three orders of magnitude. The Agency believed that the upper end of the range chosen by DOE was reasonable for the debris (blowing silty sand) which might fill the open borehole over long periods of time. Since the permeability of the actual borehole fill material at some time well into the future is unknowable, the Agency believes that the use of data based on natural materials is a reasonable approach. However, the Agency was not satisfied with the rationale for the lower end of the range chosen by DOE (i.e., 10^{-14} m^2). It is the Agency's view that there is some probability that the concrete borehole plugs will not degrade after 200 years as assumed in the CCA. Consequently, in the PAVT, the lower end of the range was set at a value consistent with intact concrete. Contrary to the commenter's statement (Comment 5.G.2), EPA used a loguniform distribution for this parameter. Use of a loguniform distribution is consistent with guidelines used for all CCA parameters where only the ends of the range are known and the range extends over several orders of magnitude. [Appendix PAR, p. PAR-8] The Agency point*s* out that the use of a loguniform distribution is conservative*,* since it biases results toward lower permeabilities.

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19 Although Appendix MASS Attachment 16-3 states that the Bell Canyon plugs are assumed to degrade after 5,000 years and a permeability of 10^{-12} to 10^{-15} m^2 is indicated for the balance of the regulatory life, this assumption was not used in PA.

The Agency does not agree with the assertion that the CCA does not model the gas build-up which would result from impermeable plugs. In the CCA gas pressure is allowed to build up in the undisturbed repository. If the repository is intruded by a borehole , the intrusion will depressurize the repository. This will almost certainly be the case, since there is a 99.7% probability of one or more intrusions in 10,000 year and an 86.9% probability of one intrusion or more in 4,000 years. [Hansen et al. 1997, Docket: A-93-02, II-G-23, Appendix E] The borehole will then be plugged and in many scenarios, the pressure will again begin to build up, as shown in the Preliminary Summary of Uncertainty and Sensitivity Analysis. [Docket: A-93-02, II-G-7, Figure 3.3.1] The final pressure after the intrusion shows highly complex behavior depending on the interaction of a number of variable parameters in a given realization and can range from about 1 MPa to about 9 MPa. In 2% of the cases the continuous plug will not degrade at all. Because the Agency was concerned that assuming only 2% of the plugs were impermeable might not be conservative, they required in the PAVT (as discussed above) that the permeability range for the degraded borehole be broadened to include a lower limit of 5×10^{-17} m^2 -- a value where gas will not escape at a significant rate. This parameter change insured that low borehole permeability after 200 years was included in more of the PAVT realizations.

One commenter said that EPA did not use realistic shaft, borehole and panel seal performance estimates (Comment 5.G.3). Without specific examples of deficiencies in EPA's estimates, the Agency cannot further address the commenter's general statement. The Agency notes that the Conceptual Models Peer Review Panel found the exploration borehole conceptual model adequate for performance assessment. [Appendix PEER, p.3-141, Docket: A-93-02, II-G-1, Vol. XV] The Agency further notes that the key parameters used in this conceptual model were reviewed by the Engineered Systems Data Qualification Peer Review Panel and determined to be adequate, as described in Docket: A-93-02, II-G-1, Appendix PEER, PEER 5 and II-G-13.

Issue H: Sample size and CCDFs

1. Monte Carlo sampling is a powerful, accurate means of combining terms of a function, each of which is uncertain in magnitude because it ranges over a definable PDF. However, DOE has employed Monte Carlo sampling to also include uncertain alternative magnitudes and competing concepts, both illegitimate applications. For example, matrix diffusion, as opposed to other mechanisms of species retardation, has been deduced from tracer testing in fractured Culebra dolomite. The range of retardation factors from such local tests cannot be uniformly applicable in other areas, particularly where dissolution channeling minimizes diffusive interchange with wallrock pore spaces. (840)

2. There is concern whether the sample size of 300 simulations is sufficient to adequately explore the range of behaviors of such a complex model (at 27). (1062)

Response to Comments 5.H.1 and 5.H.2:

The WIPP PA model calculated three hundred CCDF curves, representing 300 plausible but different sets of physical conditions of the disposal system. The performance assessment model accounts for uncertainty in physical, geological, and chemical characteristics by Latin Hypercube Sampling (LHS) of parameter values required by the various PA models that describe the behavior of the repository over time.

In the LHS procedure, a probability distribution is assigned to each uncertain parameter. The method used to construct the probability distributions varies from parameter to parameter. In cases where experimental laboratory or *in situ* data is available, these data is used to construct a distribution that covered the range of the data. In other cases, when actual experimental data is not available, an elicitation of expert opinion is used to construct the probability distribution. When there is a large degree of uncertainty for a parameter due to differing sets of experimental data or physical analogs, the range of the distribution is extended to account for the range of possibilities encountered.

A few LHS parameters are such that only two or three discrete values are possible. These are used in situations that require a choice between discrete alternatives, such as whether there will be significant gas generation due to microbial degradation of plastics, or not. In these cases, the LHS formalism is used to generate a weighted-average forecast. While this is not a typical use of the LHS formalism, the use of discrete variables in LHS is an acceptable mathematical procedure for constructing the weighted-average CCDF. An equivalent answer would be obtained by running the PA model once under each discrete choice, then combining the resulting CCDFs for these choices using the assigned probabilities as weights.

In DOE's application of the LHS procedure, one set of parameter values was selected for each run of the PA model. For hydrogeological parameters that describe properties of the salt and surrounding geological strata (e.g. matrix diffusion), the sampled value often was applied uniformly to large regions of material, as an approximation to the actual physical properties of that region. Although fluctuations in actual parameter values, such as chemical retardation, are to be expected from point to point within a region, the WIPP PA approaches this problem by using large-scale properties of regions far away from the repository and smaller regions with unique properties closer to the repository.

Due to the complexity of the models used in the PA, every parameter was not included in the formal LHS procedure. DOE selected a group of 57 key parameters for LHS which it believes have the greatest potential effects on the results of the calculations. Each parameter was assigned a probability distribution, and a total of 300 random values were selected for each parameter using the Latin Hypercube Sampling program.

The result was a set of 300 "input vectors," each containing a unique set of values for the 57 input parameters. The computer codes used 300 input vectors to generate 300 output files, in three independent populations with 100 realizations each. The CCDFGF code within the PA model simulated a set of 10,000 possible futures of the repository system for each of the 300 input vectors, resulting in a total of 3,000,000 simulated futures. The performance assessment model uses the Monte Carlo sampling technique mentioned by Comment 5.H.2 to simulate human intrusion scenarios in these thousands of futures, but not for taking samples of parameters. The

10,000 futures in each simulation run are summarized by a single CCDF. The resulting three replicates of 100 CCDFs each were compared individually and collectively to the established release limits to determine compliance.

Questions of uncertainty arise as part of the decision making process. It is important to reduce uncertainty to the extent required to avoid an improper decision concerning compliance. The probabilistic requirements set forth at Section 191.13 did not specifically address questions of uncertainty when determining compliance. The question of sufficient sample size is addressed within the decision making framework introduced at Section 194.34 (and for compliance assessment, at Section 194.55). Section 194.34(d) establishes that there must be enough CCDFs so that "at cumulative releases of 1 and 10, the maximum CCDF generated exceeds the 99th percentile of the population of CCDFs with at least a 0.95 probability." It is this criterion that EPA requires the CCA PA to meet as a demonstration that DOE has computed enough of the infinite number of possible outcomes. The requirements of Section 194.34(d), and the analogous requirement for compliance assessment at Section 194.55(d), ensure that computed values from performance assessment or compliance assessment will include values from the highest one percent of all possible results.

DOE provided a probabilistic analysis to EPA indicating that 298 CCDF curves would be enough for the maximum CCDF to exceed the 99th percentile with 0.95 probability. [CCA Chapter 8.1.4, p. 8-8 to 8-10, Docket: A-93-02, item II-G-1, Vol. 1] EPA concurred with this analysis. [CARD 34, Results of Performance Assessments, sections 34.D.4 and 34.D.5, p. 34-19; Docket: A-93-02, item V-B-2] The Agency also conducted its own analysis by fitting statistical data on CCDF curves from the CCA PA to statistical probability distributions that EPA believed were most likely to represent the full, infinite population of CCDFs. Based on the Agency's analysis, the projected 99th percentile value was significantly below the value of the maximum DOE CCDF curve at a normalized release of 1. [CARD 34, Results of Performance Assessments**,** section 34.D.5, pp. 34-20 and 34-21; Docket: A-93-02, item V-B-2] This also applied for the Performance Assessment Verification Test. [*ibid*., p. 34-21] Based upon these analyses, EPA concluded that DOE has met the criteria of Sections 194.34(d) and 194.55(d). The Agency finds that DOE has generated enough CCDF curves or simulations to "adequately explore the range of behaviors" of the repository and to determine whether the WIPP meets the containment requirements of Section 191.13.

Section 194.34 establishes a quantitative statistical procedure to account for anticipated uncertainties. The effect of variations introduced by uncertainties in parameter values are reflected in EPA's choice of the Upper Confidence Limit (UCL) for the overall mean CCDF for determining compliance at Sections 194.34(f) and 194.55(f). Uncertainties in parameter values are reflected in DOE's summary of results as the distance between the estimated overall mean CCDF curve and the UCL for the mean CCDF. In the analyses leading to the results presented in Figure 6-39 in Section 6.5.2 of the CCA [Docket: A-93-02, II-G-1, Volume I], DOE has demonstrated by using 3 independent sets of 100 simulations that the UCL for the mean is not appreciably distant from the overall mean CCDF for the 300 simulations. As demonstrated in the figure, the degree of variation in the mean for these three replicates of 100 realizations is very small relative to the distance between the UCL and the step function which indicates the containment requirements. The small relative improvement in estimating of the precise location of the UCL that may be obtained by additional simulations is not warranted given the results presented by DOE.

The number of replicates is the primary means of reducing uncertainty in the estimated mean. If more than 3 replicates of 100 were used, it is likely that the UCL for the mean would decrease, due to the greater number of sample values used for estimating the mean. The UCL for the mean given n replicates is calculated as $M_n + k_\alpha S_n/(n\text{-}2)$, where M_n is the arithmetic average of the n individual means, S_n is their standard deviation, and k is a factor that depends on the level of confidence α. Increasing n from 3 to 4 will reduce the second term in the sum by a factor of 2. The resulting UCL will be smaller, unless the mean for the new replicate lies far from the other three means. This is unlikely, however, because the means for the first three replicates are so closely grouped. The fact that DOE has been able to demonstrate compliance using as few as 3 replicates suggests that the compliance decision is a conservative one.

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3. Finally, CCDFGF modeled the probability of releases from the results of the above calculations. The outcome showed that there is no significant change in releases due to the minor addition of releases from a spalled or brine release. The releases calculated in CUTTINGS_S and BRAGFLO_DBR were not significantly more than those in the CCA. However, the releases are subject to the concentration of radionuclides in the waste, and it is suspected that changes in the solubility, which would increase the concentrations of the radionuclides, would have a more profound effect on the Castile simulation than the CCA. (1084)

4. To generate the statistical distributions from which the risks are calculated, many simulations of hydrogeologic processes are performed to generate an adequate sample size. The approach to varying the values of the many parameters in the multiple realizations can introduce errors into the final analysis. In particular, if hydrogeologic variables that are highly correlated are sampled independently, and if the correlations are ignored, then some of the realizations may be based on unreasonable or very unlikely combinations of parameters; such individual simulations should not be incorporated into the final analysis because they may skew the statistical results. (1270)

Response to Comments 5.H.3 and 5.H.4:

The Latin Hypercube Sampling (LHS) procedure used in the WIPP PA model has the capability to impose explicit correlations between parameters when correlations are known to be required. Parameter correlations involving hydrogeologic processes are used in the PA model for parameters controlling rock compressibility and intrinsic permeability. Based on hydraulic testing in these units, these parameters are highly negatively correlated. As noted in Appendix PAR [Docket: A-93-02, II-G-1, Section PAR.4], there are three places in the BRAGFLO model where this negative correlation is applied:

- A correlation of -0.99 is used in the Salado impure halite material region;
- A correlation of -0.75 is used in the Castile brine reservoir material region; and
- A correlation of -0.99 is used in the Marker Bed 139 material region.

There are also many cases of induced correlation in the PA model, where one LHS parameter is used as a "surrogate" to develop values of other important PA parameters not included in the LHS matrix. Examples of more than a dozen induced parameter correlations are enumerated in Appendix PAR.4.

Other suspected correlations have been investigated by DOE, but no evidence was found to support such correlation. Possible correlations between well-to-well transmissivity, well-to-well advective porosity, and matrix block length were investigated in Appendix MASS, Attachments MASS 15-6 and 15-10. [Docket: A-93-02, II-G-1] No evidence for such correlations was found.

Sample correlations between other pairs of parameters, considered *a priori* to be uncorrelated, are set to zero. For these uncorrelated variables, the LHS procedure uses a technique called restricted pairing to control unwanted correlations between parameters that may arise solely by chance.

Based on its review of available information, the Agency has not identified any unreasonable or unlikely correlations which will skew the PA results in a significant way. For additional discussion of DOE's treatment of parameter correlation and EPA's review, see section 14, requirement Section 194.23(c)(6) in CARD 23, Models and Computer Codes. [Docket: A-93-02, item V-B-2]

Issue I: Castile brine pocket reservoirs

1. The Compliance Certification Application presents data for the creation of reservoir parameters that may be extraneous. The data were derived from wells that clearly lie outside a reasonable distance for consideration of brine pockets underneath the repository. Therefore, data from a single well, one mile north of the repository, was used to simulate the effects of the reservoir. . . [In addition] waste permeability was increased by 41%. . .[and] the residual brine saturation range was decreased by reducing the upper value by 57%. . .The changes in the Castile reservoir parameters affected the pressures, flow, and saturation of brine and gas through the waste. The pressures were much higher than the CCA, with increase in flow rates due to an increased waste probability. (1081)

Response to Comment 5.I.1:

This comment pertains to the sensitivity analysis that EEG performed. [Docket: A-93-02, IV-G-43] With respect to this issue, EEG also states, "Finally, CCDFGF modeled the probability of releases from the results of the above calculations. The outcome showed that there is no significant change in releases due to the minor addition of releases from a spalled or brine release. The releases calculated in CUTTINGS_S and BRAGFLO_DBR were not significantly more than those of the CCA." In essence, EEG found that changes to the brine reservoir properties did not significantly alter the CCDF. The Agency agrees with the results of the EEG analysis.

Issue J: Hartman scenario

1. Where is EPA's modeling of the Hartman Scenario?(30)

2. Is there a model in the WIPP Docket that explains the occurrence of the Hartman Scenario? If DOE's model can not explain Hartman, a new model is necessary. (74)

3. How does the Agency respond to the observation that flow under the Hartman Scenario can be explained by LEFM, but not BRAGFLO? (p. 12) (77e)

4. I request that you require the DOE to resubmit a compliance [application] that includes the issues of the [Hartman] scenario, modeling air drilling releases from [either] air and mud drilling, and the possibility of drilling into the WIPP site and hitting a brine reservoir. (428)

5. The state of New Mexico Environmental Evaluation Group predicts 100 percent chance that drilling will breach the WIPP site. Is DOE EPA going to ignore this? In the Hartman well case, the brine traveled for miles and blew out another well miles away from it. This happened numerous times in the WIPP site area. Why is the EPA ignoring the potential of oil field injection to cause massive releases from WIPP? (572)

6. For fluid injection activities on leases adjacent to the site, the DOE argues that such events can be eliminated from further consideration on the basis of low consequence. The EPA raised questions regarding DOE's consequence analysis and "concluded that regardless of the consequence argument, the probability of such an injection event that affects WIPP is very low, and so this FEP can be eliminated on the basis of low probability" (CARD 32, p.42). . .

Nonetheless, EPA assigned probabilities to certain petroleum practices, such as an undetected leak occurring in the annulus, and multiplied the probability of each event and calculated that the realistic probabilities of a injection well impacting the repository was only one in 667 million (EPA, III-B, Table Q). But this value appears to be based on an optimistic view of future injection well performance and does not reflect the actual experience of documented water flows in the Salado Formation in water flood areas throughout southeast New Mexico. (698)

7. Can the DOE codes model a documented high consequence event? In other words, can the DOE code take the injection data and geologic data from the highly visible Hartman case and reproduce what is believed to have happened at the Bates Lease? Can these codes model the migration of substantial amounts of water through a single zone of the Salado Formation, two miles in the up dip direction, in about 12 years? That has yet to be shown. Unless the code is

verified with actual field data, the low consequence conclusion will remain a speculation at best. (699)

8. EEG assumes that the legal resolution of the Hartman v. Texaco case provides scientific evidence that a particular event occurred; i.e., the flow of significant quantities of water through a single zone in the Salado. Furthermore, the EEG assumes that there is enough injection data and geologic data to constrain the problem sufficiently for a meaningful verification of the DOE codes to be performed. In addressing this comment, the DOE notes that EEG did not mention hydrofracture of the Salado as a necessary component of the movement of such quantities of water over long distances in the Salado. However, as it is unlikely that the flows observed at Bates #2 occurred from intact evaporite rock, it is assumed that the EEG's statement "what is believed to have happened at the Bates Lease" is an oblique reference to the hypothesis of Bredehoeft (1997), in which a two mile or longer hydrofracture is postulated to have occurred from the Texaco Rhodes-Yates waterflood injection wells to the Bates Lease.

The stratigraphy and well-completion practices are different in the WIPP region than the Rhodes-Yates area. In its original analysis of the possible effects of fluid injection on the WIPP, the DOE investigated the effects of these differences (Stoelzel and O'Brien, 1996). This analysis found that the stratigraphic differences do matter, and that the well completion practices used at Rhodes-Yates would be expected to present greater hazard to the evaporite section. The original conclusion remains valid today: whatever its cause, the brine flow at the Bates *#2* well is not relevant to the conditions at WIPP. (918)

9. EPA's statements that the "high pressure won't occur for several hundred years, if at all" and that "[t]his is after the time ('near future') that fluid injection activities could be expected to occur in the vicinity of WIPP" (TSD III-B-21 at 147) both ignore the modeled situation where WIPP is at low pressure and becomes inundated (II-H-28 at 31-35; II-D-116(b) at 22-24) and ignore the real risk of fluid injection failure in times beyond the "near future," which EPA should, but does not, regard itself as responsible to prevent. Under a scenario involving an injection well and a second outflow well, through which releases occur, 50 EPA units would cross the regulatory boundary in about 13 years (II-D-116(b) at 33). (1003)

10. EPA has said that Stoelzel and Swift (1997)(II-l-36) indicate that "current well construction makes it unlikely that there could be a well failure of the nature that occurred in the Rhodes-Yates Field near the WIPP but outside the Delaware Basin" (id. 147) and that such a complete failure as shown in the NMAG report (II-H-28) has a "very low probability" (id.). EPA said that the probability of scenarios that move fluid to the repository via injection is "less than one in 10,000." (TSD III-B-21 at 148). EPA's probability determination ignores the "numerous" severe water flows experienced in New Mexico (See II-D-116(b) at 4). (1004)

11. Neither DOE nor EPA has presented a model that can reproduce the observed and measured blowout conditions at the Hartman *#2* Bates well. Unless a model can reproduce these actual events, that model cannot be considered valid. The model presented in Bredehoeft & Gerstle

(1997)(II-D-116(b)) reproduces the Hartman blowout and is a valid model of waterflood-caused blowouts. (1005)

12. Does EPA assume that any future injection wells will be drilled, completed, operated, and monitored entirely in accordance with 1996 technology and regulations? If not, what assumption is made in this regard? What is the basis for EPA's assumption? (1006)

13. EPA found that DOE's analysis of fluid injection should be updated to estimate the frequency of fluid injection wells that have failed or appear to have failed (TSD III-B-22 at 4). What is the result of that estimate? (1007)

14. We demonstrated in our earlier analysis that a leaking borehole could create a hydrofrac that could extend to WIPP -- similar to what happened at the Hartman #2 Bates well. We also showed that such a leaking injection well could potentially pressurize WIPP to lithostatic pressure -- let's assume this happens. Let's then assume there is a leaking outflow well in WIPP, there as a result of an earlier penetration of the repository. We further assume that this outflow borehole has a permeability of 1.0×10^{-11} m^2 ($\approx 1.0 \times 10^{-4}$ m/sec) -- the highest value used in both the PA and the PAVT. . . The potential releases are summarized [below]:

	Release	@10^{-2} EPA units/m^3	@10^{-2} EPA units/m^3
1yr	250	250 m3	0.25 EPA units
10	2,500	25	2.5
20	5,000	50	5

This two-well scenario has the potential to provide a significant release of radionuclides. We believe it should have been included in the PA. (1050)

15. The screening decision referred to by DOE (CCA, Appendix SCR.3.3.1.3.1) claims that leakage from brine injection wells is "unlikely to occur" near the WIPP for a number of reasons. (1) DOE argues that oil production near the WIPP takes place in the Brushy Canyon Formation at depths greater than 7000 feet. The truth is that some producing oil wells near the WIPP are tapping the Cherry Canyon Formation at depths of 5100 to 6200 feet. More importantly, brine injection near the WIPP takes place in the Bell Canyon Formation at depths of only 4000 to 5100 feet. (1185)

Response to Comments 5.J.1 through 5.J.15:

In January 1991, Doyle Hartman, a Lea County oil operator, began drilling a gas well (Bates #2) in Section 10, Township 26 South, Range 37 East. This location is twenty miles south and thirty-four miles east of the center of the WIPP site. At about 1:45 AM on January 16 a strong salt water flow was encountered in the lower Salado Formation at a depth of 2,240 feet. Flows as high as 1200 barrels per hour were observed and flow continued for 5.5 days before it was possible to cement the drill pipe annulus and shut in the well. Hartman incurred considerable expense in controlling the water flow, abandoning the Bates #2 well and canceling plans to drill a second well. In 1993 Hartman sued Texaco, Inc., alleging that the salt water flow was caused by operation of the Rhodes-Yates Waterflood Area, (RYW), two miles south of the Bates #2 well. A jury trial in January, 1995 in the First Judicial District, County of Santa Fe, State of New Mexico, resulted in a judgment favoring Hartman. Material presented in the lawsuit as well as technical reports by Craig W. Van Kirk for Hartman (VAN 94) and John F. Pickens for Texaco provide considerable information about this incident and other water flow problems in Lea County.

The first oil well in the RYW area was drilled in 1927 and most of the remainder of the field was developed in the 1940's. A small water flooding project began in 1964 with two injectors and two million barrels of water were injected in the next ten years. Water flooding was expanded to twenty-one injectors in 1974.

Van Kirk makes several points in reaching his conclusion that the water flows in Bates #2 well could only have come from the RYW:

- ♦ Twenty million barrels more water have been injected than the amount of produced fluids from the Bates #2 well;

- ♦ Data from Texaco well files indicate problems with water flows in the Salado as early as 1979. None of these water flows were reported to OCD, even though regulations require it;

- ♦ Texaco down-hole pressures had gradients as high as 1.3 psi per foot of depth. This pressure consists of the hydrostatic head of saturated salt water (about 0.525 psi per foot of depth) plus the injection pressure applied. OCD regulations limit the injection pressure to 0.2 psi per foot of depth unless step rate tests have been performed. Higher pressures are required to be approved by OCD and are to be held below rock fracture pressures. Van Kirk shows graphs of injection pressure history for four weeks indicating that step rate tests were conducted but that injection pressures were above the fracture pressure over 90% of the time during the seventeen year period from 1977 through 1993. In addition, no evidence of the required OCD approval was found;

- ♦ The observed pressure gradient at the Bates #2 well was 0.967 psi per foot of depth based on a shut-in pressure of 1000 psig (0.442 psi/ft.) and a hydrostatic head of 0.525 psi/ft. Van Kirk included a pressure gradient contour map for December 1 that showed a gradient of slightly over 1.00 psi/ft at the Bates #2 well (consistent with the observed gradient) and a gradient of about 1.3psi/ft in the RYW.

<u>Regulations on injection wells</u>

The State of New Mexico Energy and Minerals Department, Oil Conservation Division (OCD) has rules and regulations covering oil and gas activities on State lands. Title I of the Rules (Secondary or other Enhanced Recover, Pressure Maintenance, Salt Water Disposal, and

Underground Storage) cover all types of injection wells. There are several observations relevant to the WIPP:

- In general, notices and hearings are required for new pressure maintenance and water flood projects. However, these projects can be expanded by administrative approval;

- Salt water disposal wells can usually be approved without hearing. Thus, injection into the Bell Canyon could be handled solely by administrative approval; and

- Rule 702 specifies casing and cementing requirements which, if complied with, would prevent movement of water to any zones other than the injection zone.

The notice and hearing requirements are relevant to WIPP because it makes it more likely that possible consequences on WIPP will be recognized before injection is approved. The observed cases of water migration problems indicate that operators do not always comply with the casing and cementing requirements of Rule 702. The degree of compliance with other portions of the Title I is not known.

The Bureau of Land Management (BLM) has responsibility for wells on Federal lands. BLM regulations are not are as detailed, but are generally similar to those used by OCD. However, injection wells on BLM lands are under OCD regulation (NBM 95)

<u>Fluid injection</u>

Despite comments to the contrary (Comments 5.J.1, 5.J.4, AND 5.J.5), DOE did address the fluid injection scenario in the CCA FEP evaluation activities with an analysis of waterflooding (for enhanced oil recovery) and brine disposal activities, including modeling of a Hartman scenario. [Docket: A-93-02, Item II-G-1, Reference #611] This work examined the effects of brine injection for secondary oil recovery on the performance of the WIPP repository in a study by Stoelzel and O'Brien. [1996, Docket: A-93-02, II-A-32]

In accordance with Section 194.32(c), DOE determined that these two activities were the only fluid injection scenarios that were currently occurring or could be initiated in the near future in the vicinity of the WIPP. DOE identified the Bell Canyon Formation below the Salado and Castile Formations as the primary target for fluid injection for brine disposal. DOE stated that this scenario had the potential to produce brine inflow to the WIPP. DOE modeled the fluid injection scenario using WIPP geology, and also using the geology identified in the Rhodes-Yates Field.

The modeling results indicated that some brine could potentially get into the WIPP from fluid injection activities using conservative modeling assumptions. However, the amount of brine from the worst case scenario (the "Hartman" like scenario) was low compared to the amount of brine expected to enter the waste area naturally. DOE thus screened out the fluid injection scenario on the basis of low consequence.

EPA raised additional questions regarding DOE's screening analysis of fluid injection. EPA required DOE to use modified values for some input parameters, and to model the behavior of the disturbed rock zone consistent with assumptions used in the PA. [Docket: A-93-02, Item II-I-17] EPA also required DOE to provide additional information on the frequency of fluid injection well failures.

In supplemental work on fluid injection, DOE addressed all the issues identified by EPA. DOE modified the computer model grid configuration and added a new model to address concerns raised by both EPA and stakeholders. [Stoelzel and Swift, 1997, WPO # 44158, Docket: A-93-02, II-I-36b] DOE researched injection well operating practices in the Delaware Basin and identified significant differences between those in the vicinity of the WIPP and the Rhodes-Yates Field. DOE found that wells near the WIPP are typically less than ten years old and are constructed to much higher mechanical standards than the older wells found in the Rhodes-Yates Field. DOE identified a range of well failure scenarios, ranging from undetectable brine flow to catastrophic well failure. DOE's data indicated that the probability of a catastrophic well failure in the vicinity of the WIPP is extremely low. DOE's modeling [Docket: A-93-02, II-I-36b] confirmed that the presence of the Castile at the WIPP also substantially inhibits injected brine movement into the Salado anhydrite markerbeds.

Because the fluid injection scenarios have been the subject of many public comments, the scenarios have undergone heightened EPA scrutiny. The New Mexico Attorney General (NMAG) submitted a report that contradicted the DOE fluid injection modeling by Stoelzel and O'Brien [1996] and suggested that fluid injection activities could overwhelm the WIPP with brine. [Docket: A-93-02, II-H-29] EPA reviewed the NMAG report and found that it models highly unrealistic conditions for the WIPP area. For example, the NMAG report assumes, for all modeled scenarios, that all brine is directly injected into the anhydrite interbeds in the Salado Formation (Comments 5.J.9 and 5.J.14). The continuous injection of all of the brine into a very thin layer several hundred meters above the oil production zone would defeat the objectives of the water flooding activities designed to enhance oil recovery. Therefore, it is not considered by the Agency to be a viable operational possibility. Th*e* approach of the NMAG report ignores the fact that well operators would be attempting to inject brine into certain formations hundreds of meters below the Salado where petroleum reserves are located. Also, current well injection and construction practices makes it unlikely that there could be a well failure of the nature of the "Hartman scenario" that occurred in the Rhodes-Yates field outside the Delaware Basin (e.g., the use of multiple casings, enhanced cements, and cement logging techniques to test bonding percents). [Stoelzel and Swift, 1997, and Docket: A-93-02, II-I-31 and Attachment 1 of I-I-36]

Also, the NMAG report considers fractures in the anhydrite to extend for three or more kilometers and to remain open. A prerequisite for this condition is high pressure (Comment 5.J.9). The report states "We can only get high pressure over the entire region if the repository pressure is also high." [Docket: A-93-01, II-H-28, p. 21] The report further states "If the pressure in WIPP is below lithostatic, then the area where a fracture might remain continuously open is restricted to close into the injection well. The fracture will not be continuously open all the way to WIPP; however, it might pulse open and closed...” However, lithostatic (high pressure) conditions are predicted to occur infrequently in both DOE’s calculations in the CCA and EPA’s calculations in the Performance Assessment Verification Test. [PAVT Tables 2.1 to 2.6; Docket: A-93-02, II-G-26 and II-G-28]

EPA performed its own independent studies of fluid injection which showed that the injection analysis must consider the nature of the anhydrites, duration of injection activities, and presence of leaking boreholes. [EPA Technical Support Document for 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22] The results of this analysis show that the permeability in marker beds is probably lower than that used in the PA, and that other factors (such as injection rate, injection interval, etc.) also play a very important role in fluid injection. EPA agrees that under very unrealistic conditions, modeling can show fluid movement toward the WIPP under an injection scenario. These conditions include those modeled by Bredehoeft [Docket: A-92-01, II-H-01], such as long-term steady-state flow, two well scenarios, and pulsing flow. However, when using more realistic and reasonable but still conservative conditions in the modeling, fluid movement sufficient to impact disposal performance of the WIPP does not occur. The following are further substantiation of EPA’s position in relation to the Hartman scenario and response to the specific issues mentioned above.

The Bates lease (Hartman’*s* leaking wells) and the Rhodes - Yates Fields (Texaco) are approximately one mile apart and located in townships and ranges T26S and R37E. The WIPP site is located approximately 40 miles from these areas in T22S and R31E. The WIPP site and the Bates lease are in areas that have very different geology. The Hartman scenario took place in back-reef (Shelf) facies and the WIPP is located in the basin facies. The shelf facies is predominantly composed of carbonates and the basin facies are mainly of clastic origin (e.g., sandstones). Relatively high drilling density and larger production zones are characteristics of the shelf facies. In the Delaware Basin proper, the clastic pay zones were deposited in relatively narrow channels and show lower drilling density than the shelf facies.

The thickness of the Castile Formation is roughly 2000 ft at WIPP, while it is absent in the Shelf areas. Also, greater vertical separation between the injection zone (segment of a formation where the salt water is injected for disposal) and the WIPP geologic interval will make it more difficult for fluids to travel vertically upward. (Friction will also restrict the upward flow to an extent.) The receptive formation (Salado) is expected to behave in a similar fashion in both the areas. It is apparent that the geology in the WIPP area will play an active role in preventing fluid movement, or in an extreme case, a massive well blowout.

As discussed above, both DOE and EPA evaluated the Hartman Scenario to see if it needed to be included in modeling of brine injection as a human intrusion scenario in performance assessment. In preparing its proposed rule, EPA believed that the combination of the geologic differences and the current fluid injection practices in the WIPP vicinity compared to the Hartman-Bates makes it unlikely for there to be a repeat of the Hartman scenario at WIPP. [Section 3.6, Technical Support

Document for Section 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22] For example, the WIPP repository level is separated from potential layers where brine injection might occur by a greater thickness of salt and anhydrite interbeds than at the Rhodes-Yates field where the Hartman case occurred. Additional vertical separation and the presence of additional thief zones near the WIPP would tend to divert any flow that might leak up a hypothetical vertical pathway, as compared to the Hartman case. Interbeds in the vicinity of the WIPP Site are more numerous and are likely to be thinner than in the Hartman case, thereby reducing the likelihood of flow between the repository and the WIPP boundary. [Section 3.6, Technical Support Document for Section 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22] There are many geological differences between the WIPP site and the Rhodes-Yates field in the Hartman case. Therefore, the Agency did not believe it was necessary to model the Hartman scenario in preparation for its proposed certification decision.

Interbed fracturing

DOE recognized that anhydrite interbed fracturing could occur as a result of high repository gas pressures, and included that scenario in its performance assessment calculations. DOE's fracturing model was based in part on the results of in situ fluid injection tests into anhydrite interbeds at WIPP, and in part on theoretical considerations. For a more detailed discussion, please see Response to Comments on Brine Injection in the following section. In response to public comments questioning the validity of the fracturing model used by DOE, EPA has reviewed in additional detail the basis for that model and has compared its modeling assumptions with those of an alternative model proposed in public comments. The alternative model suggested by Comment 5.J.3 is based on linear elastic fracture mechanics (LEFM) and assumes that the fracture occurs in a previously unfractured, homogeneous, elastic continuum. While DOE's model predicts the simultaneous creation of multiple fractures, LEFM predicts the creation of a single fracture. For a given increase in permeability, DOE's model predicts a larger porosity increase than the LEFM model. In evaluating the applicability of these models to the anhydrite interbeds at WIPP, EPA notes that the interbeds contain pervasive natural fracturing, open pores and void spaces, as well as natural surfaces of weakness along bedding planes. Further, the fluid injection tests at WIPP produced multiple parallel fractures rather than single fractures. [WPO#44704] Based on actual conditions at WIPP and the results of DOE's in situ injection tests, EPA concludes that DOE's fracturing model is appropriate and adequate for use in performance assessment and that it more closely represents actual conditions at WIPP than the alternative LEFM model recommended in public comments. DOE has also provided a detailed discussion of why the conceptual model assumed by LEFM is inappropriate for the WIPP site. [Docket: A-93-02, IV-G-34]

In the Agency's performance assessment verification test, fracture lengths were found to have exceeded 1000 m in a number of realizations in Replicate 1 of the undisturbed case. [PAVT; WPO # 46674 Appendix A p. A-8, Docket: A-93-02, II-G-26] The maximum fracture length realized in Replicate 1 of the undisturbed case in the CCA was 1900 m to the north in Marker Bed 138. [WPO # 46674 Appendix A p. A-8] From the foregoing discussion it is clear that the porosity model is capable of simulating fractures that are thousands of meters long (Comments 5.J.7 and 5.J.11).

EPA's examination of the scenario modeled by Stoelzel and Swift [1997, Docket: A-93-02, II-I-36] indicates that it is realistic and compatible with current oil exploitation practices in the Delaware Basin as discussed in EPA's Technical Support Document for Fluid Injection. [Docket: A-93-02, V-B-22] EPA has concluded that although scenarios can be constructed that move large volumes of fluid to the repository through injection, the probability of such an occurrence, given the necessary combination of natural and human-induced events, is less than one in 10,000. Therefore, DOE appropriately screened fluid injection out of consideration in performance assessment. Although EPA received many public comments about the lack of a fluid injection analysis, DOE did consider fluid injection in the scope of performance. DOE's additional fluid injection assessments after submittal of the CCA adequately address the potential impact of fluid injection.

Comments 5.J.2 and 5.J.3 suggest that the [BRAGFLO] porosity model could not have predicted the migration of brine over a distance of nearly 3 km, as the court found to have occurred in the Hartman vs. Texaco case. This statement is presented without supporting rationale. This issue is addressed in DOE's analysis of brine flow from injection wells to a WIPP-type repository hypothetically located in the Rhodes-Yates oil field where the aforementioned brine migration occurred. One injection well was assumed to be located about 2 km south of the hypothetical repository. Another was assumed to be located about 3 km to the north. [WPO # 40837] In this analysis, the BRAGFLO code was modified to incorporate geologic conditions and injection pressures pertinent to the Rhodes-Yates oil field; however, the material properties and hydrofracturing model were based on the same assumptions as in the CCA. As discussed in greater detail in the next section (i.e., fluid injection) the Agency does not believe that there is sufficient information available on the Hartman scenario to perform a model validation that would provide meaningful results.

Furthermore, DOE's model predicted anhydrite interbed dilation and hydrofracturing to extend thousands of meters from each well. In at least one of the cases studied, this dilation extended over the entire 2 km distance from the south well to the repository, as well as the entire 3 km distance from the north well to the repository. [WPO # 40837 Figure Appendix A Figure 14] The Agency concludes that under appropriate conditions DOE's porosity model is capable of predicting hydrofractures that are several kilometers long and is capable of predicting the brine migration found in the Hartman vs. Texaco case.

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16. EPA and DOE are not considering the new elements related to the oil and gas drilling and the events of natural resources there at the site and that Hartman well scenario, ignoring the drilling process that is 100 percent chance of the hitting the pressurized brine pockets in the changes, and definitely changes and the chance for active release of radioactivity into our environment and greatly changes the time frame. (563)

Response to 5.J.16:

EPA recognized that the rate of drilling would be an important consideration in performance assessment. The Agency stipulated the detailed considerations that DOE was required to incorporate into performance assessment in Section 194.33. These included an estimate of future drilling rates based on average drilling rates in the Delaware Basin during the past 100 years, the separate evaluation of shallow and deep drilling rates, and the assumption that drilling rates would remain constant for 10,000 years. More detailed discussions of the required drilling rate assumptions and the Agency's acceptance of DOE's implementation of those assumptions are presented in EPA's Response to Comment, Section 8.

It is true that DOE did not incorporate the Hartman Scenario into performance assessment. While preparing its proposed decision, EPA required DOE to analyze this further and also performed its own analysis. [WPO #44158, Supplementary Analyses of the Effect of Salt Water Disposal and Waterflooding on the WIPP, and Technical Support Document for Section 194.32: Fluid Injection Analysis; Docket: A-93-02, II-G-25 and V-B-22] The Agency proposed that DOE had appropriately screened out brine injection. [CARD 32 -- Scope of Performance Assessment, Section 32.A.6, Docket: A-93-02, V-B-2] After reviewing public comments, EPA has conducted further analysis of this issue, as discussed under Response to Comments 5.J.1 through 5.J.15. As a result of this additional analysis, EPA concludes that, when using realistic and reasonable but still conservative conditions in modeling, fluid movement sufficient to impact disposal performance of the WIPP does not occur.

References

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"Report Concerning Salt Water Blow-Out January 1991 on the 'Bates Lease' Sections 10 and 15, Township 26 South, Range 37 East, NMDA, Lea County, New Mexico," Van Kirk, Craig W., September 16, 1994.

Issue K: Brine injection

1. Doctor John Bredehoeft, a former member of the National Academy of Sciences WIPP panel, which I would hope would give him some credibility, found that the Hartman scenario could cause massive releases in excess of the disposal regulations. Even if the injection occurred outside of the WIPP site boundaries. Neither DOE nor EPA has satisfactorily modeled the Hartman scenario. Instead they have simply rejected Dr. Bredehoeft's work. (555)

2. EPA also accepts the DOE model of well injection, in which injected fluids are introduced into target zones well beneath the Salado and also flow into several anhydrite beds simultaneously (CARD 23 at 136). EPA has stated that "Direct emplacement of fluid into the Salado anhydrite interbeds was found by EPA to be unrealistic" (id. 137). EPA has rejected the report on the Hartman Scenario (II-H-28), saying that it is erroneous to assume that all injected brine enters the anhydrite marker beds (CARD 23 at 147). However, in the Hartman situation a large proportion of the injected brine did enter one Salado marker bed (II-H-28 at 16; EEG-62 at 66)(II-A-41). Contrary to EPA's opinion, in the real-life Hartman situation such occurrence constituted a "viable operational likelihood." (CARD 23 at 147). (1001)

3. [In its proposed rule EPA did not use:]

> * modeling of the real life occurrence at the Hartman #2 Bates well (II-H-28 and II-D-116); (1142)

4. EPA concluded that fluid injection can be screened out based on low consequence, as shown by DOE's "supplementary information" that was not included in the CCA (at 58806). SRIC strongly disagrees with that conclusion, which is not based on the best scientific analysis and technical data, which has been done by Dr. John Bredehoeft. (II-H-28, II-D-116 and 118) (1157)

5. EPA concluded that existing boreholes in the vicinity of the WIPP site will not affect the disposal system (at 58832). Once again, such a conclusion is not based on "good science" since such science, as provided in II-H-28 and II-D-116, show that fluid injection from outside the site boundaries could disrupt the disposal system and cause releases that exceed the containment limits. (1166)

6. The screening decision referred to by DOE (CCA, Appendix SCR.3.3.1.3.1) claims that leakage from brine injection wells is "unlikely to occur" near the WIPP for a number of reasons. . (2) DOE argues that the Castile Formation, which is not present at the Bates #2 well where the Hartman scenario took place, would provide potential "thief zones" that would prevent brine injected into the Bell Canyon Formation from rising into the Salado Formation. CARD has already pointed out that recent water level rises in the Culebra dolomite at test well H-9b, located 6.45 miles south of the WIPP site, are strongly correlated with brine injection in the Bell Canyon Formation, indicating that the Castile and Salado are not reliable geologic barriers. (1186)

7. The screening decision referred to by DOE (CCA, Appendix SCR.3.3.1.3.1) claims that leakage from brine injection wells is "unlikely to occur" near the WIPP for a number of reasons. . (3) DOE argues that oil pools in the vicinity of the WIPP are smaller than at the Rhodes-Yates field. . . and therefore waterflooding on the scale of that undertaken at the Rhodes-Yates field would be "unlikely" at WIPP. The scale of waterflooding is not the concern; what is relevant to containment at WIPP is the pressure and duration of waterflooding. (1187)

8. In other words, can the DOE codes take the injection data and geologic data from the highly visible Hartman case and reproduce what is believed to have happened at the Bates Lease (Hartman 1993, Van Kirk 1994, Powers 1995). At a minimum, the codes must be able to move a substantial amount of water through a single zone of the Salado Formation, two miles in the updip direction, and in a short period of time, about 12 years. If the model, as used by Stoelzel and O'Brien, cannot move the water to the Bates Lease, then any low consequence argument based on this model may be meaningless. At this point there is no indication that a verification with actual field events has been conducted and a low consequence argument based on an unverified model could be characterized as speculation. (1257)

9. The EPA discussion on structure can be best described as tentative speculation. The discussion suggests that there might be more flow through possible increased fracturing of the anhydrites *possibly* as a result of folding, faulting, or *perhaps* salt dissolution which *might* be inferred from the varying salt bed thicknesses at the Rhodes Yates Field and the Vacuum Field. The EPA further suggests that water chemistry of the field areas in formations underlying the Salado *may* provide evidence of a greater rate of evaporite solution relative to the WIPP Site. But no such evidence is provided. Further, there is no reference to the published literature to support the hypothesis advanced by EPA. In fact, the entire comparison of the geology at the Rhodes Yates, Vacuum, and WIPP areas is filled with statements such as "relatively fresh waters *may* have been a contributing factor. . . it is also *possible* that fold and dip rates in the vicinity of the other two fields *may* contribute to increased fracturing..."(EPA 1997, V-B-22). Given the implications of Hartman scenario at WIPP, it is unclear how EPA's geologic analysis can be considered as adequate to support an EPA conclusion that a repeat of the Hartman scenario is unlikely at WIPP. (1264)

10. The occurrence at the Hartman #2 Bates well was caused by a hydraulic fracture (hydrofracture) extending from the Texaco Rhodes-Yates waterflood location to the Hartman #2 Bates well, other explanations are unsupported. (1351)

11. BRAGFLO in its current implementation is an inadequate model to predict the extent of hydrofractures. Further, Stoelzel and Swift (1997) are nonconservative in their use of BRAGFLO to compute the radius of hydrofractures caused by leaking injection wells, in that they assume uniform permeability in the entire borehole annulus around the casing of the leaking well and allow fluids to enter all maker beds simultaneously. (1352)

<u>Response to Comments 5.K.1 through 5.K.11:</u>

A number of the above comments indicate a general concern exists that brine injection type scenarios could jeopardize the containment capability of the WIPP site. For this concern to be realized, however, large volumes of injected brine would have to travel over great distances in short periods of time. A number of public comments also refer to anecdotal evidence that suggests that rapid brine movement through the anhydrite marker beds is possible. Furthermore, reviewers have raised concerns that even if DOE had wanted to model rapid brine movement through fractures, their model (i.e., BRAGFLO) is incapable of doing so. The Agency disagrees with these comments and believes that brine injection does not pose an unacceptable risk to the integrity of the repository. The basis for EPA's position is outlined in the following subsections.

DOE's approach

DOE addressed brine injection in the CCA FEP evaluation activities with an analysis of water flooding (for enhanced oil recovery) and brine disposal activities, including modeling of a Hartman scenario. [Docket: A-93-02, Item II-G-1, Reference #611] In this study, the authors evaluated the effects of two hypothetical injection boreholes near the WIPP using the BRAGFLO code. In accordance with Section 194.32(c), DOE determined that these two activities were the only fluid injection scenarios that were currently occurring at the time the application was submitted to the EPA or could be initiated in the near future in the vicinity of the WIPP.

DOE identified the Bell Canyon Formation below the Salado and Castile Formations as the primary target for fluid injection for brine disposal. DOE stated that this scenario had the potential to produce brine inflow to the WIPP. DOE modeled the fluid injection scenario using WIPP geology, and also using the geology identified in the Rhodes-Yates Field. [Docket: A-93-02, II-A-32, p. 26]

The modeling results indicated that some brine could potentially get into the WIPP from fluid injection activities using conservative modeling assumptions. However, the amount of brine from the worst case scenario (the "Hartman" like scenario) was low compared to the amount of brine expected to enter the repository naturally. DOE thus screened out the fluid injection scenario on the basis of low consequence because future fluid injection activities will not increase waste releases for the WIPP. [Docket: A-93-02, II-A-32, p. 5]

EPA raised additional questions regarding DOE's screening analysis of fluid injection after its initial review. EPA required DOE to use modified values for some input parameters, and to model the behavior of the disturbed rock zone consistent with assumptions used in the PA. [Docket: A-93-02, Item II-I-17] EPA also required DOE to provide additional information on the frequency of fluid injection well failures. [Docket: A-93-02, II-I-17]

In supplemental work on fluid injection, DOE addressed all the issues identified by EPA. DOE modified the computer model grid configuration and added a new model to address concerns raised by both EPA and stakeholders. [Stoelzel and Swift, 1997, WPO # 44158, Docket: A-93-02, II-I-36b] DOE researched injection well operating practices in the Delaware Basin and identified significant differences between those in the vicinity of the WIPP and the Rhodes-Yates Field. DOE found that wells near the WIPP are typically less than ten years old and are constructed to much higher mechanical standards than the older wells found in the Rhodes-Yates Field. This is partially attributable to the fact that NMOCD regulations applicable to injection wells were not begun until 1982. DOE identified a range of well failure scenarios, ranging from undetectable brine flow to catastrophic well failure. DOE's data indicated that the probability of a catastrophic well failure in the vicinity of the WIPP is extremely low. [Docket: A-93-02, II-I-

36b, pp. 29-33] DOE modeling confirmed that the presence of the Castile at the WIPP also substantially inhibits injected brine movement into the Salado anhydrite markerbeds.

Public commenters' approach

The NMAG submitted several reports by Dr. John Bredehoeft. entitled, The HARTMAN Scenario: Implications for WIPP, dated March 1997 and The HARTMAN Scenario Revisited Implications for WIPP, dated August 1997. [Docket: A-93-02, II-D-116] These reports contradicted the DOE fluid injection modeling by Stoelzel and O'Brien [1996, Docket: A-93-02, II-A-32] and suggested that fluid injection activities could overwhelm the WIPP with brine.

EPA review

EPA's examination [Fluid Injection TSD, Docket: A-93-02, V-B-22] of the scenario modeled by Stoelzel and Swift [1997, Docket: A-93-02, II-I-36] indicates that it is realistic and compatible with current oil exploitation practices in the Delaware Basin. EPA concludes that although scenarios can be constructed that move large volumes of fluid to the repository through injection, the probability of such an occurrence, given the necessary combination of natural and human-induced events, is very low and was therefore appropriately screened out of consideration in performance assessment by DOE. The Agency also believes that the pressure and duration of water flooding activities postulated by DOE are appropriate (Comment 5.K.7). [Section 6 of Technical Support Document for Section 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22] Furthermore, EPA is satisfied that the means by which Stoelzel and Swift modeled the introduction of brine into the anhydrite marker beds is a realistic representation of a potential injection failure scenario, and sufficient conservatism is built into other aspects of their analysis (e.g., injection volumes and durations) to provide an adequate margin of safety (Comment 5.K.11). [Technical Support Document for Section 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22]

EPA disagrees with Comment 5.K.11 that the permeability is assumed to be uniform in the entire borehole annulus around the casing of the leaking well. The borehole permeability was treated in the modeling by Stoelzel and Swift [1997, Docket: A-93-02, II-I-36] as follows. The text on p. 18 states:

> Brine injection within a borehole is simulated by defining a pressure source term at the elevation chosen for injection. The rate at which brine is injected, and the volumes of brine injected, are therefore calculated model results dependent on the assumed injection pressure and the properties of the units through which the brine flows.

The text further states, "The permeability of the borehole region above (and below) the injection or production interval is set at various values representing different degrees of cement degradation or casing and tubing leaks." This indicates that the same permeability was not used throughout the entire borehole.

Comment 5.K.6 makes the assertion that fluid injection practices have lead to water level rises in the Culebra and therefore indicates that the Castile and Salado are not reliable geologic barriers. The Agency disagrees. First, EPA does not believe that there is sufficient information to attribute the rise in the Culebra water table to fluid injection. Second, even if the rise in the Culebra water table is due to fluid injection, it would be caused by pressure pulses due to low storage effects[20] and not because large volumes of water are entering the Culebra. Although EPA received many public comments about the lack of a fluid injection analysis, DOE did consider fluid injection in the scope of performance assessment and the additional fluid injection assessments DOE made subsequent to submittal of the CCA adequately address the potential impact of fluid injection.

EPA reviewed the Bredehoeft reports [Docket: A-93-02, II-D-116] and found that they model highly unrealistic conditions for the WIPP area (Comment 5.K.1). Major areas in which the Agency believes that the Bredehoeft modeling failed to represent realistic conditions include:

- Use of unrealistically high brine volumes, injected directly into the anhydrites;
- Failure to consider the differences between the geologic settings near the WIPP and in the Rhodes-Yates field; and
- Inappropriate conceptualization of the anhydrite marker bed fracturing.

EPA's evaluation of each of these topics is detailed below.

Unrealistic injection assumptions

The Bredehoeft report assumes, for all modeled scenarios, that all brine is directly injected into the anhydrite interbeds in the Salado Formation adjacent to the WIPP site. This approach ignores the fact that well operators would be attempting to inject brine into certain formations where petroleum reserves are located hundreds of meters below the Salado. The Bredehoeft Report also does not acknowledge that current well construction practice makes it unlikely that there could be a well failure of the nature of the "Hartman scenario" that occurred in the Rhodes-Yates field outside the Delaware Basin. [Stoelzel and Swift, 1997, and Docket: A-93-02, II-I-31 and II-I-36] The continuous injection of all of the brine into a layer several hundred meters above the oil production zone would defeat the objectives of the water flooding activities designed to enhance oil recovery. Furthermore, brine injected for disposal would not be injected directly into the Salado or the Castile formations because injected flow rates would be very low. This is because 1) the permeability of these units is low, as compared to that of the other units, and 2) because the rate at which brine is injected and the volumes of brine injected are dependent on the assumed injection pressure and the properties of the units through which the brine flows. Furthermore, as noted in Response to Comments for Section 23 under Hartman Scenario, the Agency does not

[21] That is, the aquifer is under confined conditions. See Freeze and Cherry, Docket: A-93-02, II-G-1, Ref. #257, p. 48.

agree with the Hartman-type injection/fracture propagation hypothesis. Therefore, the Agency does not consider to be a viable operational possibility.

Failure to consider different geologic settings

With respect to Comment 5.K.9, the Agency acknowledges that much of the discussion in the original Fluid Injection Analysis TSD [Docket:A-93-02, V-B-22] pertaining to geological difference between the WIPP and Bates lease area was speculative. However, as described in the sections that follow, the primary reason that EPA rejects the plausibility of a Hartman-like scenario occurring at the WIPP site is related to the conceptual model(s) for fracture formation and propagation in the anhydrites, and not the geological differences between the sites. Furthermore, there are many factual geological differences between the WIPP site and the Rhodes-Yates field in the Hartman case. [Docket: A-93-02, II-B-22, p. 29] The Bates lease (Hartman - leaking wells) and the Rhodes - Yates Fields (Texaco) are approximately one mile apart and located in townships and ranges T26S and R37E. The WIPP site is located approximately 40 miles from these areas in T22S and R31E. [Docket: A-93-02, II-A-32, p. 5] The WIPP site and the Bates lease are in areas that have very different geology. The Hartman scenario took place in shelf (back-reef) facies and the WIPP is located in the basin facies. [Docket: A-93-02, II-A-32, p. 9] The shelf facies is predominantly composed of carbonates while basin facies are mainly of clastic origin (e.g., sandstones). Relatively high drilling density and larger production zones are characteristics of the shelf facies. In the Delaware Basin proper, the clastic pay zones were deposited in relatively narrow channels and show lower drilling density. [Docket: A-93-02, II-I-36b]

The Castile Formation is roughly 2000 ft thick at the WIPP [ibid., p. 9], but is absent in the shelf areas, such as where the Hartman scenario occurred, thus provides a greater vertical separation between the injection zone (segment of a formation where the fluid is injected) and the geologic strata where the WIPP is located. Also, because there is greater vertical separation between the injection zone) and the geologic strata where the WIPP is located, it is more difficult for fluids to travel vertically upward (friction will also restrict the upward flow to an extent). Although the receptive formation (Salado) is expected to behave in a similar fashion in both the shelf area and the basin area, the geology in the WIPP area, i.e., the narrow pay zones, the presence of the Castile Formation, and the greater vertical separation between the injection zone and the WIPP, will play an active role in preventing fluid movement or in the extreme case, a massive well blowout.

Inappropriate conceptualization of interbed fracturing

A fundamental disagreement that the Agency has with the modeling approach used by Bredehoeft is the means by which the model conceptualizes fracture growth. Bredehoeft's method is based on LEFM described in his report entitled, Linear Elastic Model for Hydrofracture at WIPP and Comparison with BRAGFLO Results by Walter Gerstle and John Bredehoeft, dated 3 September 1997. [Docket: A-92-02, II-D-118] LEFM predicts that injection pressures will create a single fracture in the anhydrite marker beds that will extend three or more kilometers and will remain open. The means by which fractures actually propagate is of critical importance in the evaluation of whether waterflooding scenarios may pose a potential threat to the integrity of the repository.

Bredehoeft asserts that the observations in the Hartman litigation case (see response to comments in previous section on the Hartman Scenario) support his contention that fractures have propagated long distances, thereby allowing large volumes of water to move large distances in short periods of time. Alternatively, the DOE fracture conceptualization model, which EPA accepts as reasonable, assumes that injection pressures open multiple fractures in the anhydrite marker beds. Therefore, at a specified injection rate the DOE fracture conceptualization would not allow water to move as far as that assumed in the Bredehoeft model. As further discussed in the Hartman Scenario response to comments, the Agency does not believe that the Hartman case provides a means to validate either of the fracture models. Specifically, with respect to Comments 5.K.2 and 5.K.10, the available data on the situation at the Bates #2 well and Rhodes-Yates field are simply too incomplete to perform an adequate analysis, and subsequent modeling results would be rendered inconclusive. As will be presented later in this section, however, EPA did attempt to reproduce selected results from Bredehoeft's March 1997 report as suggested by public comments.

The following discussion presents the relevant information which forms the basis for EPA's decision to accept DOE's fracture conceptualization model. Additional information is presented in the Response to Comments, Section 5, under Anhydrite Fracturing.

<u>Overview of conceptual fracturing model at WIPP</u>

In the absence of exploration boreholes that intrude the repository, repository gas pressure can potentially be lowered through the repository shaft seals, through the anhydrite interbeds intersecting the repository, through the halite surrounding the repository, or through a combination of these pathways. At repository depth the anhydrite interbeds contain open fractures that are initially brine-filled and provide a low conductivity pathway for brine to enter or gas to leave the repository. The anhydrite interbeds also contain clay layers and fractures that have been healed by natural mineral infilling, but which are nevertheless generally weaker than the intact anhydrite matrix rock. Because of its plastic nature, at repository depth the halite that has not been disturbed by repository excavations is essentially free of fractures. [Docket:A-93-02, II-G-12; also see WPO#'s 27246, Docket: A-93-02, V-B-14 and 44704, Docket: A-93-02, II-I-24]

Gas pressures in the repository will build up slowly over time as the waste materials and containers corrode and are degraded by microbial action. In recognizing this slow pressure buildup, the Agency believes that as the pressure increases, repository gas will first enter the network of open fractures in the anhydrite interbeds, displacing the resident brine. This process will begin when the gas pressure exceeds the brine pressure in the interbeds, which is less than the lithostatic pressure. As the brine is displaced, the porosity and permeability available to the gas will increase. This process will preferentially occur in the topographically higher interbeds and in the updip direction because of the lower brine pressures. As repository gas penetrates into the interbeds and increases its total volume, the gas pressure will tend to decrease. However, if the rate of gas production exceeds the rate of volume increase, the gas pressure will increase. When the gas pressure has risen to approximate the local vertical stress, the natural anhydrite fractures will begin to open, likely affecting previously open fractures, healed fractures, clay layers, and anhydrite bedding planes, and the total porosity of the anhydrite will increase. In the anhydrite beds immediately above and below the repository excavations, the process of fracture opening will begin to occur at less than lithostatic pressures because the local vertical stress has been reduced due to the repository excavations.

As the gas pressure continues to increase, gas will continue to migrate in the anhydrites, both displacing additional brine and further opening the existing fractures. Because of the pervasive nature of fracturing in the anhydrite, this process is expected to occur not in a single fracture but simultaneously in multiple fractures within the interbeds. As the gas slowly penetrates into the anhydrite beds, brine displaced by the gas can move into the adjacent undisturbed halite through Darcy flow. Significant movement of gas into the undisturbed halite is not expected, however, because of the high gas threshold pressure for two-phase Darcy flow, the low halite permeability, and the low rate of diffusive migration. However, gas is expected to enter disturbed halite that is pervasively fractured by mechanical failure following repository excavation (the disturbed rock zone around the repository) in much the same manner as it enters the anhydrite. Gas penetration of the interbeds and disturbed halite will cease when the repository gas pressure drops below the pressure of brine in those media.

At sufficiently high pressures, gas may also create small fractures in the intact halite. Such fractures are expected to initiate along preexisting planes of weakness, such as crystal boundaries, or by propagating existing fractures that extend into the intact halite from the disturbed rock zone. The rate of growth of these fractures in intact halite is expected to be so slow that halite creep will reduce the stress concentrations at the fracture tips resulting in the formation of gas bubbles rather than extended fractures. The tendency of long fractures in the anhydrite interbeds to curve upward into the halite will be constrained by the counteracting tendency of fractures to continue to propagate within the weaker anhydrite. Because of the aforementioned slow fracture growth and the creep characteristics of halite, fractures that do enter the halite will not be able to grow to sizes that are of concern to performance assessment.

Conceptual models peer review panel findings

The foregoing conceptual model for fracture propagation in anhydrite and halite provides the basis for the mathematical model used by DOE in the CCA. The conceptual model was reviewed and accepted by DOE's independent Conceptual Models Peer Review Panel under a review process mandated and evaluated by the Agency. Regarding the overall model suitability and particularly the issues of simultaneous fracture propagation and porosity increases in anhydrite interbeds raised by the NMAG, the Peer Review Panel stated in Section 3.6.2.2 of its June 1996 report that "The type of fracture propagation and dilation used in the conceptual model has been substantiated by in situ tests." and found the assumptions of increased porosity and permeability due to fracturing caused by gas generation to be reasonable. [CCA Vol. XII Appendix PEER Attachment PEER-1] The conceptual model was fully approved by the Peer Review Panel in its

December 1996 report, where it stated in Section 3.6.3.3 that the model is "... fully adequate for implementation." [WPO # 43153, Docket:A-93-02, II-G-12]

Overview of basis for DOE approach

The Agency believes that the mathematical "porosity model" used by DOE in the CCA as part of BRAGFLO adequately implements the conceptual model. Summaries of the basis for DOE's approach to modeling fracture propagation is presented in CCA Volume X, Appendix Mass, Attachment 13-2, in a paper by Beauheim et al. [WPO # 27246, Docket: A-93-02, V-B-14], and in a memorandum by Larson et al. [WPO # 44704, Docket: A-93-02, II-I-24] These summaries state that the model was developed to correct previous BRAGFLO predictions of unreasonably high gas pressures in the repository. For application to performance assessment, the model needed to be capable of addressing coupled fluid flow and fracture propagation for a gas-driven fracture, should not let the gas pressure climb much above lithostatic, and should correctly simulate the type of fracturing observed in field experiments.

The result of this effort was DOE's porosity model. To make this model adequate for application at WIPP and to address the potential errors in predicting fracture propagation with numerical models, the porosity model was fitted with particular parameters. These parameters allowed DOE's porosity model to reproduce the pore pressure-permeability relationships observed in field tests at lower pore pressures, and to mimic the fracture effects predicted by LEFM at higher pore pressures where field test data were not available. Because obtaining detailed information on hydrofractures thousands of meters long was not feasible, the Agency considered DOE's approach using a combination of field test and theoretical information to be reasonable.

The low end of the pore pressure-permeability curve was based on initial, undisturbed conditions and field test results. [Larson et al, 1997, WPO # 44704 Figure 7)(Docket: A-93-02, II-I-24] The complete experimental basis for that curve is also shown on Figure 7 of the same reference. The basis includes field test results for differential injection pressures up to 2.3 MPa, corresponding to an in situ pore pressure of over 15 MPa in the model, and covering about two-thirds of the range of pressures in the curve. The part of the curve that is not related to experimental data is small and the extrapolation to higher pore pressures invokes permeabilities as high as 1×10^{-9} m^2. [WPO # 44704 p. 14] This is a ten order of magnitude increase over the initial permeability and is considered by the Agency to adequately represent a high conductivity fracture flowpath.

DOE has presented an argument that fractures can be opened at pressures significantly below lithostatic. [Docket: A-93-02, II-G-34, Attachment 3, Item 8] The field test results also showed that the fractures did not propagate as single features as predicted by LEFM and by the laboratory tests with gelatin mentioned by public commenters. [Docket: A-93-02, II-D-118] Instead, the fractures branched into a series of subparallel fractures following partially healed, preexisting fractures or weakness planes within less than four meters from the injection hole. The existence of these branch fractures would provide fluid storage capacity near the repository beyond what would be predicted by LEFM, and would therefore tend to shorten the overall length of fractures in anhydrite. Borehole video records of branch fracturing are shown in the two tested marker beds

(MB 139 and MB 140) and in two different observation boreholes in Figure 10 of Wawersik et al. [WPO # 45491, Docket: A-93-02, V-B-1] The implications of branch fracturing are discussed by the same authors in their Summary and Conclusions on p. 33. [WPO # 45491] Additionally, the fractures were not found to propagate to their full lengths within a few seconds as would be predicted by LEFM, even over the relatively short test fracture lengths of about 30 meters. Instead, the fractures continued to propagate slowly with time for several hours. This continued propagation is discussed by Wawersik et al. beginning on p. 21. [WPO # 45491]

The Agency believes that the field test results showing long, branching fractures and continued slow fracture growth are contrary to the LEFM predictions of long single fractures developing in a matter of seconds, and those results therefore do not support use of the LEFM model.

The Agency reviewed the two references that have been used to suggest that the LEFM model is better supported by the WIPP fluid injection field tests than the porosity model. The first reference, Gerstle, Mendenhall, and Wawersik [1996; WPO # 48224, Docket: A-93-02, II-H-01] discusses on p. 3-1 the appropriateness of the LEFM assumptions for halite but not for anhydrite. Additionally, in the paper's recommendations on p. 6-3 it is stated:

> The biggest question is: is discrete fracture mechanics in general, and LEFM in particular, applicable? We have little doubt that these approaches are applicable when the body forces and pressures are relatively low and the fracture toughness is relatively high. But we did run into questions when the reverse was true (see Section 4.4). Further theoretical, numerical, and experimental work to address this question would be productive both from an engineering science viewpoint and in attempting to predict with more certainty the behavior of WIPP. It is possible that discrete fractures of the type discussed could be shown to be unlikely at depth.

The second document frequently cited to argue that the LEFM model is better supported by the WIPP fluid injection field tests is Mendenhall and Gerstle [1993; WPO # 39830, Docket: A-93-02, II-G-1, CCA Ref. #433] which also presents an argument supporting further model development and states in the introduction

> If hydrofracture of the anhydrite is to be considered a WIPP design feature, and if simple LEFM calculations are deemed not sufficiently accurate, then we believe that more defensible conceptual and numerical modeling of the WIPP anhydrite fractures should be pursued.

It is noted that both of these papers question the applicability of LEFM to WIPP anhydrites. The Agency believes that DOE did, in fact, pursue their recommendations and developed the porosity model which couples two-phase fluid flow and fracture propagation, addresses the non-objectivity issue with the continuum approach and the potential for erroneous results by calibrating the model to WIPP field test results and LEFM-predicted behavior, and adequately simulates the effects of hydrofracture branching observed in the field test results.

In evaluating the applicability of these models to the anhydrite interbeds at WIPP, EPA notes that the interbeds contain pervasive natural fracturing, open pores and void spaces, as well as natural surfaces of weakness along bedding planes. [WPO# 44704, Docket: A-93-02, II-I-24] Further, the fluid injection tests at WIPP produced multiple parallel fractures rather than single fractures. [WPO# 44704, Docket: A-93-02, II-I-24] Based on actual conditions at WIPP and the results of DOE's in situ injection tests, EPA concludes that DOE's fracturing model is appropriate and adequate for use in performance assessment and more closely represents actual conditions at WIPP than the alternative LEFM model recommended in public comments. DOE has also provided a detailed discussion of why the conceptual model assumed by LEFM is inappropriate for the WIPP site. [Docket: A-93-02, IV-G-34] Furthermore , EPA notes that BRAGFLO is more appropriate to use for WIPP than a pure LEFM model because there are pre-existing fractures in the anhydrite layers. The pre-existing fractures will produce a fracture front, such as that modeled by BRAGFLO, rather than a fracture radius, as modeled by an LEFM. As noted above, the conceptual model for fracturing in the anhydrite marker beds is better supported by a fracture front type analysis.

EPA analysis

EPA performed its own independent studies of fluid injection which showed that the injection analysis must consider the nature of the anhydrites, duration of injection activities, and presence of leaking boreholes. [EPA Technical Support Document for 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22] The results of this analysis show that the permeability in marker beds is generally lower than that used in the PA, showing that fluid is even less likely to move through the marker beds. EPA's Fluid Injection analysis also showed that other factors (such as injection rate, injection interval, etc.) also play a very important role in fluid injection. EPA agrees that under very unrealistic conditions, modeling can show fluid movement toward the WIPP under a fluid injection scenario. These unrealistic conditions include those modeled by Bredehoeft [Docket: A-93-01, II-D-116], such as long-term steady-state flow, two well scenarios, and pulsing flow. However, when using more realistic and reasonable but still conservative conditions in the modeling, fluid movement sufficient to impact disposal performance of the WIPP does not occur.

As discussed above, both DOE and EPA evaluated the Hartman Scenario to see if it needed to be included in modeling of brine injection as a human intrusion scenario in the final performance assessment calculations. In preparing its proposed rule, EPA believed that the combination of the geologic differences, fracture propagation mechanics, and the current fluid injection practices in the WIPP vicinity compared to the Rhodes-Yates makes it unlikely for there to be a repeat of the Hartman scenario at WIPP. [EPA Technical Support Document for 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22] For example, the WIPP repository level is separated from potential layers where brine injection might occur by a greater thickness of salt and anhydrite interbeds than at the Rhodes-Yates field where the Hartman case occurred. Additional vertical separation and the presence of additional thief zones near the WIPP would tend to divert any flow that might leak up a hypothetical vertical pathway, as compared to the Hartman case. Interbeds in the vicinity of the WIPP Site are more numerous and are likely to be thinner than in the Hartman case, thereby reducing the likelihood of flow between the repository and the WIPP boundary.

[EPA Technical Support Document for 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22]

As previously discussed, EPA does not believe there is sufficient information on the Hartman scenario to perform a meaningful validation of the BRAGFLO model, or that the single fracture LEFM conceptualization is appropriate means to describe fracturing in the anhydrite marker beds. However, the Agency did undertake a modeling exercise to gain a better understanding of the reproducibility of the results obtained with Bredehoeft's model as compared with DOE's model BRAGFLO. In light of this, EPA developed two scenarios in which the results from BRAGFLO were compared against those obtained by Bredehoeft. The best candidates for this comparison are the scenarios described in Chapters 4 and 5 of his March 1997 report entitled, The Hartman Scenario Implications for WIPP. [Docket: A-92-01, II-H-01] EPA notes that it appears Bredehoeft designed these problems primarily to illustrate the capabilities of his code. Bredehoeft did, however, use Hartman-like assumptions in setting the model boundary conditions, injection rates and rock properties, and public comments have considered this modeling to be representative of the Hartman scenario. Therefore, these simulations will adequately serve EPA's primary purpose in gaining a better understanding of the discrepancies between results obtained with BRAGFLO and those with Bredehoeft's model under "Hartman like" conditions.

In Chapter 4, Bredehoeft presents a problem in which flow volumes through unfractured rock are compared against flow volumes through rocks that are assumed to be fractured. Data input for this scenario are presented under Scenario 1 in Table 1. As shown in the table, there are two cases under Scenario 1, an unfractured (Case 1) and a fractured case (Case 2). The input data and modeling results for these cases are summarized below and in Tables 1 and 2:

<u>Case 1</u>

Numerical grid is 38 by 38 with each element having dimensions of 1 km by 1 km. The distance from the center of the repository grid block to the center of the injection block is 3 km. It is assumed that Bredehoeft used a thickness for MB139 of 1.0 m, based on his discussion on p. 3.

The hydraulic conductivity was set to $1X10^{-10}$ m/s, which is representative of the unfractured anhydrite marker bed.

The injection pressure was held constant at 16.7 MPa, while the pressure at the repository was set to a constant value of 12.7 MPa. Far field pressures at the model boundaries were also set to 12.7 Mpa.

<u>Results (Table 2)</u>

Bredehoeft

Bredehoeft reports a flow rate of 5.5X10^{-8} m^3/s @ 25 years. Although Bredehoeft reports this values at 25 years it is actually a steady-state result (i.e., constant in time). It is unclear, however, where in space this flow rate is occurring, i.e., the well or the repository.

EPA

The following are the steady- state (i.e., constant in time) results from the EPA modeling at various locations (also see Table 2):

WELL - Total well injection 5.55X10^{-8} m^3/s

Left face of model element containing well (toward repository) 1.54X10^{-8} m^3/s

REPOSITORY - Total flow into repository 2.3X10^{-8} m^3/s

Right face of element containing repository (toward well) 9.42X10^{-9} m^3/s

Case 2

As noted in Table 1, all of the model inputs for Case 2 are identical to Case 1 except that the value for hydraulic conductivity of the marker beds is set to a much higher value of 3X10^{-5} m/s, which is considered to be representative of fractured conditions.

Results (Table 2)

Bredehoeft

Bredehoeft reports a flow rate of 2.8X10^{-3} m^3/s @ 25 years. As noted before, these are steady-state values and it is unclear where in space this flow rate is occurring, i.e., the well or the repository.

EPA

The following are the steady-state results from the EPA modeling at various locations (Table 2):

WELL - Total well injection 1.66X10^{-2} m^3/s

Left face of model element containing well (toward repository) 4.61X10^{-3} m^3/s

REPOSITORY - Total flow into repository 6.91X10^{-3} m^3/s

Right face of element containing repository (toward well)$2.8X10^{-3}$ m^3/s

Discussion of results

The EPA BRAGFLO modeling results for Case 1, match those of Bredehoeft's quite well if his flow rate value is that for the well inflow volume ($5.5X10^{-8}$ m^3/s vs $5.55X10^{-8}$ m^3/s) (Table 2). However, it is unclear whether this rate is supposed to be representative of the flows associated with the well or the repository.

For Case 2, the EPA calculated value for the flow rate into the repository cell boundary also agrees very well with the value reported by Bredehoeft ($2.8X10^{-3}$ m^3/s vs $2.8X10^{-3}$ m^3/s) (Table 2). Again, however, it is not clear in Bredehoeft's report what rate this represents.

Of particular relevance is that the rates for the two cases should scale according to the hydraulic conductivity ratio. [Freeze and Cherry, Docket: A-93-02, II-G-1, Ref. #257, p. 170]

Case 1 flow rate/Case 2 flow rate should equal Case 1 hydraulic conductivity/Case 2 hydraulic conductivity

For example, (right face toward well flow rates)

Case 1 flow rate = $2.83X10^{-3}$ m^3/s X ($1X10^{-10}$ m/s / $3X10^{-5}$ m/s)

Case 1 flow rate = $9.43X10^{-9}$ m^3/s

This is very close to the value predicted in BRAGFLO's Case 1 solution; however, it differs significantly from Bredehoeft's value of $5.5X10^{-8}$ m^3/s. A March 5, 1998, conversation Dr. Bredehoeft [Docket: A-93-02, Item IV-E-23] indicated that he was unsure of why his numbers did not scale correctly, but that it was conceivable that he had made an error. The Agency suspects, however, that the number reported by Dr. Bredehoeft for this second case represents the volume of flow entering the right face of the element containing the repository.

Scenario 2

In an effort to further investigate Dr. Bredehoeft's model the Agency attempted a second scenario. This second scenario was designed to investigate transient flow with fracture modeling in anhydrite, and was designed after Bredehoeft's work presented in Chapter 4. The objective of this scenario was to show that hydraulic fractures can develop over large distances.

In Bredehoeft's analysis, the anhydrite marker beds are assumed to be unfractured initially, with a permeability of $1X10^{-10}$ m/s; however, as soon as the pressure increases to 2 MPa over lithostatic (12.7 MPa) to 14.7 MPa, fracturing is initiated. Once fracturing begins, the hydraulic conductivity increases from $1X10^{-10}$ m/s to a hydraulic conductivity that is representative of fractured anhydrite marker beds (i.e., $3X10^{-5}$ m/s). Constant pressure was maintained at the injection well at 16.7 MPa during the entire injection period. The injection pressure is important because the rate at which brine is injected, and the volumes of brine injected, are calculated model results dependent on the assumed injection pressure and the properties of the units through which the brine flows.

In several instances, critical aspects of Bredehoeft's work are not documented sufficiently to understand exactly what was done in order to make meaningful comparisons with BRAGFLO. For example, it is not clear how he predicted a fracture radius of 2.8 km when his grid appears to be uniformly discretized in kilometers. Without knowing the discretization, it is impossible to inject the same quantity of fluid into the well. Furthermore, if he did use grid cells on the order of 1 km X 1 km, as in his previously described simulations, there may be large numerical errors in his solution. In another situation, it is unclear whether fracture propagation distances are based on completely opened or partially opened fractures. Without a better understanding of these aspects of Bredehoeft's modeling, the Agency could not replicate Bredehoeft's results.

Bredehoeft\BRAGFLO Input Parameters

Parameterization	SCENARIO 1	
	Case 1 -Unfractured	Case 2 - Fractured
Boundary Conditions		
Injection well pressure head	9.7 Mpa (p. 25, Mar. 97)@650 m depth 16.7 MPa	9.7 MPa (p. 25, Mar. 97)@650 m depth 16.7 MPa
Injection Period	Entire simulation run to steady-state (10,000 years)	Entire simulation run to steady-state (10,000 years)
WIPP	12.7 MPa (p.25, Mar.97	12.7 MPa (p.25, Mar.97
Far Field Pressure	12.7 MPa (p.25, Mar.97)	12.7 MPa (p.25, Mar.97)
Geometry		
No. Of Layers	1 (p. 26, figure 7.1, Mar. 97)	1 (p. 26, figure 7.1, Mar. 97)
Thickness	1 m	1 m
Dimensions	2 (p. 26, figure 7.1, Mar. 97)	2 (p. 26, figure 7.1, Mar. 97)

Parameterization	SCENARIO 1	
	Case 1 -Unfractured	Case 2 - Fractured
Orientation	Areal (p. 26, figure 7.1, Mar. 97)	Areal (p. 26, figure 7.1, Mar. 97)
Area	38,000 by 38,000 meters (p. 20, Mar. 97)	38,000 by 38,000 meters (p. 20, Mar. 97)
Injection Well Placement	3 km from pressure boundary (p. 25, Mar. 97)	3 km from pressure boundary (p. 25, Mar. 97)
Spatial Discretization	40 km X 40 km 1 km spacing	40 km X 40 km 1 km spacing
Rock Characteristics		
Hydraulic Conductivity	$1x10^{-10}$ m/sec (Table 5.1, Mar 97)	$1x10^{-10}$ m/sec (Table 5.1, Mar 97)
Fracture Initiation Pressure	unfractured	14.7MPa (Table 5.1, Mar 97)
Fracture Permeability	**$1x10^{-10}$ m/sec (unfractured)**	**$3x10^{-5}$ m/sec (Fractured)** (p.21,Mar97)
Storage Coefficient .	Pore compressibility was used and a transient analysis was performed until steady-state was reached.	Pore compressibility was used and a transient analysis was performed until steady-state was reached
Fluid Characteristics		
Phase	Single/Liquid- (p. 20, Mar97)	Single/Liquid- (p. 20, Mar97)
Density	1220 kg/m^3	1220 kg/m^3

Scenario 1 Bredehoeft\BRAGFLO Results

CASE 1		
Grid Location	Bredehoeft Model	BRAGFLO
Injection well (inflow)	$5.5x10^{-8}$ m^3/sec	$5.55X10^{-8}$ m^3/s
Left face (toward repository) of element containing injection well.	Not reported.	$1.54X10^{-8}$ m^3/s
Repository inflow (total)	Not reported	$2.3X10^{-8}$ m^3/s
Right face of element containing repository	Not reported	$9.42X10^{-9}$ m^3/s

CASE 2		
Grid Location	Bredehoeft Model	BRAGFLO
Injection well (inflow)	Not reported.	$1.66X10^{-2}$ m^3/s
Left face (toward repository) of element containing injection well.	Not reported	$4.61X10^{-3}$ m^3/s
Repository inflow (total)	Not reported	$6.91X10^{-3}$ m^3/s
Right face of element containing repository	$2.8X10^{-3}$ m^3/s	$2.8X10^{-3}$ m^3/s

Conclusions

Based on a comparison between the flow rates obtained with Bredehoeft's model and BRAGFLO, EPA concludes that BRAGFLO is capable of obtaining high volumes of flow very similar to those obtained in Bredehoeft's modeling and therefore simulates the Hartman scenario as envisioned by the public comments.

The Agency, however, was unable to reproduce other aspects of Bredehoeft's work (i.e., fracture propagation distances) because the information provided is not documented to a sufficient degree to allow meaningful comparisons. Furthermore, it is known that BRAGFLO is capable of producing very long fractures as was shown in the Agency's performance assessment verification test. [PAVT; WPO # 46674, Docket: A-93-02, II-G-26, Appendix A p. A-8] In these tests, fracture lengths were found to have exceeded 1000 m in a number of realizations in Replicate 1 of the undisturbed case. The maximum fracture length realized in Replicate 1 of the undisturbed case in the CCA was 1900 m to the north in Marker Bed 138. [WPO # 46674 Appendix A p. A-8] From the foregoing discussion it is clear that the porosity model is capable of simulating fractures that are thousands of meters long.

The Agency attempted these model comparisons because commenters have stated that BRAGFLO was not capable of simulating long fractures and high flow volumes. As shown above, both of these assertions are unfounded. The Agency does not consider the results of these comparisons to be applicable to conditions at WIPP because they incorporate conceptual model assumptions concerning anhydrite fracturing that are inappropriate. EPA disagrees with Dr. Bredehoeft's work, primarily because of his conceptual model of a single, long fracture in the anhydrite markerbeds, which the Agency concludes has been shown to be fundamentally invalid.

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12. Screening out fluid injection on the basis of low consequence is not acceptable for the following reasons:

1) Stoelzel and Swift (1997) conceptual models for leaky well scenario do not represent the Hartman scenario;

2) The outflow is divided into a number of layers, when in the Hartman case, the flow occurred through a single layer;

3) Assumption of radial flow does not represent the incident at the Hartman Bates lease; and

4) The high well-bore permeability assumption does not compensate for these non-conservative conceptualizations. (44)

13. EPA states that, based on the supplementary information provided by DOE, EPA is able to screen out fluid injection (CARD 23 at 23-12). EPA points out that the modeling in Stoelzel &

Swift (1997) (II-I-36) shows that the total brine flow into the repository is only 440 m^3 showing that brine injection poses an "insignificant and acceptable risk" (CARD 23 at 136). However, the reports cited above show much larger volumes of brine entering WIPP and also escaping from WIPP. (1000)

Response to Comment 5.K.12(1):

EPA agrees that the 1997 Stoelzel and Swift report [WPO # 44158; Docket: A-93-02, Item II-I-36, Attachment b] does not specifically represents the Hartman scenario. However, as discussed in the previous section on the Hartman Scenario, EPA does not believe that it was necessary to model a scenario using a conceptual model that included only the anhydrite marker bed as the injection zone. The Agency considers such an approach to be unrealistic because oil drillers will be trying to inject fluid into formations containing petroleum that are far below the Salado. Rather, the main objective of the Stoelzel and Swift - 1997 report was to provide additional information requested by EPA. [March 19, 1997 Letter from Ramona Trovato, EPA to Al Alm, DOE, transmitting comments regarding completeness and technical sufficiency of DOE's Compliance Certification Application, Docket: A- 93-02, II-I-17] EPA asked DOE for additional information on the Department's fluid injection modeling after reviewing the initial study "The Effects of Salt Water Disposal and Waterflooding on WIPP." [Docket: A- 93-02, II-A-32] In this study, Stoelzel and O'Brien presented their approach to address fluid injection as follows:

> . . .two sets of BRAGFLO conceptual models were developed: One set representing the geologic cross section through of the WIPP area [sic], and another set representing the geology of the Rhodes-Yates area, should a hypothetical WIPP-like repository exists in that area of the Delaware Basin. Various barriers to flow are systematically removed in both sets of models, i.e., casing leaks are modeled, then casing and tubing leaks together, and finally the anhydrite layers are allowed to fracture significantly to simulate a massive hydro-frac. [Section C. Approach, p.6]

As discussed in the previous section, the Conceptual Models Peer Review Panel found, and the Agency finds, that the conceptual model developed by DOE to examine the fluid injection scenario is adequate. EPA also believes that it is unnecessary to perform additional modeling of the Hartman scenario. EPA believes that DOE and EPA have already performed sufficient modeling of fluid injection and the Hartman scenario. The Agency disagrees that it would be beneficial to perform additional modeling with a conceptual model (i.e., LEFM) that the Agency considers to be fundamentally flawed for this application, as discussed under responses to Anhydrite Fracturing comments below for section 23.The Agency finds the work by Stoelzel and O'Brien to be representative of geological and technological conditions expected at the WIPP site. [EPA Technical Support Document for Section 194.23: Fluid Injection Analysis, Docket: A-93-02, V-B-22]

Response to Comments 5.K.12(2) and 5.K.13:

As indicated above, EPA does not believe that it is realistic to model the conditions of the Hartman scenario and apply them at the WIPP where the geological and technological conditions are different (e.g., Castile Formation is present at WIPP but not at the Hartman well). However, DOE conducted a study to calculate " the potential consequence of injection wells leaking into Salado, should certain barriers to leakage fail." [Records Package, the Efforts of Salt Water Fluoride on WIPP, WPO #40837, Docket: A-93-02, II-A-32] DOE developed two sets of conceptual models to study the effects of differences between the WIPP and Rhodes-Yates on the performance of WIPP, if it were placed in the Rhodes-Yates region of the Basin. On the basis of its calculation, DOE came to the following conclusions: "In summary, these calculations show that present day petroleum injection practices and geology of the WIPP area eliminate the consequences of large amounts of brine leaking to the WIPP." [Docket: A- 93-02, II-A-32 p.6] A somewhat similar situation has been analyzed in "Supplementary Analyses of the Effect of Salt Water Disposal and Waterflooding on the WIPP." [Docket: A- 93-02, II-I-36, p.11, Fig.1C] This is part of the leaky pathways showing leaky tubing, casing and/or packer injector. Out of the 10 Radial model cases, three are designed to examine the cumulative flow into MB 139, MB 138 and Castile anhydrite. On the basis of this analysis DOE concludes, "model results indicate that, for the cases considered, the largest volume of brine entering MB139 (the primary pathway for the WIPP) from the borehole is approximately 1,500 m^3, which is a small enough volume that it would not affect Stoelzel and O'Brien's [1996] conclusion even if it somehow all reached the WIPP." [Docket: A- 93-02, II-I-36 p.55]

The Agency finds DOE's conclusions are based on realistic scenarios and assumptions. [EPA Technical Support Document for Section 194.23: Fluid Injection Analysis, Docket: A-93-02, V-B-22] Therefore, the Agency concludes that fluid injection does not need to be included in the PA modeling because of low consequences.

Response to Comment 5.K.12(3):

It appears that the commenter's concern with using radial flow is associated with the use of a two-dimensional cross sectional grid in the Stoelzel-O'Brien analysis. Bredehoeft (January 14, 1997) determined that a cross-sectional grid orientation resulted in less flow through the marker beds than an areal analysis. EPA agrees that his analysis does show that less flow occurs in the cross-sectional case. However, as with any simplifying assumption, the issue is whether the simplifications will significantly affect the overall results of the analysis. In response to Bredehoeft's concerns, EPA asked the Department to "substantiate why a two-dimensional cross sectional modeling approach is appropriate for this analysis." [March 19, 1997 Letter from Ramona Trovato, EPA, to Al Alm, DOE, transmitting comments regarding completeness and technical sufficiency of DOE's Compliance Certification Application Docket: A- 93-02, II-I-17] DOE's response to this specific issue adequately explains the assumption of flow type and its significance. The statement is quoted here:

> We have examined the appropriateness of the cross-sectional geometry used in their analysis by developing two alternative models, one using a modification of the cross-sectional geometry that allows brine flow toward the WIPP from a 180-degree arc at the

> borehole, and one using an axisymmetric radial geometry that captures flow behavior in full 360-degrees around an isolated borehole. We also began development of a third alternative as part of this study, using a two-dimensional areal model to simulate flow and fracturing in Marker Bed 139 (MB139) of the Salado Formation. The areal model was not completed and used in this analysis, however, because results of the radial model calculations did not indicate sufficient flow in MB139 to warrant further development of the areal approach"
>
> [June 17, 1997 Letter from George Dials, DOE-CAO to Lawrence Weinstock, EPA responding to EPA's letter of March 19, 1997 requesting additional information regarding water flooding. Docket: A- 93-02, II-I-36, p.6]

The Agency finds the argument for not developing the areal model to be reasonable because other modeling showed that the amount of flow would not have a significant impact on results. Therefore, EPA finds flow assumptions of the radial model to be adequate. The volume of brine projected is not significant and thus, modeling with additional dimensions is not necessary.

Response to Comment 5.K.12(4):

The premise of the comment seems to be that DOE should have modeled only "conservative" conditions. EPA disagrees with this premise because DOE is not required to conduct "conservative" modeling. DOE concluded that, based on "reasonable and realistic conditions" and modeling assumptions and parameter values which are consistent with the CCA, the outcomes of fluid injection modeling are insignificant on the performance of WIPP. [June 17, 1997 Letter from George Dials, DOE/CAO to Lawrence Weinstock, EPA responding to EPA's letter of March 19, 1997 requesting additional information regarding water flooding. Docket: A-93-02, II-I-36, p.18] Nevertheless, the following features in the model are somewhat conservative:

- Neglected pressure loss in the hole due to friction
- Larger volume of brine injected (radial model)
- Frequency and duration of injection well failure in the future.
- Location of injection borehole closer than in the real situation (ex. 2.4 km vs. 4.85 km)
- High borehole permeability.

The Agency believes the combination of all of these assumptions has lead to a conservative result and overestimates potential releases.

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14. EPA failed to review actual evidence submitted for the Hartman trial, but instead relied on a case summary. (46)

15. Did EPA review the actual data and exhibits generated as part of the Hartman trial. (79)

Response to Comments 5.K.14 and 5.K.15:

The Agency has examined the impact of fluid injection on the WIPP. As indicated before, the two areas in question are geologically dissimilar and petroleum recovery practices are different. EPA has analyzed the process, reviewed the Hartman scenario within the guidance and requirements of 40 CFRSection 194.32 (a) and (c), required DOE to extend their studies beyond the 1996 modeling. [Docket: A-93-02, III-G-1, Reference 611] Moreover, as presented in the previous section, EPA has conducted further analysis specifically related to the Hartman scenario that resolves the Agency's questions.

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16. Oil fields near WIPP are known to have numerous waterflows from injection. In the Hartman case water traveled several miles before blowing out another well. What would be the effect of a water blowing out the shaft or borehole attached to the WIPP site. (620)

Response to Comment 5.K.16:

As proposed in the CCA, adequate measures will be taken to seal the shafts. DOE has planned to use asphalt for sealing the cracks and fractures which may have been produced due to the excavation. Also, the natural process of healing (creep closure) of halite will help in this respect. Boreholes are expected to have a permeability range between $1x10^{-19}$ m^2 $1x10^{-14} m^2$. [Section 33.F.5, requirement (c)(1) of CARD 33 -- Consideration of Drilling Events in Performance Assessments, Docket: A-93-02, Item V-B-2] Moreover, in order for these to act as pathways for fluid to travel, a continuous connection between the point of injection and boreholes have to be created. This will need a pressure gradient of more than 1 psi/ft (depending upon the lithology and overburden pressure). New Mexico State regulation prohibits the surface injection pressures that would allow fracture initiation. Therefore, EPA believes that water will not blow out a shaft or borehole attached to the WIPP site.

17. EPA's "dip theory" explaining water flows under the Hartman Scenario focused on very localized phenomenon. If the Agency intends to advance this argument, it should have identified the dip for the hundreds of waterflows of record in southeast New Mexico. (47)

Response to Comment 5.K.17:

EPA agrees that this argument, by itself, is not sufficient for comparing the two sites. However, as discussed in this section and the section on the Hartman Scenario, the primary reason that EPA rejects the plausibility of a Hartman-like scenario occurring at the WIPP site is related to the conceptual model(s) for fracture formation and propagation in the anhydrites.

Furthermore, there are a host of geologic differences between the WIPP site and the field where the Hartman case occurred. EPA's conclusion that the Hartman Scenario would not be repeated at the WIPP, with respect to geology, was not based solely upon a comparison of the degree of dip, but upon a comparison of the combination of all geologic features and an examination of the likelihood of circumstances that would lead to a situation like the Hartman case.

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18. It was inappropriate for EPA to dismiss the Hartman Scenario in whole or in part on the basis of best available technology assumptions. (80)

Response to Comment 5.K.18:

The Agency believes it has reviewed the Hartman scenario adequately. The evidence of geology, environment of deposition, current drilling practices, regulations and economics have been examined. As discussed in Technical Support Document for Section 194.23: Fluid Injection Analysis [Docket:A-93-02, V-B-22], current drilling practices in the Delaware Basin have improved since those used at the Rhodes-Yates field (e.g., the use of multiple casings, enhanced cements, and cement logging techniques to test bonding percents). [Stoelzel and Swift, 1997, and Docket: A-93-02, II-I-31 and Attachment 1 of I-I-36] Based on these, the Agency decided that the dissimilarities between the Hartman scenario in time and space and the repository are substantial
and not likely to impact WIPP.

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19. In the GUSHR modeling (discussed in TSD III-B-22 at 47-49) it is said that influx varied from "less than half that calculated in the SNL modeling to more than 10 times the volume cited for the likely WIPP geology case." (at 49). The GUSHR model, however, used a marker bed permeability of 1 md (see grid at 48), whereas the Hartman #2 Bates well blowout revealed a permeability of 3 x 10^{-12} m^2 (II-D-116(b) at 6), which is equivalent to 3000 md. Again, EPA has used a model that does not correspond to observed and measured events. (1012)

Response to Comment 5.K.19:

The GUSHR modeling was not intended to model the type of fracture propagation and resulting permeabilities predicted by Bredehoeft's modeling of the Hartman scenario. [Docket:A-93-02, II-D-116] As noted in the previous section on the Hartman Scenario, the Agency has a fundamental difference in opinion on the most appropriate conceptual model for describing fracturing in the anhydrites. The GUSHR model was assigned anhydrite fracture permeabilities based on field data collected in the vicinity of WIPP. [Beuheim et. al., WPO# 27246] These data support a permeability or 1 md or less; they do not support using a permeability of 3000 md at the WIPP. Furthermore, this modeling was performed solely to guide EPA's recommendations to DOE with respect to DOE's fluid injection analysis. [Technical Support Document for Section 194.32: Fluid Injection Analysis*,* Docket: A-93-02, V-B-22] Results from the GUSHER modeling raised many of EPA's concerns that were later adequately addressed in DOE's second report pertaining to fluid injection. [Stoelzel and Swift, 1997, WPO#44158]

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16. On pages 40-42 of TSD III-B-22 EPA sets forth estimates of the probability of various events leading to a hydrofracture and waterflow into WIPP. What, if any, factual data lie behind these estimates? Why is the "realistic" likelihood of a neighboring injection well leaking 5%? Why is the "worst case" likelihood 10%? Why are the estimated likelihoods of these leaks going undetected 5% and 25%, respectively? (1010)

Response to Comment 5.K.16:

Based upon comments received during the public comment period, EPA has reexamined the "worst case" probability of the events in the chain of events that an injection well will leak and impact the WIPP repository (initially in Section 4 of Technical Support Document for Section 194.32: Fluid Injection Analysis; Docket: A-93-02, Item III-B-22). Initially, EPA based its probability values upon the professional judgment of its staff and contractors, who have years of experience in the petroleum industry. In some cases, EPA has revised its estimates based upon additional analysis that provided more data to support specific numerical values (Section 5.2 of Technical Support Document for Section 194.32: Fluid Injection Analysis; Docket: A-93-02, Item V-B-22). EPA specifically selected values in 5 percent increments to simplify mathematical calculations and to reflect that these values contain uncertainty.

The probability that a neighboring injection well would leak (original estimated probability, worst case: 10%; current estimated probability, worst case: 25%): Statistical information on historic injection well leaks for wells installed under the regulatory requirements applicable to the vicinity of the WIPP site was not reviewed at the time that the original estimate was made. The maximum plausible value for the estimated probability of a leak occurring was therefore based on professional judgement related to general oilfield experience for wells installed under the current regulatory environment in the WIPP study area. Subsequent analysis by DOE of actual injection well failure rates within the Delaware Basin in Lea and Eddy Counties, New Mexico, indicated that 24 failures occurred in a total of 112 injection wells (21.4%)(Stoelzel and Swift, 1997; WPO # 44158). Within the 9 township study area surrounding the WIPP site, 3 failures were identified in a total of 24 injection wells (12.5%). The failure rate in the WIPP study area would be expected to be lower than for the Delaware Basin as a whole because the WIPP area oilfields are younger, most wells were installed using more modern and effective practices, and the regulatory requirements are more stringent. Based on the specific injection well survey conducted by DOE, EPA estimates a probability of 25% as the maximum failure rate applicable to the WIPP area. This value is greater than was found by DOE in either the WIPP area or in the wider study area. EPA rounded up DOE's higher failure rate to the nearest five percent, in part to account for leaks that occurred and were not detected as well as those that were detected. EPA considers this probability be reasonable and adequately conservative.

Probability that a leak would remain undetected (original estimated probability, worst case: 25%; current estimated probability, worst case: 25%): This event relates to leaks that occur and remain undetected for decades. Estimates of the rates of undetected events are unverifiable and must necessarily be based on judgment. The information reported by Stoelzel and Swift (1997; WPO # 44158) for the study area near WIPP indicates that all leaks are detected within less than one year and that the NMOCD regulatory requirements for leak detection and reporting are effective (19 NMAC 15.I.704.B). Nevertheless, EPA retained unchanged the bounding probability of 25% that was originally estimated for this event. This value means that one in four leaks that occur in injection wells is assumed not to be detected. Higher non-detect rates would suggest that the NMOCD's Underground Injection Control (UIC) regulations that have been considered by industry professionals to have been effective since 1984 are, in fact, not effective and insufficient to meet the standard of protecting of human health and the environment. EPA believes that the UIC regulations are effective. Therefore, the Agency finds that the estimated "worst case" probability value of 25% is reasonable and adequately conservative.

The Agency notes that it did not base its final decision on whether brine injection should be incorporated in performance assessment using these probability estimates. The EPA notes that this estimate of low probability was only one of many reasons cited in the technical support document for EPA's proposed determination that fluid injection could be screened from the PA. After considering geologic information, well history and age, construction standards, and operating practices, the Agency concludes that reported water flows in the Salado Formation in other areas of New Mexico are not representative of conditions in the vicinity of the WIPP. (Docket: A-93-02, Item V-B-22) Even if an injection event takes place, the predicted low consequence is sufficient reason to remove it from consideration in the PA (Docket: A-93-02, Item II-I-36). The Agency made its estimate of the probability of failure of an injection well and the subsequent migration of significant volumes of brine into the WIPP repository to evaluate its expectation that such an event is unlikely.

Issue L: CCA parameters and PAVT parameter selection

1. On what did EPA base its range for hitting a brine pocket? Given the results of the TDEM survey, the lower bound seems too low. (69)

2. EPA has sampled on a range of 1 to 60%, but has provided no basis for assuming less than 60%. Based on the arguments that the geophysical (Time-domain electromagnetic survey) data may be interpreted to indicate the brine to be under 60% of the repository, and that some boreholes adjacent to the brine producing boreholes are known to be dry, the EEG is willing to accept the assumption of a fixed 60% probability of encounter, and recommends that a new performance assessment calculation be run with this fixed value. (1281)

Response to Comments 5.L.1 and 5.L.2:

In the PAVT, EPA assigned a range of values from 1% to 60% for the probability of hitting a brine pocket (ID No. 3493, parameter PBRINE)(Docket: A-93-02, V-B-30). Using data from the DOE TDEM study (Docket: A-93-02, II-G-1, Ref. #229), EPA developed probability distributions for four cases. These cases involved either random or block models for correlation between adjacent TDEM measurements and assumed either the base of the Castile or the base of the Anhydrite III layer in the Castile as the cutoff point above which brine pockets may exist. Since the TDEM measurements showed no discernable spatial correlation in any direction at distances larger than the unit of the measurement grid (250 m), two bounding analyses were performed to reflect the uncertainty in the depth to the first conducting surface -- the random model and the block model. In the random model, all points in the disposal region have the same likelihood of being underlain by brine regardless of the proximity to any specific TDEM measurement locations with higher or lower than average elevation measurements. In the block model, the best estimate of the elevation of the first conducting layer is the elevation of the nearest TDEM data point. EPA found that it made little difference whether the random model or the block model was used to characterize correlation between the TDEM measurements.

However, the simulated probability distributions for encountering brine were highly sensitive to the geologic assumption of whether or not brine pockets exist below the bottom of the Anhydrite III layer. Using the base of the anhydrite layer as the cutoff, the EPA simulations show that the fraction of the excavated area of the repository underlain by brine varies from 1 to 6% of the excavated area. Using the base of the Castile as the cutoff, the fraction of the excavated area of the repository underlain by brine ranges from about 35 to 58%. Based on these simulations and the assumption that either of the geologic possibilities is equally probable[21], EPA selected 1% as the lower limit and 60% as the upper limit for the fraction of the excavated repository area underlain by brine in the PAVT (Docket: A-93-02, V-B-30). The upper value of 60% rounds up the highest value from the TDEM data, providing a more conservative range. EPA believes that this range adequately reflects the uncertainty in the parameter PBRINE and is a more appropriate representation of the concept of reasonable expectation than the fixed value of 8% used by DOE in the CCA. This is discussed in greater detail in section 4.1 for parameter GLOBAL - PBRINE in EPA Technical Support Document for Section 194.23: Parameter Justification Report. [Docket: A-93-02, V-B-14]

EEG suggested that a fixed probability of 60% be used for encountering a brine pocket. However, EEG's own sensitivity analysis of performance parameters showed that, even when the Castile brine encounter probability was increased to 100%, there was no significant effect on the resultant CCDF as compared to the mean CCDF in the CCA. [Docket: A-93-02, IV-G-43] As EEG noted:

[21] According to the 1992 WIPP PA (Docket: A-92-03, II-G-1, Ref. 563, Volume 3, p. 5-4), Castile Formation brines are generally found in fracture zones in the anticlinal structures in the uppermost anhydrite layer (generally Anhydrite III). If it is assumed that brine is confined to the Anhydrite III layer, which is the more probable assumption based on geologic information, the maximum fraction of the repository area underlain by brine is 6%. Giving equal weights to the two scenarios, although, on the basis of physical evidence, one is more probable than the other is conservative since, if a larger fraction of the repository is underlain by brine, the potential for releases is greater.

> The results of the Castile simulation show that Castile brine assumptions do not have a significant effect on the overall CCDF. In fact, the figure shows [Figure 7.18] that the CCA may have slightly higher releases at equivalent probabilities, with the same probabilistic assumptions (drilling rate, AICs, probability of hitting a Castile brine pocket, etc.). Even when the probability of hitting a brine pocket is increased from 8 to 100%, the releases are not increased by any significant amount. [*ibid*., p.80]

EPA's Sensitivity Analysis also found that the results of performance assessment were not sensitive to changes in this parameter. [p. SA-21, Technical Support Document for Section 194.23: Sensitivity Analysis, Docket: A-93-02, Item V-B-13] The Agency believes that the probability values used in the PAVT properly reflect the subjective uncertainty in the PBRINE parameter based upon data from the TDEM study and believes they are appropriate for PA calculations.

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3. Are gas volumes of 10, 20 and 30 million cubic meters acceptable? (p. 8) (77a)

Response to Comment 5.L.3:

Gas volumes of 10, 20, and 30 million cubic meters were mentioned as *potentially* being generated in the WIPP repository on p. 8 of the New Mexico Attorney General's report, Linear Elastic Model for Hydrofracture at WIPP and Comparison with BRAGFLO Results. [Gerstle and Bredehoeft, 1997; Docket: A-92-02, II-D-118] These volumes are given at a pressure of one atmosphere and a temperature of 30^{o} C. These values are based on the ranges calculated in the PAVT. EPA checked these volumes and found them to be reasonable predictions of volumes generated in the repository although 30 million cubic meters (at standard temperature and pressure) is close to the maximum volume predicted in performance assessment to be generated under undisturbed conditions.

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4. Therefore, the appropriateness of the value of waste permeability is unchanged when assuming 0% effectiveness of passive institutional controls because closure occurs during the active control period. (104)

5. [A]n increase (or decrease) in waste permeability values of less than an order of magnitude would not have any significant effect on the final performance outcome. Therefore, the use of a single permeability value (instead of a range) does not ignore uncertainty in permeability. Rather, a single conservative value has been used because a permeability range is not expected to have any significant effect on the final outcome. (111)

Response to Comments 5.L.4 and 5.L.5:

The constant value of $1.7\text{x}10^{-13}$ m^2 used for waste permeability in the CCA was based on an investigation of waste materials by Luker, Thompson, and Butcher, 1991. [Docket: A-93-02, II-

G-1, Ref. 411] It is a composite value derived from the relative quantities of three different types of materials (combustible, metals/glass, and sludges), each with an inherent range of permeabilities.

With regard to Comment 5.L.4, EPA has found that the use of a constant waste permeability does not have a significant effect on predicted repository performance, [EPA's Technical Support Document for Section 194.23: Sensitivity Analysis, Docket: A-93-02, V-B-13], probably because of the low drilling rates during the period when creep closure is occurring.

The use of a constant permeability value for the waste was questioned by DOE's Conceptual Models Peer Review Panel in its July 1996 report because ignoring the higher permeabilities that would occur at early times was thought to possibly lead to underestimating radionuclide releases. [Docket: A-93-02, II-G-1, CCA Volume XII, Appendix PEER, Attachment PEER-1, Section 3.3.2.8] The Panel found this issue to have been adequately resolved by the results of DOE's FEP Screening Analysis DR-7 , which demonstrated that time-varying permeability had an insignificant effect on key waste room conditions. [Docket: A-93-02, II-G-1, CCA Volume XVI, Appendix SCR - Permeability Varying with Porosity in Closure Regions] A principal element of this finding was evidence that the waste will be compressed relatively quickly by salt creep, within the first few hundred years after closure, during a period when the rate of exploratory drilling is expected to be reduced by active and passive institutional controls. [Docket: A-93-02, II-G-12, Section 3.3.3] In later years, when exploratory drilling is more frequent, the waste is expected to have been compressed to the extent that the assigned constant permeability will be appropriate.

The effect of reducing the duration of passive institutional controls was examined in EPA's Sensitivity Analysis, where eliminating any effects of the 600-year period of passive institutional controls was found to not significantly change predicted repository releases. [EPA's Technical Support Document for Section 194.23: Sensitivity Analysis, Docket: A-93-02, V-B-13, Table ES-1] Because of concerns expressed by the public about the passive institutional controls credit, and because DOE did not adequately justify its value for effectiveness of the controls, EPA eliminated the effects of passive institutional controls on reducing drilling rates from the PAVT. [CARD 43 -- Passive Institutional Controls, Section 43.E.5, pp. 43-44 through 43-47 and CARD 23 -- Models and Computer Codes, Section 1.4, Requirement (a)(1), p. 23-12; Docket: A-93-02, V-B-02] Again, EPA found no significant effect on predicted repository releases. Although EPA does not believe that creep closure will necessarily be complete during the period of active institutional control, closure is expected to be rapid relative to the 10,000 year regulatory timeframe. Therefore, the Agency finds that use of a constant value for waste permeability is acceptable.

While DOE used a value of $1.7x10^{-13}$ m^2 for waste permeability in the CCA, EPA required the use of a slightly higher, corrected value of $2.4x10^{-13}$ m^2 in the PAVT. [Section 5.19 in Technical Support Document for Section 194.23: Parameter Justification Report, Docket: A-93-02, V-B-14] DOE's Engineered Systems Data Qualification Peer Review Panel found the corrected waste permeability value used in the PAVT to be reasonable when compared with permeabilities of compacted waste in municipal landfills. [Docket: A-93-02, II-G-1, Volume XII, Appendix PEER p. 5-18] That Panel estimated that uncertainties could cause the waste permeability to vary by up to an order of magnitude. [Docket: A-93-02, II-G-1, Volume XII, Appendix PEER Attachment PEER-5 p. 5-17] Nevertheless, EPA concluded that because the waste permeability is already more than two orders of magnitude higher than the permeability of any other geologic or seal component, flow through the waste would be relatively fast compared to flow into and out of the repository. Therefore, long term releases to the accessible environment would be fairly insensitive to changes in waste permeability within an order of magnitude. EPA agrees with Comment 5.L.5. Additional information on Waste Properties can be found in a memorandum from M.K. Knowles, F.D. Hansen and T.W. Thompson entitled Clarification on Waste Properties SNL, January 21, 1998. [Docket: A-93-02, IV-A-01, Attachment 5]

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6. The use of compressibility in fluid flow models is to change porosity of materials as pressure changes. In the disposal area, DOE modeled porosity change using a creep closure model rather than a compressibility model. Therefore, the compressibility was set to zero so that the compressibility did not interfere with the porosity changes calculated by the creep closure model. (112)

<u>Response to Comment 5.L.6:</u>

The comment is a clarification by DOE on why it set the compressibility to zero. EPA has reviewed the different ways that compressibility and porosity changes were handled in performance assessment. EPA believes that DOE's approaches adequately represent changes in porosity because they compute similar results to those from a fully coupled approach. [Freeze, G.A., Larson, K.W., and Davies, P.B., 1995. Coupled Multiphase Flow and Closure Analysis of Repository Response to Waste-Generated Gas at the Waste Isolation Pilot Plant (WIPP). WPO 29557. CCA Reference #261, Docket: A-93-02, Item II-G-1] In addition, the "porosity surface" approach used to model repository creep closure was reviewed in detail by DOE's Engineered Systems Data Qualification Peer Review Panel. This Panel also found the approach to be adequate. [Docket: A-93-02, II-G-1, Volume XII, Appendix PEER]

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7. [T]he gravity effectiveness factor (F_{ge}) was set at a constant value of 18.1 for use in the CCA (reference WPO 37098). The selection of this factor was not arbitrary since it was based on experimental activities conducted by the New Mexico Engineering Research Institute (NMERI) under contract to DOE. (113)

8. Based on Butcher (1996b), a constant value of 1 psi (6895 Pa) was used for this parameter to represent the tensile strength of the degraded waste. . . The value is a conservative estimate, bounding the lowest measured value of tension on surrogate simulated waste. [See Berglund and Lenke, 1995] By selecting a constant value for use in the CCA that is lower than the lowest measured value, the DOE introduced additional conservatism to those analysis using the spallings model. (115)

Response to Comments 5.L.7 and 5.L.8

Although EPA agrees that the gravity effectiveness factor in DOE's spallings model was developed from experimental data, the relevance of those experiments and of the model that used the parameter in the CCA were questioned by both EPA and by DOE's Conceptual Models Peer Review Panel. Similarly, although EPA agrees that a tensile strength of 1 psi can be used as a bounding lower value for the tensile strength of the degraded waste, the relevance of the spallings model that used the parameter in the CCA was also questioned by both EPA and by DOE's CMPRP. The issue of spallings releases was resolved in April 1997 when additional field, laboratory, and modeling information allowed the CMPRP to conclude that the spallings release volumes used by DOE in performance assessment were reasonable and probably over-estimate releases. [(Docket: A-93-02, II-G-22, Section 3.1]

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9. DOE would like to clarify how the values for BRAGFLO parameters MAXFLOW, MINFLOW and GASMIN were derived. In general, it is pertinent to note that all three parameters were not arbitrarily set, but rather, were developed following consideration of available information and experience pertinent to the Northern Delaware Basin. (114)

Response to Comment 5.L.9:

The three parameters mentioned in this comment are used by DOE in calculating direct brine releases. MAXFLOW is the maximum period of time that a borehole penetrating the repository is allowed to discharge brine, MINFLOW is the minimum period of time that a borehole penetrating the repository is allowed to discharge brine, and GASMIN is the gas flow rate below which no direct brine releases are allowed to occur. EPA has accepted the values of the three parameters mentioned in this comment. Recognizing the uncertainty in the values of these parameters, all three were evaluated in EPA's Sensitivity Analysis. [Docket: A-93-02, V-B-13, Table 3.2-1] The modeling results were not found to be sensitive to MINFLOW and GASMIN, but were found to be sensitive to MAXFLOW. Additional documentation supporting the value assigned to MAXFLOW was received from DOE, and upon further review its value was accepted by EPA. [Docket: A-93-02, V-B-14, Table ES-3 and Section 5]

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10. In addition the density of waste components (WAS_AREA/DIRNCHW, WAS_AREA/DCELLCHW, WAS_AREA/DCELLRHW) is clearly sensitive (TSD III-B-14) and is not well established in the BIR. Such situation supports the need for accurate characterization methods to measure these factors. (974)

Response to Comment 5.L.10:

EPA agrees that the Agency's Sensitivity Analysis showed that DOE's performance assessment models are sensitive to the waste density parameters identified in the comment. [Docket: A-93-

02, V-B-13, Table 3.1-1] This is probably because changes in waste density result in changes in the repository waste inventory. However, as explained in EPA's Parameter Justification Report, DOE provided additional documentation supporting the density values, and upon further review, EPA accepted the values. [Docket: A-93-02, V-B-14, Table ES-3 and Section 5] The Agency also expects that additional information on waste density will be available once characterization is conducted to meet waste acceptance criteria.

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11. EPA has noted that parameter 27 -- BOREHOLE/ DOMEGA -- the drill string angular velocity -- is a potentially sensitive parameter (TSD III-B-14 at 25). EPA has required that DOE sample a constructed cumulative distribution of 4.2 to 23 radians/sec for this value. The large range of values suggests that there are other values, such as drill bit diameter, that vary in correlation with angular velocity. EPA should address whether such correlation and variation occur and require such other variables to be sampled as well. (1037)

Response to Comment 5.L.11:

The range of drill string angular velocities was determined by DOE based on a survey of oil and gas drilling practices in the Delaware Basin and literature review. [Docket: A-93-02, II-G-1, Volume V, Appendix CUTTINGS_S, p. 49] The angular velocities are therefore representative of current drilling practices in the Delaware Basin and already incorporate influences of drill bit diameter, rig power, geologic conditions, and other aspects of drilling that could affect the angular velocities. While it is appropriate to expect correlations among these factors, the approach taken by DOE in determining the range of values of this parameter from actual field practice adequately takes these correlations into account and satisfies the requirements of Section 194.33.

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12. The DOE applied "conservatism" to many of the parameter[s] and ranges, assuming that a larger range would incorporate all the experimental evidence. Without conducting a full scale sensitivity analysis on the parameters, this conservative approach becomes less meaningful. (1077)

13. [In its proposed decision EPA did not use:]

> * sensitivity analysis that analyze the synergistic effects of varying several parameters and realistic waste characteristics. (1139)

Response to Comments 5.L.12 and 5.L.13:

EPA recognizes that the values of many of the parameters used in WIPP performance assessment are uncertain. An acceptable way to address these uncertainties is to perform multiple simulations, randomly sampling the parameter value from a range of potential values in each simulation. This method provides a range of potential outcomes in terms of normalized releases that can be evaluated relative to the probability of occurrence . The greater the uncertainty, the larger the range of values that should be used. This method for addressing uncertainty was actually and appropriately used by DOE in performance assessment.

Although issues have been raised in public comments regarding the appropriateness of selected parameter values, EPA has examined the suggested alternative parameter values and found in every case that the values used by DOE in the CCA were, in fact, acceptable. The outcome of EPA's examination determined, for example, that the effect of the alternative parameter values on performance assessment was negligible, that additional information adequately supported DOE's original values, or that the alternative parameter values recommended in public comments are not as well supported as the values already used in PA and/or the PAVT. Detailed explanations of these determinations are found in EPA's Technical Support Documents for Section 194.23: Sensitivity Analysis [Docket: A-93-02, V-B-13], Parameter Justification Report [Docket: A-93-02, V-B-14], and throughout EPA's responses to public comments on the WIPP.

The issue of waste characteristics specifically mentioned in this comment was of special concern to EPA. The Agency performed detailed reviews of DOE's Baseline Inventory Reports regarding the characteristics of wastes to be received at WIPP. [Docket: A-93-02, V-B-15 and V-B-16] Based on these reviews, EPA believes that the waste characteristics used in its analyses are realistic.

Some public comments have been received suggesting changes that would reduce the calculated releases, while other comments suggested changes that would increase the calculated releases. The average releases calculated by both the CCA and PAVT performance assessment were over an order of magnitude smaller than the regulatory limits. If only those changes that would increase the releases were considered, the impact of each was found to be so minor that they would not cumulatively or synergistically cause the regulatory limits to be exceeded. [Technical Support Documents for Section 194.23*:* Sensitivity Analysis, Docket: A-93-02, V-B-13, Parameter Justification Report, Docket: A-93-02, V-B-14] For example, the sum of the percent changes for all 33 insensitive parameters in BRAGFLO together was 47 percent (ranging from 0 percent to 10 percent each), while the percent change for the individual sensitive parameters ranged from 101 percent to 103,611 percent each. [Docket: A-93-02, Item V-B-13, Table 3.1-1] EPA therefore believes that the existing basis for the parameter values is adequate and that additional sensitivity analyses are not needed.

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14. The EPA response in Section 5.25 and Section 5.33 (Docket A-93-02, Item III-B-14) addresses concerns of Plutonium and Americium sorption onto microbial colloids and humid colloids.

The sampled parameter for the probability of microbial gas generation determines whether cellulose and plastics and rubber will be degraded by microbial action after closure of the repository. No degradation of cellulose or plastics occurs in the calculations with a 50% probability. Only cellulose degrades in 25% of the sampled vectors. Cellulose, plastics, and rubber degrade with a probability of 25%. The preliminary sensitivity analysis report (Helton,

1996) lists this parameter as the largest influence on the variation of total calculated release from the WIPP repository.

The documentation supporting this parameter does not contain any numerical justification for the probabilities assigned to this parameter. All of the hand calculations performed to calculate the gas generation parameters are included as attachments to the memo of Wang and Brush (1996). Calculations for the degradation probabilities are absent from these attachments. It is the opinion of EEG that the numerical value of this parameter constitutes expert judgment. Given the importance of this parameter to the estimates of radionuclide release, this parameter should be demonstrated to be either solidly based on scientific evidence or to be conservative. The justification for this parameter presented in support of the CCA does neither of these.

The numerical values of the degradation probability parameter should undergo peer review consistent with expert judgment. Otherwise, the parameter should be conservatively set to always specifying microbial degradation of cellulose, plastics, and rubber. (1313)

<u>Response to Comment 5.L.14:</u>

Gas may be generated in the WIPP repository by microbial degradation of organic waste materials. Because of uncertainty in whether microbial degradation would occur under repository conditions, DOE established the randomly sampled parameter PROBDEG to be used in determining the extent to which such degradation will be assumed to occur. Based on the value of PROBDEG that was sampled, the performance assessment calculation for a given run would be based on one of three possibilities -- no microbial degradation of organics, only cellulosics subject to degradation, or all organics in the repository subject to degradation. EPA considers this approach to be the same as assigning ranges of values to uncertain parameters, and therefore acceptable. In recognizing the uncertainty in this parameter, EPA included it in its sensitivity analysis and determined the effect of varying the value of this parameter from no degradation to complete degradation on key BRAGFLO model outputs, such as repository gas pressures. The results, described in EPA's Technical Support Document for Section 194.23: Sensitivity Analysis indicate that the sensitivity of the model outputs to changes in this parameter were not significant. [Docket: A-93-02, V-B-13, Table 3.1-1 and Appendix PD, and Sections PD1.17 through PD 1.24] EPA believes that the results of its sensitivity analysis provide an adequate basis for accepting the values assigned to this parameter by DOE because the exact values of the parameter will have an insignificant impact upon the results of performance assessment.

The Agency disagrees that expert elicitation of judgment is necessary for the degradation probability parameter. Parameter PROBDEG was among the performance assessment parameters that were reviewed by EPA to determine if they were based solely on professional judgment, rather than supported by experimental data. To help resolve this issue, DOE prepared a memorandum [WPO # 46411, Memorandum from S. Howarth and Palmer Vaughn to Margaret Chu "Changes in Classification of Data Category' Column in the EPA Parameter Database," Docket: A-93-02, II-G-35] that provided the basis for shifting 149 parameters previously classified as being based solely on professional judgment into other data source categories that do not require expert elicitation (including degradation probability). EPA's Parameter Review Team reviewed the supporting information listed in the memorandum for all 149 parameters. This review is documented in EPA's Technical Support Document for Section 194.23: Parameter Report. [Docket: A-93-02, V-B-12, Attachment SR, Issue 6] Specific support for determining that the parameter PROBDEG was not based solely on professional judgment was provided by WPO # 44404. [Docket: A-93-02, V-B-1] These references provided specific justification and support for reclassifying that parameter. Based on the results of that review, EPA considers all issues identified in its original parameter review to have been addressed in a satisfactory manner.

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15. The EPA Technical Support Document acknowledges that the technical evidence related to the [Hartman] case was not reviewed. Rather, the technical support document reviewed a summary of the case. From that summary, the EPA document states:

> Though a jury found the waterflood operator guilty of common law and statutory trespass in the Rhodes-Yates Field, flow paths were not identified with certainty (U.S. EPA 1997, p. 31)

If EPA intended to comment on the technical aspects and refer to these comments in the final rule, EPA should have reviewed the technical exhibits and technical testimony of the Rhodes Yates incident. (1263)

Response to Comment 5.L.15:

The Agency has examined the impact of fluid injection on the WIPP. As indicated in the Fluid Injection section, the two areas in question are geologically dissimilar and petroleum recovery practices are different. EPA has analyzed the process, reviewed the Hartman scenario within the guidance and requirements of 40 CFRSection 194.32 (a) and (c), and required DOE to extend their studies beyond the 1996 modeling. [Docket: A-93-02, III-G-1, Reference 611] Moreover, as discussed in the Hartman Scenario and Brine Injection response to comment sections, EPA has conducted further analysis specifically related to the Hartman scenario that resolves the Agency's questions.

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16. [T]he PA verification test calculations also called PAVT mandated that EPA was a demonstration that EPA's comprehensive and thorough technical review of the Sandia performance assessment work in the CCA. (288)

Response to Comment 5.L.16:

EPA believes that the PAVT results confirmed the performance assessment results presented in the CCA. The Agency agrees that it was a critical element of EPA's thorough review process.

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17. There is no consideration of the uncertainty related to the choice of features, events, and processes or choice of alternative conceptual models. This would be considered a serious omission internationally (at 11). (1053)

Response to Comment 5.L.17:

Uncertainties in the FEPs were treated in the CCA by DOE's probabilistic methodology. A total of 3,000,000 unique future scenarios were evaluated by DOE. Each used a different sequence and timing of events and processes over the 10,000-year analysis. EPA disagrees with the commenter and believes this methodology adequately accounts for uncertainties in FEPs.

Conceptual model uncertainty was also included in the CCA analysis. First, the conceptual models from previous WIPP performance assessments have been refined, extended, or modified to represent the current state of understanding of the disposal system. The conceptual models have evolved over the last two decades in response to new information and a growing understanding of the WIPP and its future performance.

18. Though the EPA did a thorough job in evaluating the parameters for the PAVT, the EEG believes that the performance assessment evaluation is still incomplete. For example, the EPA studied the evidence carefully when considering the Castile Brine Reservoir parameters and selected relevant values to assign to the parameter. Yet, the solubility of certain actinides in Salado and Castile brines or the partition coefficient of actinides for sorption onto the Culebra Dolomite and the probability of brine reservoir encounter were inadequately addressed. These few examples play an important role in compliance, as studied by the EEG in sensitivity analyses (Section 2.2 of this report). The synergetic effect off all parameters is unknown, and it is important to characterize each parameter carefully. The EEG believes that this has not been done, and perhaps a new performance assessment should be conducted with parameter values that are more easily justified through experimentation.(1312)

Response to Comment 5.L.18:

EPA disagrees with this comment. Although issues have been raised in public comments regarding parameter values and activities that were not included in performance assessment, EPA has examined each suggested activity and alternative parameter value. In every case, the Agency found that the assessment performed by DOE in the CCA was, in fact, acceptable, as confirmed by the PAVT. The outcome of EPA's examination determined, for example, that the effect of the additional activities or alternative parameter values on performance assessment was negligible, that additional information adequately supported DOE's original position, that the activity did not need to be considered on regulatory grounds, or that the alternative parameter values recommended in public comments were inadequately supported in comparison with the values used in the CCA or the PAVT. Detailed explanations of these determinations are found throughout EPA's responses to public comments on the WIPP. Some public comments have suggested changes that would reduce the calculated releases, while other comments suggested changes that would increase the calculated releases. The releases calculated by performance assessment were over an order of magnitude smaller than the regulatory limits. If only those changes that would increase the releases were considered, the impact of each was found to be so minor that they would not cumulatively or synergistically cause the regulatory limits to be exceeded. EPA therefore believes that the existing basis for the parameter values is adequate and that a new performance assessment is not needed.

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19. The Agency has directed a series of analyses, the Performance Assessment Verification Tests, that have incorporated levels of conservatism well beyond that within the Compliance Certificate Application. These verification test analyses incorporated extremely conservative ranges for 24 critical parameters, many of which were identified or recommended by shareholders and oversight groups. The extremely conservative ranges exceed those likely to be found within the WIPP environment and exceed reasonable expectations, based on objective scientific evidence. Even when incorporating these extremely conservative scenarios, the analyses showed conclusively that the performance of WIPP is more than an order of magnitude below the Environmental Protection Agency's release criteria, and well within the bounds established for safe disposal and containment. (466)

20. You have heard comments to the DOE performance assessment is conservative. Many conservative assumptions were used without uncertainties. The estimates and releases in generating the CCDF are therefore larger than should be expected under realistic assumptions, because of these conservative choices. (664)

Response to Comments 5.L.19 and 5.L.20:

The Agency agrees with these comments. Even when a very conservative analysis was performed, the repository was shown to be safe for disposal and containment.

Issue M: Fluid flow in markerbeds

1. Why did the Agency screen out intrusion scenarios involving Marker Bed 139? (p. 11) (77c)

Response to Comment 5.M.1:

This comment appears to pertain to the future drilling into a contaminated, fractured Marker Bed 139. DOE discusses the means by which this scenario was screened out in CCA Vol. XVI Appendix SCR p. SCR-114 [Docket: A-93-02, II-G-1, Volume XVI], which addresses the effect of removing contaminated drill cuttings from the interbed. DOE calculated that the incremental releases incurred in this scenario would be about 5×10^{-7} normalized release units. This amount of incremental releases is not significant to regulatory compliance. [CCA Vol. XVI Appendix SCR p. SCR-114] Since the potential releases from an intrusion into the marker beds are insignificant compared to regulatory limits of normalized releases of 1 and 10, the Agency agrees with DOE's conclusion that this scenario could be screened out from further analyses.

Issue N: Brine inflow

1. In the repository, compaction begins with air only, and ends with air, decomposition gasses and brine from inflows, all at lithostatic pressure. The greatest factor of uncertainty is the amount of brine that will enter during the long room closure period while pressure is below lithostatic. The National Academy review (NAS, 1996, App. C) summarized the competing theories, indicating cumulative inflows in the range of 500 to 800 l/m of drift. It appears that none of those computations were coupled to back pressure computations. So the calculated cumulative brine inflows may err by large amounts, and a conservative inflow may total more than 1,000 l/m. (157)

Response to Comment 5.N.1:

In performing the analysis that support the CCA, DOE did not use any of the brine flow scoping estimates made by the NAS. In fact, the modeling approach that was used in the CCA assumed atmospheric boundary conditions in the repository at the beginning of the simulation that ultimately equilibrated with far field or lithostatic pressures. This approach effectively coupled the brine inflow calculations with the transient effects of the increased pressures due to gas generation from the waste. Therefore, the calculated cumulative brine inflows are not underestimated in the CCA PA. A detailed discussion of DOE's approach to coupling the creep closure of the halite to brine inflow is contained in Sections 6.4.3.1, 6.4.3.2 and 6.4.3.3 of the CCA. [Docket: A-93-02, II-G-1, Volume I, Chapter 6, pp. 6-97 through 6-105]

Issue O: Ground-water flow and radionuclide transport in the Culebra and above

1. What model did EPA use to determine that the Culebra, rather than the markerbeds, is the only formation capable of carrying a significant horizontal flow? (31)

Response to Comment 5.O.1:

EPA used several models to investigate the fluid carrying properties of the Culebra and marker beds. The Agency performed modeling of the Culebra with DOE's computer code STAFF3D. The results of this analysis are presented in the Technical Support Document for Section 194.23: Ground-Water Flow and Contaminant Transport Modeling at WIPP. [Docket:A-93-02, V-B-7] EPA modeled the marker bed fluid-carrying properties with the computer code GUSHER, as described in the Technical Support Document For Section 194.32: Fluid Injection Analyses. [Docket:A-93-02, V-B-22] As far as determining which units were most capable of transmitting fluid, the Agency relied primarily on the field tests that DOE conducted to determine the fluid carrying properties of the units. A physical description of each of the units is described in Chapter 2 of the CCA. [Docket: A-93-02, II-G-1] Once DOE determined the physical properties of the geological units, the Department used these properties in computer models to predict the volumes, rates and directions of brine flow.

DOE modeled groundwater flow and radionuclide transport in the Culebra with SECOFL2D and SECOTP2D. [Analysis Package of the Culebra Flow and Transport Calculations (Task 3) of the Performance Assessment Analysis; Docket: A-93-02, II-G-11] The results from the SECO modeling indicate that radionuclide transport via the Culebra is not a significant contributor to the total curie releases. [Supplemental Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison with the Compliance Certification Application Calculations - WPO#46702, Docket: A-93-02, II-G-28, Section 4] Gas/brine flow and radionuclide transport in the marker beds was modeled with BRAGFLO and NUTS, respectively. [Analysis Package for the Salado Flow Calculations (Task 1) of the Performance Assessment Analysis and Analysis Package for the Salado Transport Calculations (Task 2) of the Performance Assessment, Docket: A-93-02, II-G-08 and II-G-09] This modeling indicates that the amount of brine and radionuclides reaching the Land Withdrawal Boundary over the 10,000 year regulatory period is insignificant. [Supplemental Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison with the Compliance Certification Application Calculations, Docket: A-93-02, II-G-28, Section 3] It is important to recognize, however, that in a number of CCA realizations, no brine or radionuclides from the repository reach the Culebra. Furthermore, in a few instances where the permeability in the markerbeds is enhanced due to pressure induced fracturing it is possible that the fluid carrying capacity of the marker beds is greater than in the Culebra. It is for these reasons that fluid flow and radionuclide transport in both the Culebra and the marker beds have been explicitly modeled in the CCA.

With respect to the other formations, EPA's conclusions as to the volume of water that can be transmitted is based upon Darcy flow calculations. If the transmissivity (i.e., ability to transmit water), hydraulic gradient and the cross sectional area of an aquifer or rock unit is known, it is possible from Darcy's law to predict the volume of groundwater that can be transmitted. The field data (i.e., thickness, transmissivity, and cross-sectional area) for each of the hydrogeologic units is presented in Section 2 of the CCA. [Docket: A- 93-02, II-G-1, Vol. I] When these data are compared to those associated with the Culebra, found in Section 2.1.3.5 of the CCA [Docket: A- 93-02, II-G-I], it is clear that the Culebra dolomite is the most transmissive layer above the repository, and therefore, has the ability to carry the most fluid, except as noted above, where the permeability of the marker beds has been significantly enhanced due to pressurization of the repository. Therefore, the approach taken in the CCA, in which the transport of radionuclides is modeled in both the Culebra and anhydrite marker beds is considered by the Agency to be an appropriate methodology for modeling the physical system.

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2. DOE concedes that its technique of dividing the WIPP site into model "cells" of four square kilometers (1000 acres each) means that "local-scale variations" are not "represented.". . . This "limitation" cannot be "offset" by emphasizing "larger-scale features," which only compounds the distortion caused by ignoring smaller-scale, but dominant, dissolution features. Nor can this "limitation" be "offset" by emphasizing aspects of groundwater systems that are "less sensitive" to "local-scale variations;" this completely ignores the implications of karst. (882)

3. Anderson also points out that rapid climate fluctuations are common and should be included in PA both as to their effect on groundwater flow and for their effect on fracture porosity. He states that model runs which assume increases in transmissivity of at least two orders of magnitude are indicated (II-H-03 at 5). (984)

Response to Comments 5.O.2 and 5.O.3:

Anderson [(1993, 1995, 1996), June 13, 1997 Letter from George Dials, DOE-CAO to Larry Weinstock, EPA, DOE Response to Comments made to EPA by NMAG on DOE's CCA Dated March 14, 1997 - Response to Comment 7 and Attachment, Docket: A-93-02, II-H-44] advances a hypothesis that climate change has caused episodic dissolution of halite in the Rustler and Salado formations, and precipitation and dissolution of gypsum in fractures in the Culebra, and has consequently altered the permeability of the Culebra over the past 12,000 years. DOE agreed that dissolution of the upper Salado west of the WIPP site and dissolution of fracture filling within the WIPP site has altered the permeability in the geologic past. As part of the Department's evaluation of climate change, DOE has performed simulations of regional ground-water flow which explicitly account for these dissolution processes as well as the range of climate change proposed by Anderson. [Docket: A-93-02, II-G-1, Reference #147, Corbet and Knupp, 1996, p. 119]

The episodic dissolution/precipitation cycles Anderson proposes are associated with climatic cycles. In particular, he proposes the following sequence of events. The strongest episode of dissolution occurred between 60,000 and 12,000 years ago. Most of the fractures in the Culebra at the WIPP site formed during this interval. Gypsum precipitated in fractures in the Culebra when a dryer climate occurred 12,000 to 4,000 years ago. From 4,000 years ago to the present, gypsum filling in fractures has been dissolving. Anderson's hypothesis suggests that additional dissolution will occur during the next wet climate episode. In addition, he does not agree with DOE's assertion **(**that a return to a wet climate, as under glacial conditions, is highly unlikely in the next 10,000 years. If the climate does not become wetter over the next 10,000 years, recharge to the Culebra would not promote dissolution, the transmissivity of the Culebra would not increase, and potential releases of radioactivity through the Culebra would be reduced. Consequently, Anderson [1996] concludes:

> Because one cannot realistically estimate increases in porosity due to increased wetness and flow, a safety factor which recognizes the process of dissolution of fill from fractures, and which assumes proportional increase in transmissivity, needs to be incorporated into the model runs....model runs which incorporate increases in transmissivity of 2 orders of magnitude under conditions of wet climate during the next 10,000 years are indicated.

DOE agreed with Anderson that the presence or absence of mineral fillings in Culebra fractures exerts an important control on the permeability of the Culebra and that, in some regions of the WIPP site, the fracture fillings possibly have been dissolved and reprecipitated some time in the past. [Conceptual Model for Transport Processes in the Culebra Dolomite Member, Rustler Formation, Holt, 1997, p. 1-8, SAND 97-0194; see Docket: A-93-02, ItemV-B-1] Holt's interpretation is that at some time in the past, some of the open fractures found in the western part of the WIPP area may have originally contained fibrous gypsum. [*ibid*, p. 1-10] The crux of the issue is the timing of the dissolution -- that is, whether it is currently occurring and whether it will occur or continue to occur into the future. The modeling results and analysis provided by Corbet and Knupp [1996, Docket: A-93-02, II-G-1, Reference #147] explicitly include the range of climate scenarios suggested by Anderson as well as alteration of the Culebra permeability due to past dissolution of Salado halite and gypsum in Culebra fractures.

DOE used results from these simulations to develop a conceptual model of flow in the Culebra member. As with any conceptual model, a number of simplifications and assumptions were made to perform the simulations. In addition, there is a large uncertainty in model parameters. For these reasons, neither DOE or EPA consider these simulations to be quantitative predictions. Instead, DOE has developed a suite of simulations to estimate the range of possible climate change on ground-water flow at the WIPP site, which are detailed in Corbet and Knupp. [1996, Docket: A-93-02, II-G-1, Reference #147]

These simulations were designed to examine the possible effects of climate change over the period from 14,000 years in the past to 10,000 years in the future. This period includes the transition from the wet period of the last glacial maximum to the modern dryer and warmer climate. The range of recharge rates and temporal patterns used in the simulations represent both drying of the climate that occurred between 14,000 and 8,000 years ago as well as shorter wet-dry cycles that have occurred in the Holocene. Figure 2-6 in Corbet and Knupp [1996, Docket: A-93-02, II-G-1, Reference #147] shows how the simulations included the effects of dissolution of the Salado halite, and gypsum infilling of the Culebra fractures. Their Figure 2-7 shows how the processes were represented as zones in their model. Upper Salado dissolution (Zone 2) was assumed to disrupt the fractures in the overlying Culebra, thereby increasing the permeability by an order of magnitude. Dissolution of fracture fillings (Zones 2 and 3) was assumed to increase the permeability of the Culebra by 1.5 orders of magnitude, which is relatively close to the potential increase of two proposed by the commenter.

The conceptual model developed by Corbet and Knupp [1996, Docket: A-93-02, II-G-1, Reference #147] supports Anderson's assertion that ground-water flow in the vicinity of WIPP responds to climate change. However, the changes that Corbet and Knupp observed from their modeling of flow were relatively small. DOE's conceptual model suggests the following. Ground water, under the full range of climate conditions expected, would enter the Culebra by slow vertical flow through the overlying rock layers. All water in the Culebra within the site boundary would pass through the Dewey Lake Formation over time, and through the portion of the Rustler above the Culebra. A portion of the Culebra ground water within the WIPP site boundary would enter the Culebra as direct vertical leakage from the overlying Tamarisk member. The rest of the water would enter the Culebra by vertical downward leakage outside of the WIPP site boundary and then would flow laterally to the WIPP site. During long periods of wetter climates the water-table would rise, flow direction would shift slightly towards the west, and flow rates would increase slightly (by a factor of less than 2). Although flow in the Culebra responds rapidly to changes in recharge at the water table, perhaps in hundreds of years, recharge may take tens of thousands of years to reach the Culebra. Flow rates would increase because near-surface changes in fluid pressures due to a higher water table would propagate through the overlying sediments to the Culebra. Propagation of pressure transients to the Culebra does not mean, however, that the water recharged in the past has reached the Culebra and future recharge would still pass slowly through the overlying strata before reaching the portion of the Culebra within the boundaries of the WIPP site.

Anderson [1995] presents an argument that dissolution of gypsum is presently occurring in the Culebra in a region of high transmissivity in the southern portion of the WIPP site. This region of high transmissivity is important because many of the potential release paths in performance assessment flow and transport calculations pass along this region. Anderson's position is logically based on a map published by Beauheim and Holt [1990, SAND90-2035J; Docket: A-93-02, II-G-1, Reference #515] showing the Culebra water in this region to be under saturated with respect to gypsum. However, the gypsum saturation calculations were performed without taking into consideration the high ionic strengths and are now known to be in error and *to* have been superseded by calculations presented by Siegel, Robinson, and Myers. [1990, Docket: A-93-02, II-G-1, Reference # 590] Consequently, the most recent geochemical equilibrium calculations do not support Anderson's hypothesis that gypsum is presently being dissolved in the Culebra in the vicinity of the WIPP site.

The fact, however, that water within the Culebra is in equilibrium with gypsum does not necessarily prove that gypsum dissolution will not occur for two reasons: 1) the water may have achieved equilibrium by dissolving gypsum in the Culebra, and 2) water in the Culebra may be at partial equilibrium in which changes in ionic strength along the flow paths in the Rustler may alter the solubility of gypsum. DOE's current understanding of Culebra hydrogeology and geochemistry, suggests that gypsum dissolution due to either of these processes is not occurring. The first process, that equilibrium may have been obtained by dissolving gypsum in the Culebra, is not thought to be occurring because the available data indicate that ground water that is presently entering the Culebra is already saturated with respect to gypsum. [Docket: A-93-02, II-G-1, Reference # 590, Siegel, Robinson, and Myers, 1990] The second process, that water in the Culebra may be in partial equilibrium has been evaluated by Siegel and Anderholm. [1994, Geochemical Evolution of Groundwater in the Culebra Dolomite near the Waste Isolation Pilot Plant, Southeastern New Mexico; See Docket: A-93-02, Item V-B-1] Their analysis shows that, if the water in the Culebra is a partial equilibrium system, gypsum is presently precipitating along flow paths that follow the high transmissivity region.

Although current conceptualizations suggest that dissolution in the Culebra is not occurring, and DOE has not explicitly modeled the effects that dissolution would have on the hydraulic conductivity of the Culebra, EPA has required DOE to model an analogous process. This is the effect that potash mining would have on the hydraulic conductivity of the Culebra. [Section 194.32(b)] In DOE's approach, the hydraulic conductivity of the Culebra has been assumed to increase up to 1000 times *its* present day values. These mining-related permeability increases should bound those that would be expected due to dissolution from climate change. EPA believes this is true, particularly since the permeability increases due to mining are assumed to occur immediately after the repository is closed, unlike those increases in hydraulic conductivity associated with dissolution processes due to climate change that may take thousands of years. EPA believes that DOE's approach to simulating the potential effects on Culebra transmissivity due to mining is also a reasonable way to account for the potential range of effects that may occur from potential dissolution in the Culebra.

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3. The PA procedure uses one model to calculate the fluid and solute flux up and out of a Human Intrusion (HI) borehole. This outflow flux should then be equal to the input flux (source term) in the Culebra model that is used to calculate transport distances and times. However, the source term in the Culebra model is apparently not represented as a specified flux, so it is unclear that the flux out of the borehole is equal to the flux into the Culebra for each set of realizations (or even for the mean of all realizations). The PA models should compute mass balances and budgets, to demonstrate that the two boundary conditions are indeed equivalent. Specifically, the total mass of fluid and solute that the borehole model computes to enter the Culebra over 10,000 years should equal the total mass of fluid and solute that is added to the Culebra over 10,000 years in the Culebra model. (1272)

Response to Comment 5.O.3:

In the CCA, the boundary conditions reflected by the fluid movement up the borehole are not equivalent to the boundary conditions set on fluid entering the Culebra. [Docket: A-93-02, II-G-11, Analysis Package for Culebra Flow and Transport, WPO #40516] That is, the fluid source term in the Culebra is not a specified flux boundary because no fluid is allowed to enter the Culebra from the borehole. Furthermore, steady-state conditions are assumed.

To support DOE's 1992 Performance Assessment [Docket: A-93-02, Ref #542], DOE conducted a number of calculations that suggested that the fluid entering the Culebra would not have a significant impact on the radionuclide transport in the Culebra. [Docket: A-93-02, II-G-1, Reference # 542, Reeves et al 1991, p. 3-12] During a review of these DOE calculations, the Agency determined that the assumed fluid volumes were not representative of those entering the Culebra in the 1992 PA. Therefore, EPA conducted its own analyses to investigate the effects of introducing the fluid moving up the borehole into the Culebra, and found the effects on radionuclide transport in the Culebra to be significant. Technical Support Document for Section 194.23: Ground-Water Flow and Contaminant Transport Modeling At WIPP, Issue 3, Docket: A-93-02, V-B-7]

Since the 1992 PA, however, DOE's conceptual model for fracturing of the anhydrite marker beds has been revised to allow the permeability to increase at higher pressures (see response to comments under Anhydrite Interbeds later in Section 5). This treatment of the marker beds has been largely responsible for lowering brine releases to the Culebra from the borehole in the CCA as compared with the 1992 PA. EPA's modeling, referred to above, used an injection rate of 20 m^3/yr, which was obtained from values provided in the 1992 PA. Alternatively, the volume of brine that reaches the Culebra in the CCA is less than 6 m^3/yr. [Docket:A-93-02, II-G-08, p. 7-

122] Incidentally, 95 of the 100 simulations shown in Figure 7.2.1-21 had brine flow rates of less than 1 meter per year. [Docket:A-93-02, II-G-08] This volume of water is consistent with the values originally used by DOE to show that the impact of introducing this water to the Culebra would be insignificant with respect to radionuclide transport. [Docket: A-93-02, II-G-1, Reference # 542, Reeves et al 1991, p. 3-12] Therefore, the Agency has now accepted these calculations as appropriate for supporting that the effects upon releases of fluid moving up the borehole and into the Culebra will be insignificant (i.e., less than a 1% change).

The contaminant introduced into the Culebra is immediately dispersed into the fractures over a grid block that is 50 m^2. DOE's approach artificially introduces instantaneous advection (i.e., flow) over this area. [Docket: A-93-02, II-G-11, Analysis Package for Culebra Flow and Transport*,* WPO #40516, p. 26] The Agency required that all of the flow and transport models contain a mass balance algorithm, as suggested by the commenter.

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4. Therefore, the principal conclusions of the report [Lambert and Carter] must be regarded as possibly overstated: 1) it is possible, but not proven, that the Rustler system can be modeled as a confined aquifer, 2) it is plausible that the flow regime has changed direction, but alternative interpretations based on a more steady-state model are readily visualized, and 3) although the inferred rate of movement of uranium through the aquifer near the site is probably about right, the flow rate of the water itself could be appreciably faster. (1234)

Response to Comment 5.O.4:

The primary references that pertain to DOE's understanding of geochemistry of the Culebra are cited on p. 2-123 [Docket: A-93-02, II-G-1, Volume 1, Chapter 2] and include ; Lambert [1987], Lambert and Carter [1987], Lambert and Harvey [1987], Chapman [1986], Chapman [1988], LaVenue et. al. 1990, and Siegel et. al. 1991. [Docket: A-93-02, II-G-1, Reference #377, Reference #380, Reference #378, Reference #118, Reference # 119, Reference #393, Reference #590] The issues related to geochemistry of the Culebra member that EPA has been most concerned about include the following: First, EPA expects a conceptual model that is both geochemically and hydrogeologically consistent. Until the CCA, DOE had been unable to explain why the geochemical data suggested southeastern groundwater flow directions, whereas the hydraulic data suggested that ground-water flow was to the southwest. On p. 2-123 and 2-124 of the CCA [Docket: A-93-02, II-G-1, Volume 1, Chapter 2], DOE presents a conceptual model that adequately explains the apparent discrepancies in the geochemical and ground-water flow data. A second major issue is the amount of recharge that the Culebra is receiving. Campbell et. al., 1996 [Docket: A-93-02, II-I-28] provides a good description of past and current approaches to estimating recharge of the Culebra as well as DOE's rationale for their selected values. [Response to Comment #10 regarding Models and Computer Codes in May 2, 1997 letter from George Dials, DOE-CAO to Ramona Trovato, EPA/ORIA; Docket: A-93-02, II-I-28] A third area of concern is whether dissolution of Culebra is occurring now or will occur in the future. In response to EPA's identification of numerous deficiencies in the CCA, DOE provided supplemental information concerning the issue of dissolution in the Culebra. [March 13, 1997 letter from George Dials, DOE-CAO to Ramona Trovato, EPA/ORIA, supplemental response to Enclosure 2, p. 2 of EPA's letter of December 19, 1996 to Al Alm, DOE, Docket: A-93-02, II-I-15]

The fourth major area is what the geochemical properties *are* that will affect radionuclide transport in the Culebra. These topics are primarily discussed in Sections 6.4.6.2.1 and 6.4.6.2.2 of the CCA. [Docket: A-93-02, II-G-1, Volume 1, Chapter 6] A more recent publication that has relevant information on DOE's interpretation of the geochemistry is titled Conceptual Model For Transport Processes in the Culebra Dolomite Member, Rustler Formation by Holt 1997. [SAND97-0194, Docket: A-93-02, ItemV-B-1]

In the WIPP system, three-dimensional flow and consequent leakage through confining layers would have the greatest impact on flow and transport through the Culebra, with respect to repository performance. In the CCA, the Culebra is assumed to be a fully-confined system with two dimensional areal flow. Support for this conceptualization is provided in Docket: A-93-02, II-G-1, Reference #147, Corbet and Knupp 1996. This report provides a detailed sensitivity analysis of ground-water flow characteristics in the Culebra and concludes that the majority of ground-water flow through the Culebra is horizontal. [Docket: A-93-02, II-G-1, Reference #147, Section 3, Corbet and Knupp 1996] From the perspective of potential consequences to the repository performance, neglecting vertical leakage (i.e. system is confined) into and out of the Culebra is conservative. This is because ground water leaking out of the Culebra would also tend to transport radionuclides into lower permeability units, which would increase travel times of radioactive waste to the Land Withdrawal Boundary. EPA also acknowledges that if the model calibration does not compensate for vertical leakage, a bias in the long-term predictions of the flow and transport will result. However, a model calibration that does not include this leakage would be biased towards higher transmissivities than those that are actually present, because the Culebra is the most transmissive unit. Higher transmissivities would be conservative, since higher radionuclide mass-fluxes would be predicted to arrive at the WIPP Land Withdrawal Boundary. Therefore, EPA believes that the present modeling approach is acceptable and conservative.

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5. The proposed rule (U.S. EPA, 1997, p. 58799) states: "the CCA PA results indicated that no contaminated brine traveled up an intrusion borehole past the Culebra to the Dewey Lake or other units." It is common knowledge that the postulated rise of contaminated brine up an intrusion borehole is based on the assumptions made in conducting the performance assessment rather than any specific inherent property of the system. This EPA assertion for not considering contaminant transport through the DLR is therefore also without basis. (1227)

<u>Response to Comment 5.O.5:</u>

EPA believes that the only way to determine whether significant releases from the repository to the stratigraphic units shallower than the Salado occur is to have reliable models and data for use in the performance assessment process. The Compliance criteria at 40 CFRSection 194.23(a) to

194.23(d) - (Models and Computer Codes) set forth requirements to increase the likelihood that conceptual models utilized as part of the process of performance assessment will be reliable. Reliable models and data are also required for predicting direct release scenarios to the surface. In its review of the CCA, EPA identified a number of deficiencies in conceptual models and computer codes utilized in the PA process. The Agency believes that potential weaknesses have been corrected in the CCA PA computer codes and these corrected code*s* have been used in the EPA mandated PAVT. The results of the PAVT showed that brine flows to units above the Salado. Brine flows to the Culebra, but not to the Land Withdrawal Boundary, and brine does not flow up to the Dewey Lake Redbeds. [Summary of EPA-Mandated Performance Assessment Verification Test (Replicate 1) and Comparison with the Compliance Certification Application Calculations, Docket: A-93-02, II-G-26, Salado Transport, p. 1-3] EPA believes that the inputs to the PAVT accurately reflect the properties of the repository to the extent possible. Therefore, EPA disagrees that its determination regarding contaminated brine flow is without basis.

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6. Instead of seeking the appropriate geotechnical expertise to characterize conduit geometries, or developing their own innovative means of aquifer investigations for the purpose, DOE's consultants have discounted, denied and avoided the issues. Instead, they have adopted the classical porous-media approach, treating the Culebra and other Rustler units as though they were sands instead of fractured, dissolved rocks. Likewise, lacking corresponding means of modeling transport through highly heterogeneous fractured media and karstic formations, DOE has made the damaging simplification that equivalent continuous media properties can be estimated, extended stochastically and modeled in conventional, 2-D, layer-cake stratigraphic style. . .[P]arameters and rudimentary 3-D infiltration effects (1 to 2mm/yr) on regional flows fail to incorporate the range of properties relevant to karst terrain. DOE's model work does not approximate reality. (847)

7. DOE characterizes Culebra transmissivity as varying *significantly* across the WIPP site. . . DOE claims to *capture the uncertainty associated with the spatial variability of the available data* through the use of a *stochastic model.*. . . DOE*s model assumes *that the spatial variation is random.* It is not random. It is spatially dependent. The anomalously high measure transmissivities have distinct directional orientation in the northwestern and southeastern portions of the WIPP site; these represent preferential flow paths for groundwater and should be treated as such. (884)

8. [In its proposed decision EPA did not use:]

* realistic data and modeling of Rustler flow (see also II-H-3, 5, -20, -33); (1137)

9. The EEG view is that while the effects of karst processes have not been identified at the WIPP site proper, the site is located in a karst region. Therefore, in considering the flow and transport through the Culebra, allowance should be made of this fact and the conceptual models, parameter values, and numerical modeling should be conducted with relatively conservative assumptions. (1224)

10. The CCA model of the Culebra assumes that most properties of the system, except the transmissivity, are homogeneous and uniform within each simulation realization, but that these properties varied from run to run. Field tests at WIPP, however, indicate significant variability in many of these properties. For example, the effective porosity of the aquifer varies by almost an order of magnitude, even over a distance of only 50 m (the size of one cell of the model grid). Porosity has a strong control on transport velocities and times. Hence, the variability in porosity induces variability in velocity, which means that some parts of the plume may move faster than the local average velocity. This effect cannot be captured by assuming that porosity is uniform in each simulation. One would expect other properties, such as K_d and fracture spacing, to similarly exhibit large spatial variations. The PA procedure inherently assumes that heterogeneity in these variables has no significant impact on transport, or that its effects can be adequately represented by varying uniform properties among all the realizations. Either way, the CCA has not demonstrated that this is indeed the case and that it is reasonable to ignore the spatial variability in all of these critical parameters. (1270)

11. A related important issue is the accuracy of the definition of matrix diffusion processes and parameters. Another concern is the reliability of the regional transmissivity estimates for the Culebra, which were determined using inverse methods that assumed a non leaky two-dimensional aquifer. More recent three-dimensional analyses by Sandia clearly indicated that there is significant leakage into the Culebra. (1273b)

Response to Comments 5.O.6 through 5.O.11:

DOE conducted an extensive investigative program to improve their theories of ground-water flow and radionuclide transport through the Culebra. This program consists of four primary components, including: 1) field aquifer tests [Beauheim 1996, 1989, 1987a, 1987b, 1987c, 1986 Docket: A-93-02, II-G-1, Reference #46, Reference #44, Reference #41, Reference #42, Reference #43, Reference #40], 2) field tracer tests [Holt 1997], 3) laboratory tests [Docket: A-93-02, II-G-1, Reference #318, Howarth and Christian-Frear 1996] and 4) modeling. [Docket: A-93-02, II-G-1, Reference #390, LaVenue and RamaRao 1992] Although these activities have greatly improved understanding of the geohydrologic system, EPA recognizes that a degree of uncertainty still exists. It was specifically for these reasons that EPA required DOE to address this uncertainty in the performance assessment by assigning ranges and distributions to uncertain variables, such as fracture spacings, distribution coefficients, porosities and transmissivity (Comments 5.O.8, 5.O.9, 5.O.10). EPA believes that this approach of handling uncertainty is appropriate for the CCA PA calculations because it captures the range of possibilities attributable to the site hydrogeology. This is sufficient to ensure that releases to the environment will not be underestimated, even if they are not deliberately set to be conservative. Furthermore, the values are representative of those measured in the field. The Agency does not believe it is necessary to model karst conditions since they have not been observed in the Culebra in the vicinity of WIPP (see Response to Comments, Section 3).

As discussed in Section 4-8 of Holt [1997, SAND-0194; Docket: A-93-02, Item V-B-1], all of the tracer tests that have been performed on the Culebra (H-3, H-6, H-11 and H-19) have shown that the transport behavior could be explained by a combination of anisotropy in horizontal hydraulic conductivity[22] and by diffusion into porosity not participating in advective mass transport[23] . [*ibid.*, p. 4-8] For a description of these terms please see Freeze and Cherry, 1979. [Docket:A-93-02, II-G-1 Ref#257] These tests ruled out conceptualizing the Culebra as a homogeneous medium with a single porosity. Therefore, DOE simulated the Culebra in the CCA as a fractured medium. DOE did not simulate the Culebra as a porous medium, contrary to Comment 5.O.6.

The discussion on p. 2-119 of the CCA [Docket: A-93-02, II-G-1, Volume 1, Chapter 2] suggests that at very small scales (i.e., core samples), the Culebra is more uniform in porosity, much like rock matrix porosity. However, the porosity at larger scales have a smaller range due to the effects of spatial averaging.

Comment 5.O.10 raises an issue that is true of all field modeling studies, which is that many of the modeled processes are scale dependent and spatially heterogeneous. The fact remains, however, that assumptions have to be made regarding what scale is significant in modeling those parameters that vary spatially. DOE made a decision not to spatially vary a number of the parameters within each of the 300 simulations in the CCA (Comment 5.O.11).The parameters, however, were varied among the simulations. For example, the fracture spacing in the Culebra is the same over the entire model domain for any given simulation. However, each of the 300 simulations may have a different value for fracture spacing. The Agency believes that this analysis is acceptable and that the cumulative results of all 300 vectors are not significantly different than if spatial heterogeneity was assumed in each of the simulations. In fact, the Agency believes that the releases would have been lower had spatial heterogeneity been integrated into the analysis. This is because the Culebra has been shown to be unfractured over many areas [Holt,1997, SAND-0194; See Docket: A-93-02, Item V-B-1], but nearly all of the CCA simulations assumed that it was fractured over its entire areal extent. These fractures would increase the transmissivity of the Culebra and the transport of radionuclides through the Culebra compared to the use of spatial heterogeneity.

Therefore, EPA believes that the assumption of spatial uniformity is justified because the uncertainty with respect to the degree of fracturing is captured in the statistical sampling of the fracture spacing, porosity and transmissivity.

In response to Comment 5.O.7, DOE does not assign a random variation to the spatial heterogeneity of the Culebra transmissivity as the comment suggests. The method used by DOE to predict the Culebra transmissivity is described in the Analysis Package for the Generation of Transmissivity Fields. [Docket: A-93-02, II-G-04] DOE has used the existing field data to

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23 This means that the ability of water or brine to flow through the Culebra varies with the direction in which it is measured.

24 Concentration of a contaminant would spread out from areas of high concentration to areas of low concentration and would move into open spaces (pores) in the rock, rather than joining in the current of groundwater.

calibrate 100 transmissivity fields that all fit the measured data. The CCA, in turn, selects one of the 100 fields for each simulation.

As noted in Comment 5.O.11, the means by which the field data was analyzed typically assumed a non-leaky two dimensional aquifer. However, if recharge is occurring in actuality, the water drawdown measurements would be underpredicted and the transmissivity would be overpredicted. Therefore, the transmissivity values used in the CCA may be too high and the modeling results would overpredict releases.

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12. Our calculations assume a hydraulic gradient of 0.0005 (3064 ft -3054 ft/20421 ft) between WIPP-13 and WIPP-25, and 0.0025 (3054 ft - 2968 ft/35205 ft) between WIPP-25 and WIPP-29. After the heads in the WIPP shafts recover, the hydraulic gradient between the WIPP exhaust shaft and WIPP-13 could be as high as 0.004 (3096 ft - 3064 ft/8004 ft) or as low as 0.0005 (3068 ft - 3064 ft/8004 ft). ..

Thus the groundwater travel time along the northwesterly flow path from the WIPP shafts to Laguna Grande de la Sal could be as short as 10 years [average effective porosity = 0.1%] using our estimates of karst geometry, or as long as 400 years [average effective porosity = 1%] using DOE's geometry, but never 10,000 years. (1319)

13. Multi-well pump tests have demonstrated a rapid hydraulic connection between test wells H-3, DOE-1 and H-11 in the southeastern part of the WIPP site. . .

The hydraulic gradient is 0.0013 (3008 ft - 3001 ft/5224ft) between H-3b3 and DOE-1, and 0.0015 (3001 ft - 2995 ft/3992 ft) between DOE-1 and H-11b3. It is another 1501.7 ft from H-11b3 to the WIPP site boundary. If we assume a hydraulic head of 3024 ft at the WIPP exhaust shaft, then the hydraulic gradient is 0.006 (3024 ft - 3001 ft/3852 ft) between the shaft and H-3b3; if we assume a hydraulic head of 3032 ft, then the hydraulic gradient between the shaft and H-3b3 is 0.008 (3032 ft - 3001 ft/3852 ft).

Thus the travel time along the southeasterly low path from the WIPP shafts to the WIPP site boundary could be as short as 15 years [average effective porosity = 0.1%] using our estimates of karst geometry, or as long as 200 years [average effective porosity = 1%] using DOE's geometry, but never 10,000 years. (1320)

14. We take issue with DOE's modeling of flow and transport through the aquifer(s), which has assumed flow only in the 7m Culebra, fully confined, having a T-field based upon measured T's in the mid-range and assuming continuity of values inappropriate for fractured or karstic channelization. Alternatively, one could accept DOE's estimates for that fine karst system because it is, at least based on some conductivity measures and tracer testing. However, it is our position that the majority of the average annual flux has been neglected because recharge estimated from evaporation in Laguna Grande is an order of magnitude greater than DOE deduced by calibrating its regional groundwater model. . .

Transport may be estimated on the assumption that a repository breach is sudden and copious, as would occur if a hydrofracture were driven by repository or Castile reservoir pressure, propagating up-dip and up-section until it intersects the Rustler karst system about 2 miles west of the center of the LWA. . . Assume that recharge through the vadose zone is uniform along the flow path, 10 miles long, and that the point of injection is 6 miles from the Nash Draw discharge point. . . If the cavernous zone is arbitrarily taken to be 100 ft wide and 50 ft deep at the area overlying the repository, two miles downstream of the divide, the 1% porosity would imply 50 ft^2 of conduit there, and 250 ft^2 at the discharge end. . . Transport velocity is

V = Q/A = rwx/ax = 10(100)/305/.0047 = 700 ft/year

The travel time from a point of injection , at x=21120 ft to the end, where Xo=52800 ft is

t = (52800-x)/700 = 45 years

so if waste is injected at 4 miles, i.e., 2 miles west of the shafts, it would emerge in Nash Draw in about 45 years. . . Reasonable changes in the interval between conduits or their dimensions, or the recharge rate could conceivably result in travel times as short as 5 years or as great as 500 years, but never 10,000 years. (1322)

<u>Response to Comments 5.O.12 through 5.O.14:</u>

The commenters made a number of fundamental assumptions to perform their calculations. The most significant assumptions are that radionuclide transport is channeled through a continuous single fracture, and will be unaffected by physical (i.e., matrix diffusion) or chemical sorption. The commenter ignores the actual physical processes that impact flow.

Channeling is the movement of fluid through the larger aperture portions of a fracture network (that is, areas of high permeability). DOE discusses channeling on p. 6-121 of the CCA [Docket: A-93-02, II-G-1, Volume 1, Chapter 6] and indicates that it could locally enhance actinide transport. However, DOE also presents an argument that any gas present will be in the nonwetting phase and will occupy the portions of the fracture network with relatively large apertures, where the highest permeabilities will exist locally. The presence of gas will therefore remove the most rapid transport pathways from the contaminated brine and decrease the impact of channeling. Furthermore, the brine from the repository should be completely miscible with in situ brine. Therefore, diffusion and/or dispersion will probably broaden fingers (reduce concentration gradients) until the propagating fingers are indistinguishable from the advancing front. For a description of the effects of dispersion and diffusion on contaminant fronts. [Freeze and Cherry, Docket: A-93-02, II-G-1, Ref. #257, p. 75] The potential for channeling in the Culebra is discussed in the context of the field tracer test results in Section 4.2 of Holt. [1997, Docket: A-93-02, Item V-B-1] Although these results do not rule out the existence of channeling in the Culebra, as presented in Holt [1997] the preponderance of evidence suggests that it is not widespread if it does exist.

As discussed in Section 4-8 of Holt [1997, SAND-0194; Docket: A-93-02, Item V-B-1], all of the tracer tests that have been performed on the Culebra (H-3, H-6, H-11 and H-19) have shown that the transport behavior could be explained by a combination of anisotropy in horizontal hydraulic conductivity[24] and by diffusion into porosity not participating in advective mass transport[25] . [*ibid.*, p. 4-8] For a description of these terms please see Freeze and Cherry, 1979. [Docket:A-93-02, II-G-1 Ref#257] These tests ruled out conceptualizing the Culebra as a homogeneous medium with a single porosity. Therefore, DOE simulated the Culebra in the CCA as a fractured medium. DOE did not simulate the Culebra as a porous medium, contrary to Comment 5.O.6.

Flow in the Culebra is thought to be concentrated within zones that are thinner than the total thickness of the Culebra. In general, the upper portion of the Culebra contains few fractures and vugs, and is consequently low in permeability. [Holt, 1997, Docket: A-93-02, Item V-B-1] In contrast, the lower portion of the Culebra generally contains many more fractures and vuggy zones resulting in significantly higher permeability. [*ibid.*, Section 2]

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15. The EEG has conducted a sensitivity analysis pertaining to the extent of potash reserves within the controlled area. The conclusion is that with current models and the implementation of mining in those models (increase in effective transmissivity of the Culebra), the scenario has little effect. However, simply increasing the transmissivity within the Culebra does not account for all processes involved in subsidence due to mining, and other parameters, such as fracture width, or porosity may be significantly changed. Therefore, the EEG concludes that a more accurate portrayal of mining should be included in the performance assessment, including extent and consequence. (1315)

16. The hydrogeologic effects of potash mining beneath the Rustler aquifer are not adequately modeled by assuming an increase of hydraulic conductivity (1 to 1,000, applied randomly).(1180)

<u>Response to Comments 5.O.15 and 5.O.16:</u>

Groundwater flow and radionuclide transport in the Culebra was modeled with SECOFL2D and SECOTP2D. [Docket: A-93-02, II-G-11] Both of these issues are addressed in EPA's Technical Support Document for Section 194.23: Potential Effects of Mining on Ground-Water Flow and Radionuclide Transport at the WIPP Site. [Docket: A-93-02, V-B-8] This work involved a strain analysis to predict how much the transmissivity of the Culebra would be increased due to land subsidence caused by potash mining. These results indicate that the mining effects will be captured if the transmissivity value of the Culebra is varied over three orders of magnitude (1 to 1,000). Therefore, the Agency has determined that the method by which the Culebra

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[24] This means that the ability of water or brine to flow through the Culebra varies with the direction in which it is measured.

[25] Concentration of a contaminant would spread out from areas of high concentration to areas of low concentration and would move into open spaces (pores) in the rock, rather than joining in the current of groundwater.

transmissivities are increased to simulate potential effects due to mining adequately captures the associated uncertainty. Furthermore, EPA believes that additional modeling of potential mining effects on groundwater flow and radionuclide transport in the Culebra should not be required because of the low overall contribution that the Culebra transport pathway contributed to the combined complementary distribution function (CCDF) used to display the results of PA. As shown in Supplemental Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison with the Compliance Certification Application Calculations, p. 7-5 [Docket: A-93-02, II-G-28], the contribution to the CCDF that was made by radionuclide transport through the Culebra was very small relative to the contribution made by spallings. EPA believes that it is highly improbable that this relationship would be significantly changed if additional mining effects were considered in the CCA. Therefore, EPA concludes that additional analysis of this subject is unwarranted.

Issue P: Sensitivity analysis

1. Why did EPA focus on a dozen parameters when evaluating the sensitivity of BRAGFLO results? (66)

Response to Comment 5.P.1:

When EPA identified problems with the CCA PA models and inadequacies in their database early in its review, the Agency determined that it would be necessary to mandate DOE to prepare a "substantially revised performance assessment" as indicated in an April 17, 1997 letter from Ramona Trovato to George Dials regarding performance assessment input parameters. [Docket: A-93-02, II-I-25] In order to provide a comprehensive basis for performing this revised assessment, EPA reviewed the documentation for about 1,600 principal input parameters used by DOE and performed sensitivity analyses on about 80 of those parameters using the same PA models as used in the CCA. The results of these studies provided a logical basis for changing the database in the revised performance assessment. The screening process that was used to identify the 80 parameters subjected to sensitivity analysis from the 1,600 principal input parameters involved the following primary activities: (1) reviewing the sensitivity analysis results presented in Volume 5 of the preliminary 1992 Performance Assessment [Docket: A- 93-02, Ref. 563]; (2) evaluating the work performed by Helton [1996] in which he summarized the uncertainty and sensitivity of various aspects of the 1996 CCA [WPO #42912; Docket: A-93-02, Item II-G-7]; and (3) discussing the potential parameter sensitivities with the SNL Performance Assessment team. If it was unclear whether the results would be highly sensitive to changes in a particular parameter, EPA retained the parameter in the analysis. Discussion of specific parameters and related sensitivity analysis is presented in the EPA Technical Support Document for Section 194.23: Sensitivity Analysis. [Docket: A-93-02, V-B-13] In EPA's Sensitivity Analysis, the Agency initially evaluated more than 50 parameters in the BRAGFLO model. [*ibid*., Table 3.1-1, pp. SA-16 and SA-17] Out of these parameters, the sensitivity analysis identified 12 parameters that had a significant impact on the BRAGFLO runs.

2. With respect to Attachment PD, why did EPA only vary the initial permeability? (67)

Response to Comment 5.P.2:

Appendix PD, Section PD-1.1 of EPA's Sensitivity Analysis [Docket: A-93-02, V-B-13], presents the parameter values used to study the sensitivity of key BRAGFLO model outputs to changes in the initial anhydrite permeability. The text emphasizes the fact that EPA made changes to the initial permeability because anhydrite permeability is varied in the model during the model run to simulate anhydrite interbed fracturing as gas pressure builds up in the repository. The intent of this sensitivity analysis was to check on the sensitivity to changes in this parameter and not to changes in the fracture generation parts of the model. EPA evaluated fracture generation model parameters separately, as described in EPA's Parameter Justification Report. [Docket: A-93-02, V-B-14]

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3. On page 30 of Attachment PD, the uncontrolled borehole flow is assumed to be 20 days, what is the source of this time period? (68)

4. The maximum period of uncontrolled borehole flow in the direct brine release scenario (PD-2.3) is tested with a high value of 20 days (PD-30). The parameter is sensitive at that value (Table ES-I). However, there is no basis for using a maximum of 20 days, since there is no showing that a borehole might not flow for longer than that. Similarly, the minimum period of uncontrolled borehole flow (PD-2.4) is analyzed at a range of one to five days, whereas the time might well be longer than five days, if the driller elected to allow the hole to flow. (964)

5. Another direct release scenario involves direct brine release, which is the direct release of contaminated brine upon a drilling intrusion. DOE has not modeled direct brine releases from air drilling, and this deficiency should be remedied. Modeling of direct brine releases includes minimum and maximum time periods. DOE assumes that a release will last at least three days (time needed to set casing) and as much as 11 days (time required to control a previous blowout; see TSD III-B-14 at 36-37). The use of the 11 day limit without an explanation of what factors affect the time required to control a well and create supposed "close analogies" (id. 37) is not appropriate. (1036)

Response to Comments 5.P.3 through 5.P.5:

The period of 20 days was determined by EPA as an upper bounding value for controlling borehole flow. It is based on an upper limit of 11 days that was used by DOE as the maximum period of time required before a well would be brought under control in the Delaware Basin. The 11 day upper limit is based on a review of current practices in which regaining control of the South Culebra Bluff Unit 1 well in January 1978 was found to be the most problematic in the recent history of the basin. [WPO # 40520 p. 189 and WPO #43672 p. 10; Docket: A-93-02, items II-G-5 and V-B-1] Regaining control of this well was time consuming because it required bringing in outside experts to help in the activity, and involved the processes of attempting to exercise control with locally available resources, deciding to access outside help, contracting and mobilizing specialized outside personnel and equipment at the site, and finally sealing the well.

EPA considers the maximum time required to regain control of a serious blowout to be specific to the region where the well is located and the transportation facilities available to quickly bring in the necessary emergency personnel and equipment. The 11 days required to control the South Culebra Bluff Unit 1 well provides a conservative test of the emergency processes in the Delaware Basin because that incident occurred 20 years ago and better transportation facilities and emergency equipment are available today that would allow recovery in a shorter period of time. A conservative upper bound for purposes of sensitivity analysis was decided by the Agency to be 20 days based on an evaluation of the variables to be considered in the process of emergency recovery, listed in the previous paragraph. Attempts to exercise control with locally available resources could at most last a few extra days than the 11 days in the Culebra Bluff incident, not a few extra weeks. Deciding to access outside help would likely occur in the same time frame of one to two days as occurred in the Culebra Bluff incident. Contracting and mobilizing specialized outside personnel and equipment at the site would likely take no more than several days if the personnel were available, or a few extra days if they were not. The controlling uncertainties of this scenario are therefore measured in days rather than weeks. Because serious blowouts of wells reaching the Castile formation have been rare, the Agency found it reasonable to look qualitatively at the possible uncertainty based upon one well blowout in particular. In addition, EPA notes that it is economically beneficial to a company to regain control of a blowout as soon as possible in order to resume production. Therefore, the Agency believes it is unlikely that any blowout will continue for periods of time more than twice those already observed at Culebra Bluff. Based on the foregoing considerations, the Agency considered it to be conservative and appropriate to extend the time required to recover a well from 11 days, as at the Culebra Bluff well, to 20 days.

The minimum period of borehole flow used in the CCA is based on the time required to drill through the Castile and cement intermediate casing. [WPO # 40520 p. 189; Docket: A-93-02, item II-G-5] The low value selected by EPA for the sensitivity analysis is equal to one day, and the high value is equal to five days, based on a DOE survey of current drilling practices. [WPO # 43672 p. 9; Docket: A-93-02, item V-B-1] The high end of this range is also equal to the low end of the range of maximum period of borehole flow. This configuration was necessary to avoid possible outcomes where the maximum period is selected to be shorter than the minimum period. These variations were considered sufficient to adequately test the sensitivity of the PA model to changes in this parameter. The minimum period is based on the realistic assumption that the driller will act expeditiously to stop the flow and reduce brine handling and disposal costs.

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6. EPA's sensitivity analysis (TSD III-B-13) has several problems. The submodel approach for testing sensitivity (at ES-I) is not shown to be related in any particular way to the compliance demonstration. Further, why the analysis should use the average of the outputs of the submodels is not explained or justified; where outputs have inverse correlations, averaging all outputs would disguise the significance of a parameter value change (see SA-9, PM-4). . . In addition, most of

the sensitivity analyses varied only one parameter, rather than varying others also, which could show a significant combined result (SA-3). Partial and limited sensitivity analyses give no valid answer. Further, the sensitivity analysis fails to vary any conceptual models. (960)

7. [I]t appears to us that many of the tests conducted for the purpose of certification used averages or some value between the lowest and highest measurements. Such an approach may be acceptable for certification but it is not an acceptable method for us when evaluating the safety of our underground miners. In such situations we believe the only valid measurement to use is the one that presents the highest safety risk. If this were done using the parameters stated by DOE, the results would be different from those determined using averages or some other more favorable parameter value. (1338)

Response to Comments 5.P.6 and 5.P.7:

The basis for the approach taken in EPA's sensitivity analysis is described in Section 2.2 of the Sensitivity Analysis Report. [Docket: A-93-02, V-B-13] EPA adopted the submodel approach for several reasons. The submodels provided intermediate results that would be more sensitive measures of model reactions to changes in input parameters than could be obtained by evaluating only the resultant CCDFs.

DOE's PA model uses almost 1,600 parameters. Even an important parameter may change the final results of PA by a relatively small percentage because so many parameters contribute to the final results. The different submodels contain far fewer parameters than the complete PA. Therefore, a change in any one parameter will cause a greater percentage change in the output from a submodel than in the final result of the entire PA modeling. It is for this reason that EPA chose to use submodels. This approach provided intermediate results that would be a more sensitive measure of reactions of a model to changes in input parameters than the resultant CCDFs used to determine compliance.

Also, most of these sensitivity analyses were performed by fixing all sampled parameters at their median values and running the submodel three times for the low, baseline (i.e., median or constant), and high values of the parameter or group of parameters for which sensitivity was being evaluated. The Agency notes that the nature of the testing -- which included three model runs at low, average, and high parameter values -- means that it is not practical to develop mean CCDFs. It would be necessary to run all of the PA codes for each parameter change a hundred times to create a single CCDF. Therefore, except for those parameters included in the CCDFGF code, it would have been extremely cumbersome and time-consuming to perform a sensitivity analysis on the final results of PA. It is also more efficient to calculate using submodels, because the submodels use only the relevant subset of all the PA codes. The two analyses run using the CCDFGF submodel are exceptions. The parameters being studied in the CCDFGF submodel runs (the probability of encountering a Castile brine pocket and the passive institutional control drilling reduction factor) are both used only in this submodel to determine the final CCDF; thus, the selected performance measure was necessarily the CCDF itself. These two analyses were run by keeping fixed the values of the parameters in question and by using the remaining parameters from Replicate 1 of the CCA PA calculations. The resulting 100 model runs (vectors) for each high and low parameter value are sufficient to produce meaningful high and low mean CCDFs for comparison.

Averaging of the percent changes in the key submodel outputs was a significant step only for the BRAGFLO parameters, where average results were developed based on 11 model outputs. EPA evaluated the BRAGFLO-DBR and CUTTINGS_S parameters using only one model output, the cumulative release to the ground surface. The SOURCE TERM parameters were evaluated using only two model outputs, the solubilities of the key actinides americium and plutonium. EPA evaluated the CCDFGF parameters by directly using the mean CCDF curves.

The 11 BRAGFLO model outputs selected for this study are all considered important indicators of repository conditions. They include measures of repository gas pressure, gas saturation in the repository, brine flow to the Culebra, brine flow into the anhydrite interbeds, and anhydrite interbed fracturing. Each of these outputs is important to the different actinide release pathways supported by BRAGFLO modeling results. Therefore, EPA gave equal weight to each in determining the sensitivity results by averaging their results.

Concerning the issue of possible inverse correlations raised in Comment 5.P.6, EPA used absolute values of the percent changes in computing the average percent changes. This allowed the analysis results to focus on the issue of sensitivity (magnitude of changes in results, due to changes in input parameters), regardless of whether the change *in the output* was positive or negative. If two parameters had inverse relationships, those relationships would not cancel each other out because the final results would be an average of the absolute values (magnitude).

The primary objective of the sensitivity analysis was to provide the Agency with one of many means to assess whether the ranges and distributions of the various parameters used in performance assessment were appropriate. Although the sensitivity analysis was an important aspect of the Agency's parameter review activities, the most critical parameter evaluations are integrated throughout many of the Technical Support Documents. [Parameter Report, Sensitivity Analysis, and Parameter Justification Report; Docket: A-93-02, Items V-B-12, V-B-13, and V-B-14] The Agency performed extensive reviews of the sources of data of the parameters and exhaustive modeling of those processes that would have the greatest impact on potential releases. Over the course of this modeling, EPA gained considerable insight into the importance of parameters and appropriate parameter ranges and distributions. EPA's sensitivity analysis was an added safety factor to allow the Agency to identify the importance of secondary parameters (i.e., those parameters that impact performance assessment less than the primary processes and parameters investigated in the TSDs). The Agency's sensitivity analysis also was a supplement to DOE's sensitivity analysis found in Appendix SA of the CCA. [Docket: A-93-02, item II-G-1]

Although there may be some combinations of parameters in which the combined sensitivity may not have been tested during the sensitivity analysis, this does not mean that the ranges and distributions DOE placed on these parameters were ignored or were not thoroughly evaluated by the Agency. EPA reviewed all of the parameter values and their sources in detail. As described in EPA's Technical Support Document for Section 194.23: Parameter Report [Docket: A-93-02, V-B-12], each of the parameters has documentation leading back to the origin of its selected range and distribution (e.g., laboratory studies). A complete sensitivity analysis of different possible combinations of parameters would have been less valuable than the ultimate test, the PAVT simulations performed to verify the CCA PA. In these simulations, the combined effects from multiple parameters are expressed as cumulative impacts on the CCDF.

EPA varied single parameters in most of the analyses to identify those parameters that were most important to performance assessment results. One of the problems with varying multiple parameters simultaneously is that it becomes difficult to determine which parameter (or parameters) led to the observed result. In fact, the chain of performance assessment models used for WIPP had become so complex that it was very difficult to estimate the relative importance of individual parameters. The ability to determine the importance of individual parameters is important because this allows one to improve the model's predictive capability by focusing resources on those parameters that are most important and have the greatest impact upon results.

The objective of the sensitivity analysis was to determine the importance of selected individual parameters and groups of parameters to performance assessment results. Evaluating the conceptual models was the objective of the Conceptual Models Peer Review Panel, as required by Section 194.27. EPA also reviewed the conceptual models, and has concluded that there are no plausible alternative models that warrant incorporation into the sensitivity analysis. [Docket: A-93-02, V-B-6, Section 2.0 Alternative Model Requirements] EPA believes that its sensitivity analysis achieved its purpose in providing sound input for developing the parameter base for the PAVT.

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8. The analysis of anhydrite permeability, porosity, and initial pressure parameters uses the porosity model of anhydrite fracturing, which is inadequate, as explained in the report cited above. It should be noted that, despite this deficiency, anhydrite permeability showed an average change of 2,347% (TSD III-B-13, Table ES-1). (961)

9. Anhydrite permeability is clearly a sensitive parameter (TSD III-B-14 at 11-12), and EPA's statement that the anhydrite permeability values are "extensive, appropriate, well-documented" (id. 12) is simply inaccurate, since they are not supported by data. And EPA's statement that "the changes in interbed permeability with pressure have been based on laboratory and field data" (CARD 23 at 138) is plainly incorrect. (1020)

Response to Comments 5.P.8 and 5.P.9:

Comment 5.P.8 correctly observes that the sensitivity analyses for anhydrite permeability, porosity, and initial pressure did not involve changes in the interbed fracture model in BRAGFLO, and any hydrofracturing that was predicted in those realizations was modeled using BRAGFLO's fracture model. EPA has thoroughly reviewed DOE's porosity fracture model in BRAGFLO and the alternative LEFM model proposed by the commenter in the report referenced in the comment. The Agency has concluded that the model incorporated into BRAGFLO is expected to have a better predictive capability for the anhydrite interbeds at WIPP than the LEFM model, as discussed more thoroughly in the discussion of interbed fracturing in the response to Comments 5.J.1 through 5.J.15 in the section on Hartman Scenario comments.

In summary, EPA has reached the following conclusions regarding hydraulic fracture modeling at WIPP. After a detailed review, EPA does not agree with the assertion in Comment 5.P.8 that the porosity model of anhydrite fracturing is inadequate. DOE's fracture model is based in part on the results of field tests at WIPP and in part on theoretical considerations. [WPOs # 27246 and # 44704, Docket: A-93-02, V-B-14 and II-I-24, respectively] It recognizes that the anhydrite interbeds are previously fractured, bedded media containing open pores and voids through which brine can migrate. The open pore volume allows gas to enter at multiple locations and displace the resident brine when gas pressure is sufficiently high. Preexisting surfaces of weakness in the anhydrite result from natural fracturing and bedding planes and strongly influence the nature and occurrence of hydraulic fracturing. Field tests have created multiple planes of fracture propagation within the interbeds close to the point of injection.

The alternative fracture model proposed in the commenter's report is based on LEFM. This model is based on the assumption that the anhydrite interbeds are a previously non-fractured, non-porous, homogeneous elastic medium. The report identifies gelatin as an example of such a medium. The commenter's report correctly points out that fractures tend to occur as single features that can be very long in homogeneous elastic media, such as the gelatin described in the report. The commenter's report specifically states that the LEFM model does not predict the simultaneous generation of multiple fractures, even though such fractures were observed in DOE's field tests. [Beauheim et. al. WPO#27128, Docket: A-93-02, II-G-1, CCA Ref. #52] See responses to comments for Anhydrite Fracturing, Response to Comments, Section 5.

The lack of similarity between the ideal homogeneous elastic medium upon which LEFM theory is based and the highly discontinuous, fractured anhydrite that forms the interbeds at WIPP is striking. Although EPA recognizes that accurate prediction of fracture propagation in natural rock is difficult, DOE's fracture model incorporates actual field data, is based on a more accurate representation of the anhydrite than the LEFM model, and is considered by EPA to provide a better predictive capability when compared to field data.

Comment 5.P.9 correctly states that the sensitivity to anhydrite permeability is large. However, as stated in EPA's Parameter Justification Report [Docket: A-93-02, V-B-14, Section 3.5], the anhydrite permeability values upon which DOE based its analysis are extensive, appropriate, well documented, and were collected under an NQA-1 quality assurance program. They are based on 5 in situ hydraulic tests and 31 laboratory tests from anhydrite interbeds in the Salado, and screened for both scale effects and repository-induced disturbance. [CCA Volume XI, Appendix PAR p. PAR-81, Docket: A-93-02, II-G-1] The Agency considers DOE's treatment of anhydrite permeability in the CCA to be adequately supported by the field data.

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10. EPA states that it has determined that the increase in porosity of the Marker Bed 139 anhydrite is not a sensitive parameter (TSD III-B-14 at 10). This conclusion is not credible in light of the demonstrated large differences in fracture length seen in comparisons of the porosity model and the LEFM model (II-D-118 at 10-11). (1019)

Response to Comment 5.P.10:

EPA disagrees with the comment. Page 10 of the Parameter Justification Report [Docket: A- 93-02, V-B-14] discusses the insensitivity of the initial undisturbed porosity of the anhydrite marker beds. The large differences in fracture length predicted by the two models are due to the differences in the final porosities calculated by the model rather than the initial porosities assigned as a parameter value. Therefore, the commenter's observation about differences in fracture length has no bearing upon the sensitivity of the parameter for the porosity of Marker Bed 139 anhydrite.

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11. Long term borehole permeability (PD-1.5) is assessed only by lowering the low value to 1 x 10^{-17} (PD-6). There is no explanation of the origin of this figure. A proper sensitivity analysis would include a study of the effect of replacing a partial borehole plug with a full-length plug, which would essentially perform without degradation, according to DOE analyses. (MASS Att. 16-3 at 8-13). Such a plug would almost certainly be required, if in the future the repository were penetrated. (962)

Response to Comment 5.P.11:

The basis for the low value of long term borehole permeability is described in EPA's Sensitivity Analysis Report, Appendix PD, Section PD-1.5. [Docket: A-93-02, V-B-13] The low end of DOE's range for this parameter in the CCA was 1 x 10^{-14} m^2. This value was lowered to 1 x 10^{-17} m^2 in EPA's sensitivity analysis. The permeability of an intact, undegraded borehole plug is 5 x 10^{-17} m^2, or one-half order of magnitude greater than the value used as the low end of the range in the sensitivity analysis. This change represents a three order of magnitude decrease in the low value for borehole permeability used in the CCA. EPA considered this change to be sufficient to adequately check the sensitivity of the BRAGFLO performance measures to this parameter. Since the state of the borehole plugs over time is unknowable, the permeability range encompassed values based on intact plugs at the low end to fully degraded plugs at the high end.

The objective of the sensitivity analysis was to determine the importance of selected individual parameters and groups of parameters to performance assessment results. Evaluating the conceptual models, and in particular the various borehole plugging scenarios, was the objective of the Conceptual Models Peer Review Panel, as required by Section 194.27. The borehole plugging scenarios proposed by DOE were based on a survey of current practices and were accepted by the Panel. [CCA Volume XII, Appendix PEER, Attachment PEER-1, Section 3.12] A longer plug would reduce the amount of gas that could leak through the intact plug. This would tend to cause the pressure in the repository to bleed off at a slower rate. Thus the repository pressure at the time of any subsequent intrusion (should it occur) would be higher and pressure-driven short term releases (spallings and direct brine release) could be greater, if the pressure threshold of 8 MPa was exceeded at the time of subsequent intrusion. Using the information presented on pp. C-7 and C-8 of Appendix C to MASS Attachment 16-3 [Docket:A-93-02, II-G-1], it can be seen that the amount of gas flowing through the plug is proportional to the permeability and inversely proportional to the plug length. The expected variability in plug length for a complete plug compared to a partial plug is 900 m versus 40 m [*op. cit.*], less than two orders of magnitude, while the expected range of borehole (i.e., degraded plug) permeabilities is about six orders of magnitude. Permeability uncertainty is far greater than plug length uncertainty, and thus, would be expected to have a greater impact upon the results of performance assessment. Consequently, EPA did not choose to include plug length in its parameter sensitivity analyses in addition to permeability.

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12. Steel corrosion rate (PD-1.16) was varied only as to the lower end of the range. The sensitivity analysis should include the use of higher corrosion rates. . . (963)

13. [T]he PA verification test calculations also called PAVT that EPA mandated was a demonstration that EPA's comprehensive and thorough technical review of the Sandia performance assessment work in the CCA. (288)

Response to Comments 5.P.12 and 5.P.13:

The basis for varying only the low end of the range of steel corrosion rates is described in EPA's Sensitivity Analysis Report, Appendix PD, Section PD-1. [Docket: A-93-02, V-B-13] In the sensitivity analysis, EPA compared the impact of the minimum and maximum values of a selected parameter on BRAGFLO output parameters. Based on calculational considerations in the sensitivity analysis, it was not possible to use zero as the lower limit so the lower limit was set at a very small value close to zero (i.e., $1x10^{-30}$ m/s). EPA found that changing this parameter from essentially zero to the CCA maximum produced a 7% change in the BRAGFLO output parameters and the parameter was judged to have an insignificant impact as compared to several other CCA parameters. However, for the PAVT [WPO # 46674; Docket: A-93-02, Item II-G-26], EPA required that the steel corrosion rate be twice that which was used in the CCA (Comment 5.P.13). The Agency's judgment was based on the technical basis for selecting the upper limit of the parameter and the need to account fully for uncertainty, not on the sensitivity analysis of the BRAGFLO results to variations in the parameter. For additional discussion see Response to 5.F.4 through 5.F.8 in the section entitled Gas Generation Model Comments, Response to Comments, Section 5.

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14. The sensitivity analysis of solubility values (PD-4.1) uses the range adopted by DOE for sampling purposes. However, it would be far more appropriate to use values such as those proposed by EEG for solubility in the presence of nesquehonite or no backfill, since such values are a realistic possibility. (965)

Response to Comment 5.P.14:

The basis for the range of solubility values used in EPA's sensitivity analysis is presented in the Sensitivity Analysis Report, Appendix PD, Section PD-4.1. [Docket: A-93-02, V-B-13] Actinide solubilities are calculated values in the WIPP performance assessment. Actinide solubility in the presence of MgO backfill was estimated by SNL/DOE. A range of over three orders of magnitude was considered by EPA to be large enough to test the sensitivity of the model to variations in the parameters for solubility to test the impact of changing the solubility on the results. Therefore, the high and low values of DOE's range were used as the high and low values in the Agency's sensitivity analysis.

The Agency does not agree that the solubility values suggested by the EEG are appropriate. To see the Agency's response to EEG's solubility values, see the responses to comments on solubility in Section 24.

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15. The overall sensitivity analysis is flawed by not using synergistic effects of multiple parameters, by not varying conceptual models, and by not using upper and lower limits of waste characteristics. Moreover, the submodel approach (ES-1) is not explained and justified beyond the unsupported statement that it is "a more sensitive method." The sensitivity analysis was based on Replicate 1 (SA-3), apparently because EPA believed vector 46 produced "the greatest direct bine [sic] release" (DBR1). In fact, Replicate 3 showed the highest release concentrations of Am-241, Pu-239, U-234, and Th-230 (CCA at 8-7). (1149)

16. EPA inappropriately used a flawed sensitivity analysis as the basis to screen out important parameter values as being insensitive. Thus, various parameter values that EPA accepted because they are not sensitive in fact are sensitive, but were never analyzed by EPA as to their effect on compliance. (1150)

Response to Comments 5.P.15 and 5.P.16:

EPA performed its sensitivity analysis to independently investigate the sensitivity of the most important parameter values and parameter values that had insufficient supporting information. EPA's analysis was a supplement to DOE's sensitivity analysis found in Appendix SA of the CCA. [Docket: A-93-02, Item II-G-1] DOE's sensitivity analysis included some evaluation of the effects of multiple parameters, as well as single parameters.

EPA varied single parameters in most of the analyses to identify those parameters that were most important to performance assessment results. One of the problems with varying multiple parameters simultaneously is that it becomes difficult to determine which parameter (or parameters) led to the observed result. In fact, the chain of performance assessment models used for WIPP had become so complex that it was very difficult to estimate the relative importance of individual parameters. The ability to determine the importance of individual parameters is important because this allows one to improve the model's predictive capability by focusing resources on those parameters that are most important and have the greatest impact upon results.

Although issues have been raised in public comments regarding the appropriateness of selected parameter values, EPA has examined the suggested alternative parameter values and found in every case that the values used by DOE in the CCA were, in fact, acceptable. The outcome of EPA's examination determined, for example, that the effect of the alternative parameter values on performance assessment was negligible, that additional information adequately supported DOE's original values, or that the alternative parameter values recommended in public comments were inadequately supported. Detailed explanations of these determinations are found in EPA's Sensitivity Analysis [Docket: A-93-02, V-B-13], Parameter Justification Report [Docket: A-93-02, V-B-14], and throughout EPA's responses to public comments on the WIPP. The issue of waste characteristics specifically mentioned in this comment was of special concern to EPA. The Agency performed detailed reviews of DOE's Baseline Inventory Reports of the characteristics of wastes to be received at WIPP. [Docket: A-93-02, V-B-15 and V-B-16] Based on these reviews, EPA believes that the waste characteristics used in its sensitivity analyses are realistic.

The basis for the approach taken in EPA's sensitivity analysis is described in Section 2.2 of the Sensitivity Analysis Report. [Docket: A-93-02, V-B-13] EPA adopted the submodel approach for several reasons. The submodels provided intermediate results that would be more sensitive measures of model reactions to changes in input parameters than could be obtained by evaluating only the resultant CCDFs.

DOE's PA model uses almost 1,600 parameters. Even an important parameter may change the final results of PA by a relatively small percentage because so many parameters contribute to the final results. The different submodels contain far fewer parameters than the complete PA. Therefore, a change in any one parameter will generally cause a greater percentage change in the output from a submodel than in the final result of the entire PA modeling. It is for this reason that EPA chose to use submodels. This approach provided intermediate results that would be a more sensitive measure of reactions of a model to changes in input parameters than the resultant CCDFs used to determine compliance.

Also, most of these sensitivity analyses were performed by fixing all sampled parameters at their median values and running the model three times for the low, baseline (i.e., median or constant), and high values of the parameter or group of parameters for which sensitivity was being evaluated. The Agency notes that the nature of the testing -- which included three model runs at low, average, and high parameter values -- means that it is not practical to develop mean CCDFs. It would be necessary to run all of the PA codes for each parameter change a hundred times to create a single CCDF. Therefore, except for those parameters included in the CCDFGF code, it would have been extremely cumbersome and time-consuming to perform a sensitivity analysis on the final results of PA. It is also more efficient to calculate using submodels, because the submodels use only the relevant subset of all the PA codes. The two analyses run using the CCDFGF submodel are exceptions. The parameters being studied in the CCDFGF submodel runs (the probability of encountering a Castile brine pocket and the passive institutional control drilling reduction factor) are both used only in this submodel to determine the final CCDF; thus, the selected performance measure was necessarily the CCDF itself. These two analyses were run by keeping the values of the parameters in question fixed and using the remaining parameters from Replicate 1 of the CCA PA. The resulting 100 model runs (vectors) for each high and low parameter value are sufficient to produce meaningful high and low mean CCDFs for comparison.

The mean CCDFs produced by the three performance assessment replicates have been found to be nearly identical, and Replicate 1 has been routinely selected for analyses of this type by both DOE and EPA. For example, Replicate 1 of the CCA performance assessment modeling was used in determining the sensitivity of model results to changes in the two CCDFGF parameters analyzed, as described in Section 2.2 of the Sensitivity Analysis Report. [Docket: A-93-02, V-B-13] Replicate 1 was used for the sensitivity analyses using BRAGFLO-DBR to provide consistency with the other sensitivity analyses. Vector 46 of Replicate 1 was used because it provided the largest direct brine release upon second penetration of the vectors in Replicate 1.

Some public comments have been received suggesting parameter changes that would reduce the calculated releases, while other comments suggested changes that would increase the calculated releases. The average releases calculated by both the CCA and PAVT performance assessment were over an order of magnitude smaller than the regulatory limits. If only those changes that would increase the releases were considered, the impact of each was found to be so minor that they would not cumulatively or synergistically cause the regulatory limits to be exceeded. [EPA Technical Support Document for Section 194.23: Sensitivity Analysis; Docket: A-93-02, V-B-13] EPA did not perform a separate sensitivity analysis run on groups of parameters that it determined were insensitive through individual parameter tests because the cumulative calculated sensitivity of these insensitive parameters is so small compared to the sensitive parameters. For example, the sum of the percent changes for all 33 insensitive parameters in BRAGFLO together was 47 percent (ranging from 0 percent to 10 percent each), while the percent change for the individual sensitive parameters ranged from 101 percent to 103,611 percent each. [Docket: A-93-02, Item V-B-13, Table 3.1-1] EPA therefore believes that the existing basis for the parameter values is adequate and that additional sensitivity analyses are not needed. EPA based its sensitivity analysis on a comprehensive review of the CCA database parameters [EPA's Parameter Report, Docket: A-93-02, V-B-12], and believes that all parameters that are both sensitive and uncertain have been identified.

Issue Q: General model and parameter issues

1. Because of the synergistic effects of the many models and parameter values used in the CCA, the EEG has consistently advised the EPA to reject the idea of accepting certain values on the basis of partial sensitivity analysis. We do believe the models and the parameters should be completely and satisfactorily justified individually and the final set computations should be run with fully justified values. Only then can the compliance with the containment requirements be determined. (194)

2. [T]he EEG has consistently advised the EPA to reject the idea of accepting certain values on the basis of partial sensitivity analysis. In other words, we are steadfast in our belief that all the models and the parameters should be completely and satisfactorily justified, individually, and the final set of computations should be run with the fully justified values. Only then can the compliance with the containment requirements be determined. (721)

3. Because of the synergistic effects of the many models and parameter values used in the CCA, the EEG has consistently advised the EPA to reject the idea or accept certain values on the basis of partial sensitivity analysis. In other words, we are steadfast in our belief that all the models and the parameters should be completely and satisfactorily justified, individually, and the final set of commutations should be run with the fully justified values. Only then can the compliance with the containment requirements be determined. (354)

4. Because of the synergistic effects of the many models and parameter values used in the CCA, the EEG has consistently advised the EPA to reject the idea of a set of accepted certain values on the basis of partial sensitivity analysis. We believe that all the models and the parameters should be completely and satisfactorily justified individually, and the final set of computations run with fully justified values. Only then would the compliance with the containment requirements be determined. (488)

5. Monte Carlo sampling is a powerful, accurate means of combining terms of a function, each of which is uncertain in magnitude because it ranges over a definable PDF. However, DOE has employed Monte Carlo sampling to also include uncertain alternative magnitudes and competing concepts, both illegitimate applications. For example, matrix diffusion, as opposed to other mechanisms of species retardation, has been deduced from tracer testing in fractured Culebra dolomite. The range of retardation factors from such local tests cannot be uniformly applicable in other areas, particularly where dissolution channeling minimizes diffusive interchange with wallrock pore spaces. (840)

Response to Comments 5.Q.1 through 5.Q.5:

The Agency does not agree with these comments. A sensitivity analysis is a standard process used to determine the relative importance of input parameters to the results of a complex series of calculations. The results are considered sensitive to a parameter if a change in the value of a parameter significantly influences the outcome of the calculation. A sensitivity analysis therefore provides a means for focusing attention on those parameters that most strongly influence the overall results. Given the hundreds of input parameters used in the WIPP performance assessment model, the alternative suggested in the comments of giving equal weight to the precision and accuracy requirements of all input parameters is unnecessary because the process would only affect parameters that have little influence on the outcome of the calculations, the results of the analyses that have already been performed would remain substantially unchanged, and the process would be undesirable because of the high cost and long time involved.

The Agency performed a sensitivity analysis to evaluate the importance of individual parameters on performance assessment results. After performing this analysis, the Agency required DOE to do a comprehensive recalculation of the entire performance assessment in the PAVT. The purpose of the PAVT was to perform a complete evaluation of the synergistic effects of changing important and questionable parameters on the outcome of the performance assessment calculations. See EPA's Sensitivity Analysis and Parameter Justification Reports [Dockets A-93-02, V-B-13 and A-93-02, V-B-14] for more detailed descriptions of the parameter review and selection process.

Focusing the analysis on the parameters to which the modeling results are most sensitive is a widely practiced approach because it is both practical and effective. Contrary to the recommendations in the comments, there is no need to subject each of the hundreds of parameters in the WIPP performance assessment database to the same level of scrutiny. For example, there is no need to rigorously examine values based upon commonly accepted physical values, such as the ideal gas constant. Detailed scrutiny was appropriately reserved for the most important parameters.

6. Finally, the extensive and detailed calculations using conservative models and model parameters to examine the consequences of human intrusion so that radioactive releases, even from repeated direct penetration into the waste, will be well below EPA criteria and will present no health and safety issues. (456)

7. You have heard comments on the DOE performance assessment is conservative. Many conservative assumptions were used without uncertainties. The estimates and releases in generating the CCDF are therefore larger than should be expected under realistic assumptions, because of these conservative choices. (495)

8. Specific examples of worst-case assumption overkill include requirements for chemical backfill, massive panel closure systems, and even more massive permanent passive markers. Their rationale is at best dubious and, at worst, amounts to appeasement before blackmail. (549)

Response to Comments 5.Q.6 through 5.Q.8:

EPA concurs with these comments. After extensive analysis that involved many conservative assumptions, EPA believes that the WIPP has been shown to meet the Agency's regulatory criteria and to provide for the safe disposal of TRU waste.

Issue R: Anhydrite fracturing

1. On page 1-145 of III-B-6, what Salado interbed fracturing properties are based on laboratory data? (71)

Response to Comment 5.R.1:

The Agency considered gas migration in hydrofractured anhydrites to be an important potential release pathway and specifically identified eight model parameters governing fracture development that required additional information in a March 19, 1997, letter to DOE. [Docket: A-93-02 II-I-17] Those parameters were No. 2177 (S_MB_139 - DPHIMAX; the incremental increase in anhydrite porosity in Marker Bed 139), No. 2180 (S_MB_139 - PF_DELTA; the incremental pressure for full fracture development), No. 586 (S_MB_139 - PI_DELTA; the incremental pressure for fracture initiation), No. 2178 (S_MB_139 - KMAXLOG; the maximum permeability in altered anhydrite), No. 2158 (S_ANH_AB - DPHIMAX; the incremental increase in anhydrite porosity in anhydrite beds A and B), No. 528 (S_ANH_AB - POROSITY; the initial porosity of anhydrite beds A and B), No. 567 (S_MB138 - POROSITY; the initial porosity of Marker Bed 138), and No. 588 (S_MB139 - POROSITY; the initial porosity of Marker Bed 139). As documented in the Agency's Technical Support Document for Section 194.23: Parameter Justification Report [Docket: A-93-02, V-B-14], the Agency found the parameter values assigned to the first five of these parameters to be appropriately based on field data as described by the additional information provided by DOE. The uncertainty associated with the last three parameters prompted their inclusion into the Agency's Technical Support Document for Section 194.23: Sensitivity Analysis [Docket: A-93-02, V-B-13], in which the initial anhydrite permeability, initial anhydrite pore pressure, and initial anhydrite porosity were varied. Of these three parameters, the Agency found that DOE's modeling results were sensitive only to changes in initial anhydrite permeability. Upon additional review, the Agency determined that DOE's anhydrite permeability values were adequately based on field and laboratory tests of WIPP anhydrites as discussed in Docket: A-93-02, II-I-24, Comment No. 9.

BRAGFLO uses a pore-pressure versus rock permeability curve to calculate porosity of the Salado anhydrite interbed*s* in the BRAGFLO porosity/fracture model. The porosity/fracture model determines how much gas pressure would build up and how fractures might form as gas pressure increases. This is important to performance assessment because pressure build-up in the anhydrite interbeds can cause fractures that speed up the flow of contaminated brine out of the repository. Essentially, the low end of the pore pressure-permeability curve used in BRAGFLO was based on initial, undisturbed conditions and field test results at WIPP, and not on laboratory data. [WPO # 44704 Figure 7, Docket: A-93-02, II-I-24] Figure 3 of Larson et al. [1997; WPO # 44704] shows part of the experimental basis for the pore pressure-permeability curve used in the porosity model. The complete experimental basis for that curve is shown on Figure 7 of the same reference. The basis includes field test results for differential injection pressures up to 2.3 MPa, corresponding to an in situ pore pressure of over 15 MPa in the model, and covering about two-thirds of the range of pressures in the curve. The part of the curve that is not related to experimental data is small and the extrapolation to higher pore pressures invokes permeabilities as high as 1×10^{-9} m^2. [WPO # 44704 p. 14] This is an increase of ten orders of magnitude over the initial permeability. The Agency considers this an adequate representation of a high conductivity fracture flowpath. This is sufficient and conservative because repository pressures never reach 15 MPa, or that part of the curve for which values are extrapolated. [Docket A-93-02, II-G-07, p. 3-42] The low end of the pore pressure-porosity curve was also based on initial, undisturbed conditions and field test results. [WPO # 44704 p. 9 and Figure 6]

In addition to the aforementioned pore pressure-permeability relationships, the field tests also provided information about the nature of fracturing in the anhydrite interbeds that was useful in developing the conceptual and mathematical fracturing models. These test results are described by Wawersik et al. [WPO # 45491, 1997, Docket: A-93-02, V-B-1] and Beauheim et al. [WPO # 27128, Docket: A-93-02, II-G-1, CCA Ref.# 52] The field test results demonstrated that the fracture initiation process begins at pore pressures lower than the approximately 15 MPa lithostatic pressure because of the stress relief in overlying and underlying interbeds afforded by the repository excavation. [WPO # 27128 p. 1161] Wawersik et al. [WPO # 45491, p. 33] gives an example of a test that included a preexisting, open, fluid-filled and pressurized WIPP anhydrite fracture whose opening was initiated at a primary breakdown pressure of 11.6 MPa. The modeling assumption that fractures begin to open at less than lithostatic pressures may not be applicable to the far field (i.e., ambient) pressures already at lithostatic away from the repository. However, the Agency considers this simplifying assumption to be conservative because it will tend to increase predicted fracture lengths.

The field test results also showed that the fractures did not propagate as single features as predicted by LEFM and by the laboratory tests with gelatin. [Docket: A-93-02, II-D-118, p. 3-1] Instead, fractures branched into a series of subparallel fractures following partially healed, preexisting fractures or weakness planes less than four meters from the injection hole. The existence of these branch fractures would provide fluid storage capacity near the repository beyond what would be predicted by LEFM, and would therefore tend to shorten the overall length of fractured anhydrite. Borehole video records of branch fracturing are shown in the two tested marker beds (MB 139 and MB 140) and in two different observation boreholes in Figure 10 of Wawersik et al. [WPO # 45491] The implications of branch fracturing are discussed by the same authors in their Summary and Conclusions on p. 33. [WPO # 45491] Additionally, the fractures were not found to propagate to their full lengths within a few seconds, even over the relatively short test fracture lengths of about 30 m. Instead, the fractures continued to propagate slowly for several hours. This continued propagation is discussed by Wawersik et al. beginning on p. 21 [WPO # 45491, Docket: A-93-02, V-B-1]

In summary, the Agency investigated the basis of and sensitivity to key parameters associated with anhydrite hydrofracturing and flow as part of its CCA performance assessment review and found them to be adequate.

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2. III-B-6 states, "there is no evidence suggesting large scale heterogeneous properties that would contribute to potential anhydrite fracturing." On what basis did EPA make this statement? (73)

Response to Comment 5.R.2:

EPA made its statement regarding anhydrite fracturing based on an understanding of geologic principles and rock mechanics. Based on these principles, EPA determined that long preferential lines of fracture will not grow. Instead, any fracturing of the anhydrites will occur along a broad front. [Docket: A-93-02, II-G-34, Attachment 5] The DOE conceptual model for fracture propagation in anhydrite and halite provides the basis for the mathematical model used by DOE in the CCA. The conceptual model was reviewed and accepted by DOE's independent Conceptual Models Peer Review Panel under a review process mandated and evaluated by the Agency. Regarding the overall model suitability and particularly the issues of simultaneous fracture propagation and porosity increases in anhydrite interbeds, the Peer Review Panel stated in Section 3.6.2.2 of its June 1996 report that "The type of fracture propagation and dilation used in the conceptual model has been substantiated by in situ tests." The Peer Review Panel found the assumptions of increased porosity and permeability due to fracturing caused by gas generation to be reasonable. [CCA Volume XII Appendix PEER Attachment PEER-1] The conceptual model was fully approved by the Peer Review Panel in its December 1996 report, where it stated in Section 3.6.3.3 that the model is "... fully adequate for implementation." [WPO # 43153, Docket: A-93-02, II-G-12]

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3. TSD III-B-22 assumes that the BRAGFLO code correctly models fracture flow (at 43). Where is the "detailed review" of the code promised by the text? (1011)

Response to Comment 5.R.3:

A general description of the Agency's review of BRAGFLO is described in Sections 5.4.1 and 5.4.2 of the Technical Support Document for Section 194.23: Models and Computer Codes. [Docket: A-93-02, V-B-6] These sections indicate that EPA reviewed the mathematical and numerical formulations and successfully executed the code verification and validation tests. [Docket: A-93-02, II-G-03, Volumes 1 to 12] Following this review EPA did have some concerns regarding BRAGFLO which were expressed in a March 19, 1997 letter to DOE. [Docket: A-93-02, II-I-17] Specifically, these concerns were related to the methodology by which BRAGFLO incorporated the fracturing of the anhydrite marker beds. In response to this request, DOE submitted additional information on the field tests supporting its conceptual model and the actual mathematical and numerical implementation in the computer code. [Docket: A-93-02, II-I-24] The Agency reviewed the additional information and was satisfied that the conceptual model was adequately implemented into the mathematical and numerical schemes within the code. [Sections 4.4.1.1, 5.4.1 and 5.4.2 of the Technical Support Document for Section 194.23: Models and Computer Codes; Docket: A-93-02, V-B-6]

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4. We presented several reports about fracturing and marker beds that run beneath WIPP; showing how those fractures would be created by fluid injection or by gas pressure in WIPP; How experts show that DOE's prediction of the extent of fracturing conflicts with principles of fracture mechanics and was not supported by the data. EPA never raised these issues because EPA apparently lacked the skills or the initiative to do so. (403)

Response to Comment 5.R.4:

EPA has received the following technical reports and memoranda in comments related to fracturing in the anhydrite interbeds at WIPP:

> Prediction of Gas-Driven Hydrofracture at WIPP by Walter Gerstle, Fred Mendenhall, and Wolfgang Wawersik, dated 1 July 1996, from Walter Gerstle [Docket: A-92-02, II-H-01];
>
> The HARTMAN Scenario: Implications for WIPP by John Bredehoeft, dated March 1997, from the New Mexico Attorney General (NMAG) [Docket: A-92-02, II-D-116];
>
> Technical Review of The HARTMAN Scenario: Implications for WIPP by Peter Swift, Dan Stoelzel, Rick Beauheim, Palmer Vaughn, and Kurt Larson, dated 13 June 1997 [WPO #45968, Docket: A-92-02, II-I-36];
>
> Rebuttal: Technical Review of The HARTMAN Scenario: Implications for WIPP (Bredehoeft, 1997) by Swift, Stoelzel, Beauheim, Vaughn & Larson, June 13, 1997 by John Bredehoeft, dated 28 July 1997, from John Bredehoeft [Docket: A-92-02, II-D-116];
>
> Response to John Bredehoeft's memorandum of July 28, 1997, titled "Rebuttal: Technical Review of the HARTMAN Scenario: Implications for WIPP" by Peter Swift, Rick Beauheim, Palmer Vaughn, and Kurt Larson, dated 28 August 1997 [WPO #47389, Docket: A-92-02, II-I-63];
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> The HARTMAN Scenario Revisited: Implications for WIPP by John Bredehoeft and Walter Gerstle, dated August 1997, from the NMAG [Docket: A-92-02, II-D-116];
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> Linear Elastic Model for Hydrofracture at WIPP and Comparison with BRAGFLO Results by Walter Gerstle and John Bredehoeft, dated 3 September 1997, from the NMAG [Docket: A-92-02, II-D-118]; and
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> Response to Bredehoeft's July 28 Rebuttal: Technical Review of The Hartman Scenario: Implications for WIPP (Bredehoeft, 1997) by Swift, Stoelzel, Beauheim, Vaughn, & Larson; September 5, 1997 by John Bredehoeft, dated 12 September 1997, from John Bredehoeft. [Docket: A-93-02, II-D-119]

The last and most comprehensive comments on hydraulic fracturing at WIPP that were critical of EPA's acceptance of DOE's fracture modeling were presented in the NMAG report Linear Elastic Model for Hydrofracture at WIPP and Comparison with BRAGFLO Results by Walter Gerstle and John Bredehoeft, dated 3 September 1997. [Docket: A-93-02, II-D-118] EPA has prepared detailed responses to the issues raised in that report (See Responses to Comments, Section 5, on the Hartman Scenario and Brine Injection, especially response to Comments 5.K.1 through 5.K.11.)

In summary, EPA has reached the following conclusions regarding hydraulic fracture modeling at WIPP. After a detailed review, EPA does not agree with the assertion in this comment that "...

DOE's prediction of the extent of fracturing conflicts with principles of fracture mechanics and was not supported by the data." DOE's fracture model is based in part on the results of field tests at WIPP and in part on theoretical considerations. [WPOs # 27246 and # 44704, Docket: A-93-02, V-B-14 and II-I-24, respectively] It recognizes that the anhydrite interbeds are previously fractured, bedded media containing open pores and voids through which brine can migrate. The open pore volume allows gas to enter at multiple locations and displace the resident brine when gas pressure is sufficiently high. Preexisting surfaces of weakness in the anhydrite result from natural fracturing and bedding planes and strongly influence the nature and occurrence of hydraulic fracturing. Field tests have created multiple planes of fracture propagation within the interbeds close to the point of injection.

The alternative fracture model proposed in the commenter's report is based on LEFM. This model is based on the assumption that the anhydrite interbeds are a previously non-fractured, non-porous, homogeneous elastic medium. The report identifies gelatin as an example of such a medium. In homogeneous elastic media the commenter's report correctly points out that fractures tend to occur as single features that can be very long. The commenter's report specifically states that the LEFM model does not predict the simultaneous generation of multiple fractures, even though such fractures were observed in DOE's field tests. The lack of similarity between the ideal homogeneous elastic medium upon which LEFM theory is based and the highly discontinuous, fractured anhydrite that forms the interbeds at WIPP is striking. Although EPA recognizes that accurate prediction of fracture propagation in natural rock is difficult, DOE's fracture model incorporates actual field data, it is based on a more accurate representation of the anhydrite than the LEFM model, and is considered by EPA to provide a better predictive capability of the observed field data. (See Response to Comments, Section 5, on Anhydrite Fracture and Hartman Scenario, especially response to Comments 5.K.1 through 5.K.11)

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5. The porosity model obscures the significance of certain scenarios, e.g., drilling into contaminated Marker Bed 139 and the occurrence of deep abandoned boreholes that penetrate Marker Bed 139 (See II-D-118 at 11). (1021)

<u>Response to Comment 5.R.5:</u>

This comment appears to be based on the commenter's belief that the extent of hydraulic fracturing was underestimated by DOE, and therefore that the extent of contaminated drill cuttings that could be removed by future drilling into Marker Bed 139 was also underestimated. DOE also performed further analysis on fracturing of anhydrite interbeds. [April 23, 1998 Memo of EPA contractor's interactions with Sandia National Laboratories staff on fractured interbed calculations ; Docket: A-93-02, Item IV-E-25] For a further discussion about drilling into contaminated markerbeds, see the Response to Comments, Section 8.

Because the Agency found DOE's porosity model to adequately describe flow and transport within the marker beds, [Technical Support Document for Section 194.23: Models and Computer Codes; Docket: A-93-02, V-B-6, Section 1.3.23] the Agency also accepts DOE's use of the associated conceptual model in screening out this scenario. The Agency concurs with DOE that the incremental releases incurred in this scenario, calculated to be about 5 x 10^{-7} normalized release units, are not significant to regulatory compliance because they are well below the release limits as permitted by Section 191.13. [CCA Volume XVI Appendix SCR p. SCR-114]

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6. The BRAGFLO model is intended to mimic a linear fracture mechanics (LEFM) model at a pressure slightly above lithostatic, however, the BRAGFLO parameters deviated from LEFM in that:

- ♦ 0.5 cm dilation for 1 km fracture became 1 cm at 3.0 MPa above initial pressure;
- ♦ A 1 percent porosity at 3.0 MPa above initial pressure became 1 percent at 2.7 MPa above initial pressure; and
- ♦ The maximum porosity increase became 5 percent for MB139 and 25 percent for Anhydrite A and B (10 times LEFM maximum porosity increase).

In addition, BRAGFLO, when compared to the LEFM model, underestimates the extent of the fracture by a factor of 5. In contrast, the anhydrite fracturing model presented by Bredehoeft agrees with the LEFM model. Therefore, the Bredehoeft fluid injection model represents the effects of anhydrite fracturing with better accuracy than the BRAGFLO model used by Stoelzel and O'Brien. (59)

7. Where is EPA's response to NMAG's previously submitted comment that BRAGFLO was inadequate? In particular, where is the response to the comment that BRAGFLO could not adequately address anhydrite fracturing? (75)

8. With respect to the comparisons of different models for brine flow and fracture radii, which does the Agency favor? (Table 2) (77d)

9. DOE examined two models to account for changes in permeability of the anhydrite interbeds that are expected to intersect the disturbed zone surrounding the excavated disposal rooms. These models are the Porosity Model and the Aperture Model. Both models are able to deal with the issue of changes in permeability of the interbeds resulting from fracturing associated with changes in pressure within the interbeds. . . Both of these models can be used to simulate the effects of the formation of fractures either with relatively short lengths and relatively large apertures, or with relatively long lengths and relatively small apertures, with their corresponding areas of influence surrounding the repository in response to changes and rates of changes in pore pressure. Both models produced similar solutions and have been used to match field data on permeability versus pore pressure. (108)

10. BRAGFLO has incorporated fracture conductivity as a function of effective stress, but far greater fluxes would occur as hydrofracture exceeds elastic limits and opens clay partings at

salt/anhydrite contacts and within the salt beds, or as existing anhydrite fractures open upon reaching fluid pressures at or above lithostatic. Furthermore, creep closure will stretch the anhydrite beds above and below the rooms, panels and the repository, opening steep fractures appreciably, and enhancing continuity. (841a)

11. BRAGFLO computes two-phase displacement along marker beds, incorporating smoothly increasing conductivity as effective stress across fractures decreases. But it does not anticipate a sudden opening and a dramatic increase of flow as a parting opens. . . [Experience such as the Hartman case suggests an abrupt escape of fluids via a single fracture that will curve upwards or jump step-wise upwards to the Rustler. (842)

12. Though the steep fractures in anhydrite beds probably contain and convey most of the brines in the Salado, they are so short and in such intimate contact with salt that their pressures must have had abundant time to have equilibrated with the salt. The clay laminae bounding anhydrite beds may be residual, not depositional, reflecting the dynamics of changing fracture porosity with tectonics and salt deformation. Brine migration and salt regellation may produce fracture fillings of pure salt and corresponding residual clay along the adjoining impure halite beds. So native fluid pressures in anhydrite should be assumed essentially lithostatic, not the 12.5 MPa adopted by DOE for use in BRAGFLO. (843)

13. [B]ecause slab failures in the roof and floor of rooms will access the interbeds, continuity from room to room and panel to panel will follow the naturally-fractured anhydrite beds, since they extend across panel seal regions and stressed pillars. Along anhydrite beds below the repository strata, brine will drain to down-dip rooms. Air and generated gasses will migrate along roof anhydrites to up-dip rooms at pressures that will increase towards lithostatic as creep closes the deepest, partially-filled rooms. The considerable closure energy of the entire repository volume that is filled with compressed air and gas is available to drive a single pneumatic fracture. Thus failure of the sealed disturbed repository will be by sudden rupture and discharge to the atmosphere. It will not be, as envisioned by DoE and modeled by BRAGFLO, a gradual bleed-off to the far-field via the marker beds. (844)

14. There is an alternative route to building confidence in the reasonableness of the BRAGFLO predictions. The petroleum industry stakes millions of dollars routinely on its ability to design and execute hydrofracture jobs. Warpinski and Hansen (1998) (Attachment 5) compare and contrast the Bredehoeft and Gerstle (1997) fracture model and the BRAGFLO fracture model to industry standard models and documented field experience. The principal conclusions of this comparison are:

- The Bredehoeft and Gerstle (1997) model of fracturing excludes the three essential features of any hydrofracture analysis, and instead focuses on a secondary effect;
- The BRAGFLO model treats all of the essential features of hydrofracture physics in an acceptable manner;

- ♦ LEFM-based fracture models routinely overpredict the extent of fracture length, and industry practitioners deliberately alter the formulation of LEFM governing equations to reduce predicted fracture lengths;

- ♦ The hypothesis of Bredehoeft and Gerstle (1997) regarding the events at the Bates *#2* well cannot be confirmed using the standard practices of the petroleum industry.

In the case of gas-generated fractures from the WIPP, the anhydrite and halite permeabilities are very low, creating a low leak-off condition. The fractures are constrained to the interbeds. The rates of fluid injection (i.e., gas production) are calculated by BRAGFLO probabilistically to evaluate the range of uncertainty in future repository conditions. In replicate I of the CCA calculations, two of 100 vectors created gas at a high enough rate to drive fractures 1900 meters away from the repository (less in the down dip direction). (919)

15. Contrary to EPA's statement (TSD III-B-21 at 147), a fracture of 3 km radius is demonstrably possible, as shown by the linear elastic fracture model (II-D-116(b) at 14-16). Further, the BRAGFLO porosity model plainly understates the extent of a hydrofracture by a factor of 5 (II-D-116(b) at 19). It has been repeatedly pointed out that the "porosity" model of anhydrite fracturing used in BRAGFLO fails to represent the fracture process (id.), but EPA has failed to respond to the substance of such comments (id. 19-21). (1002)

16. Linear elastic fracture mechanics (LEFM) is a currently accepted and widely used model for describing fractures in geologic media. LEFM modeling predicts fracture behavior far different from the "porosity model" used in BRAGFLO and relied upon by DOE and EPA in demonstrating compliance. The LEFM report (II-D-118) shows fracture behavior at gas volumes of 10 million m^3, 20 million m^3 and 30 million m^3. Such volumes generate fractures of 3068 to 4118 m radius (id. 8). (1014)

17. [T]he BRAGFLO model shows that, even before lithostatic pressure is reached, gas flows simultaneously into and increases the porosity and permeability of the DRZ, the shaft, Anhydrites A and B, and Marker Beds 138 and 139. Such behavior is not plausible, since tensile failure almost always occurs locally in a crack. Moreover, in the porosity model, pore pressure increases below lithostatic pressure cause significant porosity and permeability changes -- a process not known in nature. (1015)

18. The porosity model is said to be supported by data in Beauheim et al. (SAND 94-05590(1994). However, that paper shows less than an order of magnitude increase in permeability when confining pressure is increased more than 4 MPa (Fig. 15) -- data that would support only a very small section of the "porosity" model permeability curve. Further, as to porosity itself, Larson et al. (1997)(II-l-24) asserts that the porosity of Marker Bed 139 increases from 1.1% to 2.1% when pore pressure increases from initial conditions to 15.2 MPa (at 12). It is claimed (id. Fig. 6) that this "1% porosity increase [is] at a pressure reflective of the highest flow rate experimental conditions, consistent with Beauheim et al. (1993)." These statements are

incorrect. Wawersik et al. (SAND95-0596)(1997) present the same data and report a residual fracture aperture of 0.2 mm and an average fracture opening during the "most extensive pressure cycle" of approximately 0.3 mm (at 32). An opening of 0.3 mm in a bed of 85 cm (Marker Bed 139) is about a 0.035% porosity increase -- not the 1% that the BRAGFLO porosity model uses. (1016)

19. The porosity model significantly understates fracture distances. (See LEFM report (II-D-118) at 10-11). A fracture caused by gas and brine movement into Marker Bed 139 North would extend 400 to 1000 m using BRAGFLO modeling and would have a radius of nearly 2000 m using LEFM. A fracture in Marker Bed 139 South would extend only 100 m using BRAGFLO modeling and would have a radius of 1575 m using LEFM. (1017)

20. EPA states that its "concerns" about the anhydrite fracture parameters were "ultimately resolved when DOE provided documentation that appropriately supported these parameters," citing II-1-24. (TSD III-B-12 at 12: see also TSD III-B-6 at 1-145; CARD 14 at 14-28, 14-34). EPA also says that "EPA believes that DOE provided necessary information to address these issues." (CARD 14 at 14-70). However, the data cited by EPA do not support the fracture parameters used by DOE. (See II-D-118 at 9). (1018)

21. [In its proposed decision EPA did not use:]

> * realistic fracture flow modeling, using Linear Elastic Fracture Mechanics (LEFM) (see also II-D-116, -118 and -119); (1136)

22. Fractures which occurred as a result of excavating the WIPP repository are potential pathways for release of radioactive and hazardous materials. Models which fail to include the observed changes in these interbeds are inadequate. DOE must include actual data to support its modeling of behavior, site characterization, laboratory results, and capillary pressure. DOE should include relative permeability curves which reflect relative pressures versus permeabilities. (1199)

23. [L]aboratory experiments on individual fractures support the assumptions used to formulate the permeability-porosity relationship of BRAGFLO anhydrite fracture model, but these experiments also strongly indicate that the model is only applicable at pore pressures more than 1 MPa below the lithostatic pressure. Above this pressure threshold the conventional cubic law model applies to the relationship of permeability and porosity. However, the exponent used in the BRAGFLO model is much larger than can be supported using experimental evidence.

The laboratory evidence also supports the concept of increased compressibility with pore pressure. It does not seem reasonable for compressibility to increase with pore pressure above the lithostatic pressure. (1268)

24. We have shown through laboratory testing, as a consequence of fluid pressure in excess of lithostatic in a solid medium, that in addition to horizontal hydrofractures, vertical hydrofractures

can develop. . . Thus, a new mechanism has been identified that can hydraulically connect the repository to the surface environment. . . Obviously, the original concept of WIPP as "impermeable envelope" for containing nuclear waste becomes highly questionable under the scenario of generation of waste gases. To preclude hydrofracture development, so that WIPP can function as intended, gas pressures must never be allowed to reach lithostatic levels. . . It therefore seems essential either to vent such waste gases in a controlled way, or to prevent them from occurring in the first place.

On possible approach . . . is to allow the materials to corrode and to degrade to low chemical potential prior to sealing the repository. Perhaps, first emplacing the waste barrels within the repository, and then adding brine or other chemicals can accelerate the waste degradation, with attendant gas generation. (1318)

25. The fracture model used by DOE in the modeling of the repository under pressure understates the length of fracture in an anhydrite bed, because it exaggerates the extent to which fracturing increases porosity. (1347)

26. The fracture model used by DOE in the modeling behavior of the repository under pressure understates the extent of any one fracture by modeling the occurrence of simultaneous fractures in several beds. (1348)

27. The fracture model used by DOE in the modeling behavior of the repository under pressure, in critical respects, is unsupported by data. (1349)

28. More accurate modeling should be employed in assessing the undisturbed performance of the repository and in analyzing both intrusions and nearby drilling penetrations, such as drilling into a contaminated Marker Bed 139 and the occurrence of abandoned boreholes penetrating Marker Bed 139. (1350)

29. Linear Elastic Fracture Mechanics (LEFM) is a widely used and accepted model for fractures, including hydrofracs. Using LEFM, the three scenarios analyzed in Bredehoeft (1997) are examined and found still to pose compliance problems for WIPP. These scenarios are: 1)a hydrofrac extending from a leaking injection well to WIPP at low pressure, 2) a hydrofrac extending from a leaking injection well to WIPP at high (lithostatic) pressure, and 3) a hydrofrac extending through WIPP and encountering a poorly plugged well that leaks upward. Under scenario 3) the containment limits are significantly violated in a few years. (1353)

Response to Comments 5.R.6 through 5.R.29:

The Agency agrees with everything the commenter states in Comment 5.R.13, with the exception that the closure energy will drive a single pneumatic fracture, thereby creating a release avenue to the atmosphere as a result of vertical hydrofracturing. DOE has evaluated the effect that stratigraphic dip (i.e., slope) will have on brine flow and gas migration. These studies are described in a report entitled The Effect of Stratigraphic Dip on Brine Inflow and Gas Migration at the Waste Isolation Pilot Plant by Webb and Larson (1996)(SAND94-0932. [Docket: A-93-02, V-B-1] The results of these studies indicate that the stratigraphic dip does play an important role in the movement of gas and brine. It is for this reason that DOE has incorporated the dip into the mesh geometry for the computer model BRAGFLO, which is used to model gas and brine flow within the repository. In order to address the issue of whether a single vertical fracture will occur it is important to review the overall conceptual model of fracturing within the repository as discussed below.

<u>Overview of conceptual fracturing model at WIPP</u>

Gas pressures in the repository will build up slowly over time as the waste materials and containers corrode and are degraded by microbial action. In the absence of exploration boreholes that intrude the repository, repository gas pressure can potentially be lowered through the repository shaft seals, through the anhydrite interbeds intersecting the repository, through the halite surrounding the repository, or through a combination of these pathways. At repository depth the anhydrite interbeds contain open fractures that are initially brine-filled and provide a low conductivity pathway for brine to enter or gas to leave the repository. The anhydrite interbeds also contain clay layers and fractures that have been healed by natural mineral infilling, but which are nevertheless generally weaker than the intact anhydrite matrix rock. Because of its plastic nature, at repository depth the halite that has not been disturbed by repository excavations is essentially free of fractures.

The Agency believes that as the pressure increases, repository gas will first enter the network of open fractures in the anhydrite interbeds, displacing the resident brine. This process will begin when the gas pressure exceeds the brine pressure in the interbeds, which is less than the lithostatic pressure. As the brine is displaced, the porosity and permeability available to the gas will increase. This process will preferentially occur in the topographically higher interbeds and in the updip direction because of the lower brine pressures. As repository gas penetrates into the interbeds and increases its total volume, the gas pressure will tend to decrease. However, if the rate of gas production exceeds the rate of volume increase, the gas pressure will increase. When the gas pressure has risen to approximate the local vertical stress, the natural anhydrite fractures will begin to open, likely affecting previously open fractures, healed fractures, clay layers, and anhydrite bedding planes, and the total porosity of the anhydrite will increase. In the anhydrite beds immediately above and below the repository excavations, the process of fracture opening will begin to occur at less than lithostatic pressures because the local vertical stress has been reduced due to the repository excavations.

As the gas pressure continues to increase, gas will continue to migrate into the anhydrites, both displacing additional brine and further opening the existing fractures. Because of the pervasive nature of fracturing in the anhydrite, this process is expected to occur not in a single fracture but simultaneously in multiple fractures within the interbeds. As the gas slowly penetrates into the anhydrite beds, brine displaced by the gas can move into the adjacent undisturbed halite through Darcy flow (i.e., non-turbulent flow). Significant movement of gas into the undisturbed halite is not expected, however, because of the high gas threshold pressure for two-phase Darcy flow, the low halite permeability, and the low rate of diffusive migration. However, gas is expected to enter disturbed halite that is pervasively fractured by mechanical failure following repository excavation (the disturbed rock zone around the repository) in much the same manner as it enters the anhydrite. Gas penetration of the interbeds and disturbed halite will cease when the repository gas pressure drops below the pressure of brine in those media.

At sufficiently high pressures, gas may also create small fractures in the intact halite. Such fractures are expected to initiate along preexisting planes of weakness, such as crystal boundaries, or by propagating existing fractures that extend into the intact halite from the disturbed rock zone. The rate of growth of these fractures in intact halite is expected to be so slow that halite creep will reduce the stress concentrations at the fracture tips resulting in the formation of gas bubbles rather than extended fractures. The tendency of long fractures in the anhydrite interbeds to curve upward into the halite will be constrained by the counteracting tendency of fractures to continue to propagate within the weaker anhydrite. Because of the aforementioned slow fracture growth and the creep characteristics of halite, fractures that do enter the halite will not be able to grow to sizes that are of concern to performance assessment (i.e., hundreds of meters).

Conceptual models peer review panel findings

The foregoing conceptual model for fracture propagation in anhydrite and halite provides the basis for the mathematical model used by DOE in the CCA. The conceptual model was reviewed and accepted by DOE's independent Conceptual Models Peer Review Panel under a review process mandated and overseen by the Agency. Regarding the overall model suitability and particularly the issues of simultaneous fracture propagation and porosity increases in anhydrite interbeds raised in comments, the Peer Review Panel stated in Section 3.6.2.2 of its June 1996 report that "The type of fracture propagation and dilation used in the conceptual model has been substantiated by in situ tests." and found the assumptions of increased porosity and permeability due to fracturing caused by gas generation to be reasonable. [CCA Volume XII Appendix PEER Attachment PEER-1] The conceptual model was fully approved by the Peer Review Panel in its December 1996 report, where it stated in Section 3.6.3.3 that the model is "... fully adequate for implementation." [WPO # 43153, Docket: A-93-02, II-G-12] EPA performed an independent review of the anhydrite marker bed conceptual model and found that it is supported by data, and adequately predicts fracture propagation. [Section 1.3.23 of EPA Technical Support Document for Section 194.23: Models and Computer Codes, Docket: A-93-02, Item V-B-6]

Overview of basis for DOE approach

EPA has concluded that the mathematical "porosity model" used by DOE in the CCA adequately implements the conceptual model. Summaries of the basis for DOE's approach to modeling fracture propagation is presented in CCA Volume X, Appendix Mass, Attachment 13-2, in a paper by Beauheim et al. [WPO # 27246, Docket: A-93-02, V-B-14], and in a memorandum by Larson et al. [WPO # 44704, Docket: A-93-02, II-I-24](Comments 77d and 108). These summaries state that the model was developed to correct previous inaccurate BRAGFLO predictions of unreasonably high gas pressures in the repository. For application to performance assessment, the model needed to be capable of addressing coupled fluid flow and fracture propagation for a gas-driven fracture, should not let the gas pressure climb much above lithostatic, and should correctly simulate the type of fracturing observed in field experiments.

The result of this effort was DOE's porosity model. To make this model adequate for application at WIPP and to address the potential errors in predicting fracture propagation with continuum models -- refer to NMAG comments Appendix Section 1.1; and Mendenhall and Gerstle [WPO # 39830 p. 2, Docket: A-93-02, II-G-1, CCA Ref. #443] for additional information on this issue-- the porosity model was fitted with parameters that allowed it to reproduce the pore pressure-permeability relationships observed in field tests at lower pore pressures, and to mimic the fracture effects predicted by LEFM at higher pore pressures where field test data were not available. Because obtaining detailed information on hydrofractures thousands of meters long was not feasible, the Agency considered DOE's approach using a combination of field test and theoretical information to be reasonable.

The low end of the pore pressure-permeability curve was based on initial, undisturbed conditions and field test results. [WPO # 44704 Figure 7, Docket: A-93-02, II-I-24] With reference to Comment 5.R.24, Figure 3 of Larson et al. [1997; WPO # 44704] was annotated by DOE to show only part of the experimental basis for the pore pressure-permeability curve used in the porosity model (Comments 5.R.23 and 5.R.24). The complete experimental basis for that curve is shown on Figure 7 of the same reference. The basis includes field test results for differential injection pressures up to 2.3 MPa, corresponding to an in situ pore pressure of over 15 MPa in the model, and covering about two-thirds of the range of pressures in the curve. The part of the curve that is not related to experimental data is small and the extrapolation to higher pore pressures invokes permeabilities as high as 1×10^{-9} m^2. [WPO # 44704 p. 14] This is an increase of ten orders of magnitude over the initial permeability and is considered by the Agency to adequately represent the field data and simulate a high conductivity fracture flowpath. This is sufficient and conservative because repository pressures never reach 15 MPa, or that part of the curve for which values are extrapolated. [Docket A-93-02, II-G-07, p. 3-42] Thus pore pressure and permeability will not actually be in the portion of the pore pressure-permeability curve where values are extrapolated.

With reference to Comments 5.R.19 and 5.R.21, the Agency concurs that the field test data do not directly support a 1% porosity increase in Marker Bed 139; however, the comment appears to have been based on the short note on Figure 6 of Larson et al. [1997, WPO #44704, Docket: A-93-02, II-I-24] rather than on the more detailed explanation beginning on p. 9 of the accompanying text. As explained in the aforementioned reference [WPO # 44704 p. 10], the 1% porosity increase is not based only on the field data but also on interpretive LEFM calculations for fractures generated at 0.5 MPa above lithostatic. Such fractures would be much longer than the approximately 30 m fractures generated during the field tests. The average fracture opening of 0.3 mm reported by Wawersik et al. for "... the last and most extensive pressure cycle in MB 139 ..." [WPO # 45491 p. 32, Docket: A-93-02, V-B-1] was for a pressure cycle that was longest in duration (about 180 seconds; see WPO # 45491 Figure 7, Pressure Cycle 4) and had the greatest injection volume [9.5 L; see WPO # 45491 Table 2], but occurred under the lowest injection pressure of any of the four cycles. [WPO # 45491 Table 2] Because of the lower injection pressure and longer test time, the results of this test do not necessarily represent the greatest fracture dilation that occurred during the field experiments. Additionally, as is discussed later in this response under Issue 6, it is not appropriate to directly apply dilations of 30 m field test fractures to fractures that are thousands of meters long.

In addition to the aforementioned pore pressure-permeability relationships, the field tests also provided information about the nature of fracturing in the anhydrite interbeds that was useful in developing the conceptual and mathematical fracturing models. These test results are described by Wawersik et al. [WPO # 45491, 1997; Docket: A-93-02, item V-B-1] and Beauheim et al. [WPO # 27128, Docket: A-93-02, II-G-1, CCA Ref. #52] The field test results demonstrated that the fracture initiation process begins at pore pressures lower than the approximately 15 MPa lithostatic pressure because of the stress relief in overlying and underlying interbeds afforded by the repository excavation. [WPO # 27128 p. 1161] An example is given by Wawersik et al. [WPO # 45491, p. 33] of a test that included a preexisting, open, fluid-filled and pressurized WIPP anhydrite fracture whose opening was initiated at a primary breakdown pressure of 11.6 MPa. Although the modeling assumption that fractures begin to open at less than lithostatic pressures may not be applicable to the far field away from the repository, the Agency considers this simplifying assumption to be conservative because it will tend to increase predicted fracture lengths. Furthermore, DOE has presented an argument, which is described later in this response under Issue 8, that fracturing can occur at pressures significantly below lithostatic. [Docket: A-93-02, II-G-34, Attachment 3, Item 8]

The field test results also showed that the fractures did not propagate as single features as predicted by LEFM and by laboratory tests with gelatin [Docket: A-93-02, II-D-118, p. 3-1] (Comments 5.R.6, 5.R.15, 5.R.16, 5.R.22, 5.R.17 and 5.R.20). Instead, the fractures branched into a series of subparallel fractures following partially healed, preexisting fractures or weakness planes within less than four meters from the injection hole (Comment 5.R.12). The existence of these branch fractures would provide fluid storage capacity near the repository beyond what would be predicted by LEFM, and would therefore tend to shorten the overall length of fractured anhydrite. Borehole video records of branch fracturing are shown in the two tested marker beds (MB 139 and MB 140) and in two different observation boreholes in Figure 10 of Wawersik et al. [WPO # 45491, Docket: A-93-02, V-B-1] The implications of branch fracturing are discussed by the same authors in their Summary and Conclusions on p. 33. [WPO # 45491] Additionally, the fractures were not found to propagate to their full lengths within a few seconds as would be predicted by LEFM, even over the relatively short test fracture lengths of about 30 m. Instead, the fractures continued to propagate slowly with time for several hours. This continued propagation is discussed by Wawersik et al. beginning on p. 21. [WPO # 45491]

The Agency believes that the field test results showing long, branching fractures and continued slow fracture growth are contrary to the LEFM predictions of long single fractures developing in a matter of seconds, and those results therefore do not support use of the LEFM model in the manner recommended in the comment. The LEFM model does not couple fluid flow with fracture propagation, thus the statement in Comment 5.R.11 that a long single fracture would develop very rapidly cannot be been supported by the model. It is noted that propagation of hydrofractures up to 4000 m long over a matter of seconds. Although short laboratory fractures may develop within seconds, such a rate of propagation is unrealistic for long fractures because, as discussed later in this response under Issue 6, fluid transport rates are generally slow and depletion of pressure occurs along the fracture.

The Agency reviewed the two references that have been used to suggest that the LEFM model is better supported by the WIPP fluid injection field tests than the porosity model. The first reference, Gerstle, Mendenhall, and Wawersik [1996; WPO # 48224, Docket: A-93-02, II-H-01] discusses on p. 3-1 the appropriateness of the LEFM assumptions for halite but not for anhydrite. Additionally, in the paper's recommendations on p. 6-3 it is stated:

> The biggest question is: is discrete fracture mechanics in general, and LEFM in particular, applicable? We have little doubt that these approaches are applicable when the body forces and pressures are relatively low and the fracture toughness is relatively high. But we did run into questions when the reverse was true (see Section 4.4). Further theoretical, numerical, and experimental work to address this question would be productive both from an engineering science viewpoint and in attempting to predict with more certainty the behavior of WIPP. It is possible that discrete fractures of the type discussed could be shown to be unlikely at depth.

The second document frequently cited to argue that the LEFM model is better supported by the WIPP fluid injection field tests is Mendenhall and Gerstle [1993; WPO # 39830, Docket: A-93-02, II-G-1, CCA Ref. #433] which also presents an argument supporting further model development and states in the introduction, "If hydrofracture of the anhydrite is to be considered a WIPP design feature, and if simple LEFM calculations are deemed not sufficiently accurate, then we believe that more defensible conceptual and numerical modeling of the WIPP anhydrite fractures should be pursued." *EPA* note*s* that both of these papers question the applicability of LEFM to WIPP anhydrites. The Agency believes that DOE did in fact pursue their recommendations and developed the porosity model which couples two-phase fluid flow and fracture propagation, addresses the non-objectivity issue with the continuum approach and the potential for erroneous results by calibrating the model to WIPP field test results and LEFM-predicted behavior, and adequately simulates the effects of hydrofracture branching observed in the field test results.

EPA notes that BRAGFLO is more appropriate to use for WIPP than a pure linear elastic fracture mechanics (LEFM) model because there are pre-existing fractures in the anhydrite layers. The pre-existing fractures will produce a fracture front, such as that modeled by BRAGFLO, rather than a fracture radius, as modeled by an LEFM. As noted above, the conceptual model for fracturing in the anhydrite marker beds is better supported by a fracture front type analysis.

The comparisons of predicted fracture radii of the porosity and LEFM models described by Comment 5.R.6 do not mention that the fracture radii presented for the porosity model were defined by Stoelzel and Swift [WPO # 44158 p. 43, Docket: A-93-02, II-I-36] as the extent of "complete fracturing" where the fracture permeability was increased by at least six orders of magnitude from an initial value of less than $1x10^{-18}$ m^2 to at least $1x10^{-12}$ m^2. The total length of fracturing predicted by the porosity model, if defined as the full distance where permeability increases occur, would be greater than those referred to in Comment 5.R.6. In the Agency's performance assessment verification test [PAVT; WPO # 46674 Appendix A p. A-8; Docket: A-93-02, Item II-G-26], fracture lengths were found to have exceeded 1,000 m in a number of realizations in Replicate 1 of the undisturbed case. The maximum fracture length realized in Replicate 1 of the undisturbed case in the CCA was 1,900 m to the north in Marker Bed 138. [WPO # 46674 Appendix A p. A-8; Docket: A-93-02, Item II-G-26] From the foregoing discussion, it is clear that the porosity model is capable of simulating fractures that are thousands of meters long.

As detailed below in this response under issue 7, the Agency does not believe that LEFM provides a credible methodology for predicting fracture propagation beyond a few tens of meters (Comment 1353). EPA concludes that the results from Dr. Bredehoeft's modeling are not realistic or representative of the processes affecting potential releases, since his modeling is based on LEFM concepts. The Agency disagree that the Gerstle and Bredehoeft modeling shows that WIPP may not be able to comply with EPA's containment requirements, because the Agency finds that this modeling is not valid.

DOE provided a response to issues related to the concerns raised by the commenters, which was presented as Attachment 5 to a DOE February 24, 1998 transmittal. [Docket: A-93-02, IV-G-34] In DOE's response DOE summarized Gerstle and Bredehoeft comments as follows:

1. "LEFM" (linear elastic fracture mechanics), as they [Gerstle and Bredehoeft] apply it, is the "most reasonable" model for predicting hydrofracture in salt or anhydrite.

2. "LEFM" (linear elastic fracture mechanics), as they [Gerstle and Bredehoeft] apply it, is widely used by the oil and gas industry for predicting fracture behavior.

3. BRAGFLO does not correctly account for the mechanics of the fracture.

4. Gas-driven cracks will extend thousands of meters from the repository.

5. The "LEFM" results are consistent with hydraulic fracturing models while BRAGFLO is not.

6. A gas-driven hydrofracture will develop over seconds, thus leaving little time for leakoff.

7. Wawersik's stress test experiments validate their "LEFM" model.

8. It is impossible to have permeability and porosity increase at pressure levels less than lithostatic.

9. The observed behavior in the Hartman case supports their "LEFM" results and shows hat waterflooding or brine injection operations could result in fracturing into the WIPP site.

DOE begins its discussion with a summary of the basic principles behind linear elastic fracture mechanics. It is a branch of solid mechanics that deals with the fracture of brittle materials. From a mathematical viewpoint, the development of LEFM is derived from an examination of the near-tip stress field around a crack. A key aspect of LEFM is a hypothesis that assumes that the strength of the material at the crack tip becomes a material property (i.e., fracture width) at failure. DOE noted that this hypothesis works for very brittle materials and can be applied to reasonable sized fractures of less than a meter. DOE also asserted, however, that the extension of this hypothesis to large cracks (e.g., tens or hundreds of meters) has never been demonstrated by any laboratory or field evidence. [Attachment 5 to February 24, 1998 transmittal; Docket: A-93-02, IV-G-34] The Agency has reviewed the citations provided by DOE, as well as additional material cited in Section 8 of EPA's Technical Support Document for Section 194.32: Fluid Injection Analysis [Docket:A-93-02, V-B-22] and has found no evidence contrary to DOE's assertions.

In Attachment 5, DOE continued their response by addressing the topics raised by Gerstle and Bredehoeft listed above. A synopsis of DOE's discussion is presented below along with EPA's conclusions.

1. LEFM (linear elastic fracture mechanics), as they [Gerstle and Bredehoeft] apply it, is the "most reasonable" model for predicting hydrofracture in salt or anhydrite.

All industry models for hydrofracturing have three principal components:

- Width equation -- defines the opening of the crack for conductivity and storage
- Flow equation -- defines the pressure drop due to fluid flowing down the fracture
- Leakoff equation -- defines the fluid loss to the formation.

DOE's conclusions regarding these issues are presented below:

> If we now examine the Gerstle-Bredehoeft model, it can be seen that they have only one mechanism, the tip equation. There is no flow equation, the width is not coupled to the flow, and there is no leakoff. Thus they have ignored the three dominant mechanisms associated with a hydraulic fracture and instead concentrated on a secondary effect.
>
> However, the one physical aspect they did consider is of questionable validity here, as the application of the LEFM model to material such as anhydrite or salt for conditions lasting centuries is impossible to substantiate, as it violates all of the assumptions needed for LEFM. It furthermore brings into question the application of LEFM to fractures that are orders of magnitude larger than the scale over which it has been verified. No part of their "LEFM" model can be substantiated with any laboratory or field evidence.

> Considering the absence of all important physics in the Gerstle and Bredehoeft model and the dubious application of LEFM to large fractures in materials such as salt and anhydrite, their contention that the "LEFM" model is the 'most reasonable' model for predicting hydrofracture behavior at WIPP is demonstrably wrong.

EPA's conclusion: DOE's arguments are consistent with the Agency's understanding of the problem and technical position.

2. "LEFM" (linear elastic fracture mechanics), as they [Gerstle and Bredehoeft] apply it, is widely used by the oil and gas industry for predicting fracture behavior.

With respect to use of LEFM methods within the oil and gas industry, DOE states the following:

> As explained in the previous section, the Gerstle and Bredehoeft model has no resemblance whatsoever to hydraulic fracture models used by the industry. Their model would predict fractures so long that well spacing rules would need to be extended to several square miles.

DOE accompanies its discussion with an example comparison of the LEFM model to a commercial model. The LEFM model predicted fracture lengths an order of magnitude greater and average pressures two orders of magnitude less than predicted by conventional fracturing models.

EPA's Conclusion: The Agency finds that the results of the comparison make intuitive sense. If fractures were to migrate as far as predicted by LEFM, fluid injection for oil recovery would be nearly impossible.

3. BRAGFLO does not correctly account for the mechanics of the fracture.

DOE indicates in its discussion that BRAGFLO adequately treats the three components of the hydraulic fracture mechanisms (i.e., width, flow and leakoff equations). DOE further states

> Thus, it can be seen that BRAGFLO has all three elements that every commercial hydraulic fracture simulator must have. It does not have a tip equation because commercial simulators have shown that the tip equation has little effect on fracture behavior. In fact, by not having a tip equation the BRAGFLO model gives a conservative estimate because the tip effect would only serve to reduce fracture lengths (in this case, the lengths of the increased porosity and permeability zones).

EPA's Conclusion: The Agency agrees that BRAGFLO contains all of the criteria necessary to adequately model the propagation of hydraulic fractures in the anhydrite marker beds.

4. Gas-driven cracks will extend thousands of meters from the repository.

Although DOE provided rationale for why gas-driven cracks will not extend thousands of meters in its preceding responses, the Department also provided additional information under this topic. This additional information includes a calculation that shows that the amount of gas generated in the repository over the 10,000 year time frame is orders of magnitude less than that required in a single year to keep the fracture open at its maximum extent with the LEFM model. Furthermore, DOE points out that since LEFM fails to account for flow or pressure drop along the fracture, the predicted length would be significantly overestimated. DOE also states:

> Compounding the pressure-loading problem, the idea that LEFM can be extrapolated to large crack sizes is undergoing considerable scrutiny by the oil industry at this time. Most diagnostic data from commercial fracturing shows that pressures are higher and cracks are shorter that predicted by the models. To achieve the measured results, crack modelers are adding enhanced tip-effect mechanisms to minimize length extension. These tip effects are the equivalent of having fracture toughnesses that are 2-4 orders of magnitude greater than those measured in the lab. Thus, one of the current theories is that there is a scale dependence to cracks in the earth which results in a dilatant zone around the crack tip or some other effect which hinders length growth. This is the opposite direction that the Gerstle-Bredehoeft model leads.
>
> When one attempts to put all of the physics into the problem and to apply the knowledge gained from oil-industry hydraulic fracture research, it is clear that such "LEFM" fractures would have lengths reduced by 1-2 orders of magnitude.

EPA's conclusion: DOE argument's are consistent with the Agency's understanding of the problem and the technical facts.

5. The "LEFM" results are consistent with hydraulic fracturing models while BRAGFLO is not.

To show that the fracture conceptualization in BRAGFLO is closer to that of other hydraulic fracturing models than LEFM, DOE compared both models to an analytical solution that provides an exact representation of fracture formation. For given conditions, the analytical solution results in a fracture length of 366 meters. The text also states:

> This number is an order of magnitude smaller than that give by Gerstle and Bredehoeft and consistent with the BRAGFLO results for the zone of modified permeability and porosity.

EPA's Conclusion: As indicated in the discussion above, the Agency agrees that the fracture conceptualization in BRAGFLO is closer to that of other hydraulic fracturing models than LEFM. However, DOE failed to provide the actual results of the LEFM and BRAGFLO comparison to the analytical solution.

6. A gas-driven hydrofracture will develop over seconds, thus leaving little time for leakoff.

The basic argument put forth by Gerstle and Bredehoeft is that the hydrofracture could develop rapidly (over a matter of seconds), thus leaving little time for the fluid to leak off into the anhydrite and halite. DOE asserted that if Gerstle and Bredehoeft had considered fluid flow, the gas flow out of the repository would be very slow and the crack would quickly stabilize.

EPA's conclusion: DOE argument's are consistent with the Agency's understanding of the problem and the technical facts.

7. Wawersik's stress test experiments validate their "LEFM" model.

DOE's response to this issue in its entirety is the following:

> Gerstle and Bredehoeft note that the fractures in the Wawersik stress-test experiments had residual apertures of 0.2 mm and likely had open apertures of 0.3 mm. Since this is about the aperture that they predict for a 100 m fracture, they contend that these results support their model. This statement is an inappropriate extension of Wawersik's work, seeing as how the stress test pump had a few liters of water injected in a few minute time period, compared to the continuous repository outflow of a low viscosity gas that would occur for years. Furthermore, the stress tests resulted in multiple fractures radiating from the borehole, rather than a single radial crack. There is nothing about these two fracture cases that are even distinctly related.

EPA's Conclusion: The Agency does not follow all of DOE's arguments, particularly DOE's concern with the time and amount of fluid injected during the test. If models could not be validated beyond the length of the experiment, there would be little chance to validate any model. The Agency does believe, however, that the test does not validate the LEFM model for use at WIPP for the following reasons;

Those physical processes which LEFM fails to model (e.g., pressure drop along the fracture and fluid flow) will cause the discrepancies between the measured and predicted values of fracture length to become more pronounced as the length of the fracture grows. This is one of the reasons why the LEFM model works for fractures less than a meter long. As the fracture length increases, however, the LEFM predictions will move farther from reality. Therefore, validation tests conducted over a relatively small area may show reasonable agreement with the LEFM approach. However, waste would need to travel several kilometers from WIPP to the accessible environment. The Agency concludes that the distance over which waste must travel precludes the use of the Wawersik test results to suggest that the LEFM is validated for the necessary distances.

8. It is impossible to have permeability and porosity increase at pressure levels less than lithostatic (Comments 5.R.13 and 5.R.18).

DOE's response to this issue in its entirety is the following:

Gerstle and Bredehoeft question the possibility of permeability and porosity increasing significantly at pressures less than lithostatic, which is the vertical stress due to the weight of the overburden. However, industry hydraulic fractures most generally occur at pressures below the lithostatic value. Fractures are created when the stress exceeds the minimum in situ stress, which is usually much less than the lithostatic stress. If the horizontal stress in the anhydrite is less than lithostatic, fractures will form when pressures exceed that lower stress value. Furthermore, porosity and permeability changes can occur even below the minimum in situ stress level. Many laboratory fracture experiments have shown that natural fractures and other weakness planes (such as those that exist in the anhydrite) are highly stress sensitive withe permeabilities often changing by an order of magnitude for the first few MPa of loading. The oil industry now understands this behavior and has begun conducting step-pressure tests to examine the stress sensitivity of reservoirs at pressures below fracturing pressure.

EPA's conclusion: DOE argument's are consistent with the Agency's understanding of the problem and technical facts.

9. The observed behavior in the Hartman case supports their "LEFM" results and shows that waterflooding or brine injection operations could result in fracturing into the WIPP site.

To address this issue, DOE performed several simulations with a conventional fracture simulator. The results of its analysis indicated that injection-induced fracture lengths cannot become excessively large under any realistic conditions.

EPA's Conclusion: DOE modeling results are consistent with the Agency's understanding of the problem and technical facts.

<u>Issue S: Anhydrite interbeds</u>

1. EPA did not use realistic flat tractor flow modeling using the LEFM model. EPA did not and still has not modeled the real life base flow to show that its models are valid. The only modeling record that shows that, that uses that shows major violations of the standards. You did not use realistic data in modeling a Rustler flow. You didn't use 3D backflow modeling. You didn't use realistic shaft bored hole and panel seal performance estimates. (233)

<u>Response to Comment 5.S.1:</u>

The comment is not clear about the concerns being raised. The Agency is not aware of anything called "flat tractor flow modeling." Also, EPA does not understand what the commenter means by "real life base flow" and "backflow modeling." EPA considers that the data used in modeling Rustler flow were realistic. EPA's assessment of Rustler flow is found in Sections 1.3.17, 1.3.18 and 1.3.19 in EPA Technical Support Document for Section 194.23: Models and Computer Codes.[Docket: A-93-02, Item V-B-6] In addition, EPA considers that the shaft borehole and panel seal performance estimates used in the PAVT were realistic. EPA's assessment of these performance estimates is found in sections 3.8 (BH_OPEN-PRMX_LOG), 4.3 (BH_SAND-PRMX_LOG), 5.4 (PAN_SEAL-PRMX_LOG), 5.16 (CONC_PLG-POROSITY), and 5.17 (CONC_PLG-PRMX_LOG**)** in the EPA Technical Support Document for Section 194.23: Parameter Justification Report. [Docket: A-93-02, Item V-B-14]

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2. Is the BRAGFLO model actually supported by data? (p. 9) (77b)

Response to Comment 5.S.2:

Yes. EPA assumes that the commenter is referring to the means by which the anhydrite marker bed fracturing is simulated in BRAGFLO. The Agency believes that the mathematical "porosity model" used by DOE in the CCA adequately implements the conceptual model. Summaries of the basis for DOE's approach to modeling fracture propagation are presented in CCA Volume X, Appendix Mass, Attachment 13-2; in a paper by Beauheim et al. [WPO # 27246, Docket: A-93-02, V-B-14]; and in a memorandum by Larson et al. [WPO # 44704, Docket: A-93-02, II-I-24] These summaries state that the model was developed to correct previous BRAGFLO predictions of unreasonably high gas pressures in the repository. For application to performance assessment, the model should be capable of addressing coupled fluid flow and fracture propagation for a gas-driven fracture, should not let the gas pressure climb much above lithostatic, and should correctly simulate the type of fracturing observed in field experiments.

The low end of the pore pressure-permeability curve used in BRAGFLO was based on initial, undisturbed conditions and field test results. [WPO # 44704 Figure 7] Figure 3 of Larson et al. [1997; WPO # 44704, Docket: A-93-02, II-I-24]shows part of the experimental basis for the pore pressure-permeability curve used in the porosity model. The complete experimental basis for that curve is shown on Figure 7 of the same reference. The basis includes field test results for differential injection pressures up to 2.3 MPa, corresponding to an in situ pore pressure of over 15 MPa in the model, and covering about two-thirds of the range of pressures in the curve. The part of the curve that is not related to experimental data is small and the extrapolation to higher pore pressures invokes permeabilities as high as 1 x 10^{-9} m^2. [WPO # 44704 p. 14, Docket: A-93-02, II-I-24] This is an increase of ten orders of magnitude over the initial permeability. The Agency considers this an adequate representation of a high conductivity fracture flowpath because the anhydrite marker beds are *modeled* to fracture along multiple fracture planes, which will increase spaces where fluid can move, raising the permeability and conductivity substantially. Hydraulic conductivities due to this additional fracturing would not exceed ten orders of magnitude over the initial permeability, which is consistent with the field test results. [WPO # 44704, Docket: A-93-02, II-I-24] The low end of the pore pressure-porosity curve was also based on initial, undisturbed conditions and field test results. [WPO # 44704 p. 9 and Figure 6]

In addition to the aforementioned pore pressure-permeability relationships, the field tests also provided information about the nature of fracturing in the anhydrite interbeds that was useful in developing the conceptual and mathematical fracturing models. These test results are described by Wawersik et al. [WPO # 45491, 1997, Docket: A-93-02, V-B-1] and Beauheim et al. [WPO #

27128, Docket: A-93-02, II-G-1, CCA Ref. #52] The field test results demonstrated that the fracture initiation process begins at pore pressures lower than the lithostatic pressure of approximately 15 MPa because of the stress relief in overlying and underlying interbeds afforded by the repository excavation. [WPO # 27128 p. 1161] Wawersik et al. [WPO # 45491, p. 33] gives an example of a test that included a preexisting, open, fluid-filled and pressurized WIPP anhydrite fracture whose opening was initiated at a primary breakdown pressure of 11.6 MPa. The modeling assumption that fractures begin to open at less than lithostatic pressures may not be applicable to the far field where pressures are at lithostatic (i.e., pressure due to the overlying rocks.) However, the Agency considers this simplifying assumption to be conservative because it will tend to increase predicted fracture lengths, which will allow more brine to carry radionuclides out of the repository.

The field test described by Beauheim et. al. [WPO 27246, Docket: A-93-02, V-B-14] also showed that the fractures did not propagate as single features as predicted by LEFM and by the laboratory tests with gelatin. [Docket: A-93-02, II-G-34, Attachment 3 , Item 8] Instead, fractures branched into a series of subparallel fractures following partially healed, preexisting fractures or weakness planes less than four meters from the injection hole. The existence of these branch fractures would provide fluid storage capacity near the repository beyond what would be predicted by LEFM, and would therefore tend to shorten the overall length of fractured anhydrite. Borehole video records of branch fracturing are shown in the two tested marker beds (MB 139 and MB 140) and in two different observation boreholes in Figure 10 of Wawersik et al. [WPO # 45491, Docket: A-93-02, V-B-1] The implications of branch fracturing are discussed by the same authors in their Summary and Conclusions on p. 33. [WPO # 45491, Docket: A-93-02, V-B-1] Additionally, the fractures were not found to propagate to their full lengths within a few seconds, even over the relatively short test fracture lengths of about 30 m. Instead, the fractures continued to propagate slowly for several hours. This continued propagation is discussed by Wawersik et al. beginning on p. 21. [WPO # 45491]

Issue T: Air drilling direct brine releases

1. Air drilling has been established in the Delaware Basin in Lincoln Federal Well No. 1. Previous studies of air drilling included the amount of solid material through a spalled event that would reach the surface. Dr. John Bredehoeft, a hydrologist who is a member of the NAS WIPP committee, concluded that released spalled material could be as high as 1,500 to 2,000 cubic meters. These values were obtained from using the code of the Hansen investigation. Dr. Bredehoeft also stated in his analysis that the use of GASOUT, the code used in Dr. Hansen's investigation, may not be entirely appropriate for this type of modeling. Yet it can give an indication of the magnitude of the problem. The solid release of material upon breaching the repository is only half the issue. When a borehole intrudes the repository, brine will also be brought to the surface, and depending on the solubility of the actinides, radionuclides such as plutonium or uranium will be brought to the surface with it. . . My analysis for the air drilling scenario using the same codes as were used in the CCA and PAVT has shown that as much as 1,000 to 2,000 cubic feet of brine could be brought to the surface. The analysis includes solubilities from a DOA analysis to actinides in solution with different mineral phases of the

backfill material. If the solubilities are sufficiently high, then the practice of drilling with air could bring enough material to the surface to violate the EPA standards. (368)

2. [T]he Bredehoeft calculations were made incorrectly and the results were interpreted inappropriately, leading to an extreme over-estimate of the spall release. (655)

3. EEG has investigated the effect of air drilling on direct brine release, . . .The results show that brine releases to the surface could be between 1000 and 2000 m^3, compared to a maximum of 180 m^3 from the EPA's PAVT computations. The CCDF from the EEG's runs show that the overall mean for all types of releases (including brine release from air drilling) comes very close to the EPA limit at 10^{-3} probability for the actinide solubilities assumed in the CCA and violates the standard at the "no backfill" and "nesquehonite" solubilities. (697)

Response to Comments 5.T.1 through 5.T.3:

EPA disagrees that direct brine releases due to air drilling will result in violation of the containment requirement of 40 CFR 191.13. To investigate this issue, EPA convened a meeting to discuss the possible impact of air drilling on the repository. At that meeting, it became clear that the releases postulated by Commenter 5.T.3 and referred to in Comment 5.T.1 were the result of inappropriate use of the CCA BRAGFLO Direct Brine Release (DBR) computer codes appropriately. [Summary of U.S. EPA, Office of Radiation and Indoor Air meeting with EEG on January 26, 1998, Docket: A-93-02, Item IV-E-10] Parameter input errors (e.g., assigning properties of air to both the drilling fluid and the brine in the repository artificially increased the mobility of the brine in the repository to that of air (Comments 5.T.3 and 5.T.2). This greatly increases the transmissivity in the repository and inflates brine release predictions (flow is directly proportional to fluid mobility). This inflation results in the large releases that Comments 5.T.3 and 5.T.1 report at the surface.

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4. The flow of brine up an intruded borehole was calculated separately in BRAGFLO_DBR. The results proved that the increased pressures in the repository from changing the selected parameters would result in higher and more incidents of releases to the surface. (1083)

Response to Comment 5.T.4:

The Agency agrees that under some circumstances, higher pressures in the repository would lead to greater direct brine releases. However, the repository's ability to meet the containment requirement when parameters are changed was tested in the performance assessment verification test required by EPA. Results of this test indicate that the WIPP still meets the containment requirements 40 CFR 191.13, even when parameters are changed in a conservative manner.

Issue U: 2D vs 3D BRAGFLO modeling

1. DOE's argument that additional brine will be consumed by corrosion cannot be defended based on the data. (38)

2. An increase in direct brine releases may not be problematic if solubilities like those in the CCA or PAVT were present; however, if solubilities were consistent with the presence of nesquehonite or with no backfill, the potential impact of increased brine releases is important. Therefore EPA should use 3D BRAGFLO to assess the validity of the 2D BRAGFLO results. (39)

3. The comment concerning brine inflow is concerned with the adequacy of 2D simulations as used in the DOE's application compared to 3D simulations. The comparison used in the screening on this in the application assumed that, as the comment points out, that brine is not consumed. These assumptions allow for brine consumption and to allow gas to interact with various brine saturations would lower brine saturation and improve the comparison between 2D, 3D simulations, and, therefore, improve the justification for the adequacy of the 2D simulations in the application. (498)

4. EEG's concerns in their December 31, 1997 letter to EPA over the adequacy of 2 dimensional calculations used in BRAGFLO are unfounded. . . EEG extrapolated an older FEP analysis inappropriately, and came to a misleading conclusion by not considering the details of the assumptions used in the original FEP analysis. (659)

5. The comment concerning brine inflow is concerned with the adequacy of 2D simulations as used in the DOE's application compared to 3D simulations. The comparison used in the screening on this in the application assumed that, as the comment points out, that brine is not consumed. These assumptions allow for brine consumption and to allow gas to interact with various brine saturations would lower brine saturation and improve the comparison between 2D, 3D simulations, and, therefore, improve the justification for the adequacy of the 2D simulations in the application. (667)

6. EEG recommends that several 3D BRAGFLO simulations of the repository should be performed using the parameter values of vectors used in the CCA performance assessment. The 3D BRAGFLO simulations should be used to provide repository conditions for the normal suite of direct brine release calculations. The calculations should also be assessed in terms of impact on spallings calculations. (687)

7. The following criteria may be used to select the CCA vectors for running the 3D simulations to bound the magnitude of the problem.

- ♦ [T]he simulations should be limited to parameter vectors that result in pressures above 12.7 MPa at some time during the 10,000 year time frame.
- ♦ Direct brine release calculations should be sensitive to increased brine saturations above the waste residual brine saturation. . .

- ♦ The potential for brine consumption by corrosion should be assessed. Vectors with both slow and fast corrosion rates that also meet the above two criteria should be run.

- ♦ If the first simulations indicate a large change in saturation, then assess whether the 3D BRAGFLO simulations indicate a much larger number of significant direct brine releases than those calculated in the CCA. Simulations using brine saturations on the order of 0.1 and 0.3 should be performed. (688)

8. Concerning the 2D BRAGFLO model of the repository. EPA states that the 2D model may overestimate gas saturation and underestimate brine saturation and that such result is conservative because it will predict higher gas pressures (CARD 23 at 116). EEG has pointed out, to the contrary, that the 2D BRAGFLO model misstates brine saturation in the repository at high pressures. EEG recommends that several 3D BRAGFLO runs be performed to compare with 2D results. (See Letter, Neill to Marcinowski, Dec. 31, 1997, at 3-4 and End. 2)(IV-D-12). We join in that recommendation. (1022)

9. [M]ore complex supplementary 3D calculations were performed in concert with EEG's recommendations made during discussions with EEG at a January 17, 1998 meeting (Vaughn, Bean, Schreiber and Dotson, 1998). These results collectively show that the 2D geometry used by BRAGFLO in the 1996 CCA performance assessment calculations is appropriate and does not result in an underestimate of direct release during human intrusion. In all cases investigated (10 simulations using 9 CCA realizations) the 2D simulations consistently predict either the same or larger repository pressure and brine saturation than their 3D counterparts. Both larger pressure and brine saturation in the repository at the time of intrusion would lead to larger releases. Thus, the 2D geometry results in a conservative estimate of the releases when compared to results from a 3D representation. (914)

10. [In its proposed decision EPA did not use:]

* 3D BRAGFLO modeling (see also IV-D-12); (1138)

11. The results of FEP S -1 screening analysis suggests that the two dimensional BRAGFLO model used in the CCA calculations may be misrepresenting repository performance at pressures above the anhydrite fracture pressure. . .The discrepancy between the 2D and 3D versions of BRAGFLO may have resulted in an underestimate of radionuclide releases to the surface. (686)

<u>Response to Comments 5.U.1 through 5.U.11:</u>

Concerns associated with these comments are related to an analysis performed by the commenter (Comments 5.U.6 and 5.U.7) and presented on December 10, 1997 during stakeholder meetings [Docket: A-93-02, IV-E-8, pp. 11, 12, and 17] in which the commenter raised the following issues:

- 3D BRAGFLO predicts larger brine inflow above the anhydrite fracturing pressure than 2D BRAGFLO;

- 3D BRAGFLO predicts greater brine saturations at high pressure than 2D BRAGFLO; and

- Greater repository saturations at high pressure may result in substantially greater direct brine release than calculated in the CCA.

The commenter's conclusions are primarily based on Figure 15 of FEP S1. [Docket: A-93-02, II-G-1*,* Appendix MASS, Attachment 4-1] This figure entitled, Cumulative Net Brine In and Outflow at Repository - Doubled Gas Generation Rate compares the results for a BRAGFLO 2D versus 3D simulation. This figure shows that there is a discrepancy in the brine inflow into the repository for the 2 and 3 dimensional simulations. The net inflow for the 3D simulation after 1,000 years is about 6 x 10^6 kg (about 5,000 m^3) and less than 0.5 x 10^6 kg (about 400 m^3) for the 2D simulation. This figure also shows that after the first thousand years the 2D and 3D results are similar.

The differences in the 2D vs. 3D results are largely caused by the occurrence of fracturing in the anhydrite marker beds. That is, although the 2-D simulation predicts fracturing in the anhydrite layers, the magnitude of the average porosity and permeability changes are different from those in the 3-D simulations (see Figure 16, FEP S1). Furthermore, fracturing for the 3-D simulations is spread over the 3-D geometry, whereas fracturing for the 2-D case occurs to the south and north only (p. 16, FEP S1). Therefore, any conditions that accentuate the occurrence of fracturing within the anhydrite marker beds will lead to discrepancies between the 2 and 3D analysis. Because of this, the Agency must assess how representative the conditions are that were used in the 2D/3D BRAGFLO simulations in comparison to the actual conditions expected at WIPP.

The first obvious inconsistency between the CCA simulations and the FEP analysis [Docket:A-93-02, Appendix MASS. Attachment 4-1] on which most of the comments are based is the actual gas generation rates that were used in the 2D/3D FEP comparison. Gas generation rates in the 2D/3D FEP simulations were fixed at 3200 mol/(drum/yr). This value was twice the expected rate of 1600 mol/(drum/yr) that was reported in Appendix PORSURF. [Docket: A-93-02 Volume XVI, Attachment 1, p. 9] These gas generation rates lead to pressures far higher than those observed in the CCA, namely 17.5 MPa and 16.5 MPa for the 2D/3D BRAGFLO simulations, respectively. These pressures, in turn, lead to more pronounced fracturing at earlier times. Therefore, one would expect that, under these conditions, there would be a certain amount of divergence between the 2D and 3D results.

As explained below, however, these results are not representative of the conditions modeled in the CCA PA (Comment 5.U.1 and 5.U.4). The BRAGFLO 2D/3D FEP comparison was a simplistic analysis intended merely to show whether use of BRAGFLO in two dimensions was acceptable. In the CCA simulations, however, pressures rarely exceed lithostatic pressure because gas generation rates are dependent on brine saturations, iron and cellulose inventories and the consumption of brine during corrosion reactions. For example, pressure induced fracturing occurs before 1000 years in only five realizations of the 300 vectors in the CCA undisturbed scenario. The BRAGFLO 2D/3D FEP comparison did not include any of these factors (Comment 5.U.5). A closer inspection of the Base Case scenario (i.e. the case where gas generation is set at 1600 mol/(drum/yr)) provided in the FEP analysis shows that it is more representative of the gas generation rates used in the CCA. [Docket: A-93-02, II-G Volume XI, Appendix PAR, Table PAR-10] Therefore, the pressures obtained in the Base Case FEP analysis would be most like the CCA simulations. In this example, Figure 10 of the FEP analysis indicates that brine inflow into the repository is actually higher in the two dimensional simulation.

An issue that the commenter raised, with respect to the brine inflow into the repository, is what would happen to the additional 10-15 m^3 /yr of brine that the 3-D simulation showed that could potentially enter the repository under unrealistic conditions. [Summary of US EPA/ORIA WIPP Certification Stakeholder Meetings, Meeting with EEG, December 10, 1997; Docket: A-93-02, IV-E-8, pp. 11-12] The commenter also noted that rarely did brine consumption in the entire repository exceed 10 m^3/yr. To address this issue, the factors that are controlling brine consumption need to be considered. The first and foremost factor is the amount of brine flowing into the repository, the second is the rate at which the brine is being consumed (i.e., gas generation rate) and the third factor is the amount of steel and cellulose in the repository.

With respect to the amount of steel and cellulose being consumed, Figure 2.2.9 in Helton's uncertainty and sensitivity analysis indicates that at least 20 percent of the original steel is still present in the waste panel for all but one of the CCA vectors at the end of 10,000 years. [Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification for the WIPP, Docket: A-93-02, II-G-7, p. 2-12] Thus, it can be concluded that brine consumption is limited by the brine availability and not by the substrate. Furthermore, Helton's analysis shows that the amount of gas generated by corrosion [*ibid*., Fig. 2.2.1, p.2-12], the amount of steel remaining in the repository [*ibid.,* Fig. 2.2.2, p. 2-12] and the amount of brine consumed by corrosion are all highly correlated. [*ibid*., Fig. 2.2.8, p.2-17] Therefore, it can be concluded that at least 20 percent more brine than is currently predicted in the CCA could flow into the repository without significantly affecting the direct brine releases. In most cases the additional brine could be significantly higher than 20 percent of what is currently predicted, because there is still at least 20 percent of the original steel in all but one of the CCA vectors at the end of 10,000 years that the brine could react with. Therefore, in response to the commenter's observation, any additional brine that flows into the repository will simply be consumed during the gas generation process (Comment 5.U.1). The reason that brine consumption in the entire repository rarely exceeds 10 m^3/yr is that, as noted above, BRAGFLO predicts that very little brine enters the repository. This is consistent with the conceptual model and field observations. [Sections 2.2.1.3 and 6.4.5 of the CCA, Docket:A-93-02, II-G-1, Vol. 1] If additional brine were to enter the repository, however, there is sufficient metal to allow the brine consumption/gas production reaction to take place at higher rates.

A related question is whether any additional brine could flow into the repository at rates that are faster than the gas generation rates and thereby increase the brine saturation in the repository. It is exactly for this reason that the gas generation rates are statistically sampled in the CCA over a broad enough range to capture the associated uncertainty and thereby incorporates the situation where brine inflow exceeds gas generation rates.

To more completely address concerns related to the geometry assumed in BRAGFLO, DOE performed a number of simulations that compared BRAGFLO2D and 3D results (Comment 5.U.8 and 5.U.9). [February 24, 1998 Letter from George Dials, DOE responses to EEG Issues on EPA's proposed decision to certify WIPP, Docket: A-93-02, IV-G-34, Attachment 1, February 25, 1998 memorandum] DOE's results show that the use of a two dimensional representation does not result in an underestimate of direct brine release during human intrusion. In all cases investigated (10 simulations using 9 CCA realizations), the 2D simulations consistently predict either the same or higher repository pressures and brine saturations than their 3D counterparts. Higher saturations and pressures in the repository at the time of intrusion would lead to larger releases. The Agency, therefore, agrees with DOE's conclusion that the 2D geometry results in conservative estimates of the releases as compared to those results from a three dimensional conceptualization (Comment 5.U.10). The Agency performed an independent review of DOE's analysis and found it to be technically sound. EPA also found that DOE's conclusions are adequately justified. EPA's review is documented in Section 4.4.5 of the Technical Support Document for Section 194.23: Models and Computer Codes [Docket: A-93-02, V-B-6]

In summary, EPA believes that the current two dimensional conceptualization for BRAGFLO is appropriate for the following reasons (Comments 5.U.2, 5.U.6, 5.U.7): 1) results of actual 2 and 3 dimensional model comparisons, 2) the 3-D/2-D BRAGFLO comparison exaggerated the differences in the amount of brine that would flow into the repository and is not representative of what is modeled in the CCA PA , 3) there is sufficient metal in the repository to react with any additional brine and 4) the selected gas generation range will account for the temporal aspects of gas generation and brine inflow. DOE has also prepared a number of arguments, with which the Agency concurs, for why three dimensional simulations are unnecessary. These are presented in Responses to EEG Issue Concerning Impact on Direct Release to 2D Repository Fluid Flow Modeling, P. Vaughn and J. Schreiber, January 15, 1998. [Docket: A-93-02, IV-G-7, Attachment 6]

Issue V: Documentation

1. On page 1-76 of III-B-6, the reference to Appendix A-12 is in error. (70)

Response to Comment 5.V.1:

EPA agrees with the commenter. The reference should be to p. Appendix A1-1 and Section 3 of EPA Technical Support Document for Section 194.24: EPA's Evaluation of DOE's Actinide Source-Term. [Docket: A-93-02, Item V-B-17] EPA has corrected this reference in its documentation.

2. Page 4-60 of III-B-6 states, “input data were chosen to produce the appropriate results consistent with the LEFM model.” Inputs to what model? (72)

Response to Comment 5.V.2:

Page 4-60 is referring to DOE’s interbed fracture model, which implements DOE’s Salado Interbeds Conceptual Model. This statement reflects DOE’s explanation for using specific input data, as found in the CCA [Docket: A-93-02, II-G-1], Volume XI, Appendix PAR, Table PAR-36.

Issue W: Incorporation of future states in modeling

1. DOE’s PA model does not even consider whether climate changes may affect the permeability of the Culebra. (143b)

2. In DOE’s performance assessment, however, the climate change model is implemented through the use of a single parameter, an increase in hydraulic conductivity in the Culebra dolomite, because EPA criteria erroneously allows DOE to do so. (877)

3. [F]ull-glacial conditions, cyclical or otherwise, have never been incorporated into DOE groundwater models. (878)

Response to Comments 5.W.1 and 5.W.3:

The comments appear to be concerned with the effect that higher precipitation rates could have on the ability of the Culebra to transmit water and radionuclides. Insofar as larger amounts of recharge to the Culebra, that is under saturated with respect to gypsum, will allow greater amounts of gypsum to be dissolved from the fractures within the Culebra. The potential effect on DOE’s Performance Assessment is that these dissolution processes would increase the transmissivity of the Culebra and allow greater volumes of radionuclides to be transported to the Land Withdrawal Boundary.

EPA agrees that DOE’s PA model does not address climate changes by changing the permeability of the Culebra dolomite. However, the Agency does not believe this is necessary in order to model the effects of climate changes. DOE addressed the effects of wetter climate conditions and the effect of previous dissolution of fracture in fillings in the Culebra on recharge rates and groundwater flow velocities in Corbet’s SECOFL3D analyses of the regional groundwater basin model. [Docket: A-93-02 Reference # 147] However, DOE’s modeling efforts in SECOFL3D did not explicitly consider the potential increase in the dissolution of the fracture in fillings in the Culebra as a result of the introduction of groundwater that is less saturated with respect to gypsum and its impact upon permeability of the Culebra.

In a letter dated January 24, 1997 [Docket: A-93-02, Item II-I-03, Enclosure 2], DOE provided additional information at EPA’s request [Docket: A-93-02, Item II-I-01] regarding the transmissivity[26] uncertainty resulting from potential fracture infilling dissolution. Specifically, documentation supporting DOE's analysis was contained in a Sandia National Laboratories memorandum included in DOE's response, dated January 16, 1997. [Corbet et al., Docket: A-93-02, Item II-I-03, Enclosure 2] Corbet and Knupp's SECOFL3D analysis of the regional groundwater basin model provided additional documentation.

The Corbet et al. memorandum states that it is "not possible, at this time, to absolutely rule out some change to the hydraulic properties of the Culebra over the next 10,000 years," and also acknowledged that dissolution has taken place in the Culebra's fracture in fillings. It concluded, however, "For any climate scenario, it is likely that groundwater is saturated with respect to gypsum before it reaches the Culebra and will not dissolve additional gypsum from the Culebra." Corbet et al. also stated, "Although flow in the Culebra responds rapidly to changes in recharge at the water table, perhaps in hundreds of years, recharge takes tens of thousands of years to reach the Culebra." Thus, DOE found that it was not necessary to model the Culebra with higher transmissivities to account for the potential for fracture infilling dissolution due to increases precipitation. Accordingly, DOE only modeled a range of transmissivities that were measured in situ in the Culebra.

DOE did not model the effects of full glaciation near the WIPP site, as suggested in comment 878. DOE reasoned that glaciers did not extend to the Delaware Basin during the last ice age, and therefore, it was unlikely that they would extend to the vicinity of the WIPP during the next 10,000 years. However, DOE's approach does model wetter climate conditions using a range of precipitation up to 2.25 times the current rainfall (CCA at p. 6-166; Docket: A-93-02, Item II-G-1, Vol. 1). More precipitation would be expected in a cooler climate, such as under full glacial conditions. DOE's groundwater modeling assumes that precipitation will not exceed its values during the current geologic era, the Holocene, which encompasses 10,000 years (CCA at pp. 6-167 and 6-168; Docket: A-93-02, Item II-G-1, Vol. 1). EPA finds that this approach to modeling climate change is appropriate because it considers conditions during the past 10,000 years of geologic history as a surrogate for possible variations during the next 10,000 years. EPA also finds DOE's modeling to be somewhat conservative because it assumes that precipitation will be at its current level or greater in the future (CCA at pp. 6-165 through 6-168; Docket: A-93-02, Item II-G-1, Vol. 1).

Since DOE's arguments are somewhat qualitative in nature, EPA also relied upon more quantitative aspects of the CCA to make a determination of whether the uncertainties associated with potential dissolution of the Culebra had been adequately captured by DOE's Performance Assessment. This included the following: 1) other Culebra parameters were statistically sampled in the CCA that would have the same effect on radionuclide transport as an increase in permeability 2) DOE made adjustments to the transmissivities in the Culebra to account for the potential effects of mining subsidence; and 3) results of the CCA indicate that the releases associated with radionuclide transport through the Culebra are relatively insignificant when compared to those related to spallings.

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[25] Transmissivity is equal to the permeability multiplied by the aquifer thickness.

In addition to hydraulic conductivity, the parameters that will have the greatest impact on radionuclide transport through the Culebra are the advective porosity, matrix half block lengths, hydraulic gradients and distribution coefficients. The advective porosity is sampled over two orders of magnitude [CCA, Docket:A-93-02, II-G-1, Appendix PAR, p. PAR-155], the matrix half block lengths are sampled over one order of magnitude [*ibid.*, PAR-152], the matrix distribution coefficients are sampled over one to four orders of magnitude depending on the radionuclide [*ibid.*, pp. PAR161 - PAR178] and the Climate Index is used to adjust the hydraulic boundaries up to a factor of 2.25. [*ibid.*, PAR-150] EPA's position is that the range of uncertainty placed on all of the above parameters is sufficient to capture uncertainties associated with potential dissolution within the Culebra due to climate change. Furthermore, the climate index places an artificially steep hydraulic gradient on the system that leads to faster radionuclide transport velocities, because, in actuality, if the hydraulic conductivities were raised, then the hydraulic gradient would decrease.

The subsidence due to potash mining scenario in the CCA [Docket: A-93-02, II-G-I, p. 6-136], which involved raising the permeabilities of the Culebra by a factor of 1 to 1,000, provides the closest analog to what the effects would be if dissolution in the Culebra had been considered and incorporated through changes in permeability. The results from DOE's uncertainty analysis on subsidence due to mining indicate that travel times of radionuclides to the Land Withdrawal Boundary would be increased due to the directional change in hydraulic gradients. [Docket:A-93-02, II-G-11, p. AP-019] These results, however, do not indicate that if dissolution occurred in the Culebra, it would lead to slower velocities of radionuclide transport. The results merely make the point that there is significant uncertainty associated with where the dissolution would occur, as well as the effects it would have on the modeling results. EPA, therefore, believes that DOE's uncertainty analysis on subsidence due to mining was also appropriate for capturing the uncertainty related to dissolution in the Culebra due to climate change.

EPA's decision not to require additional modeling of climate change effects upon Culebra permeability was also based on the overall contribution that the Culebra transport pathway contributed to the combined complementary distribution function (CCDF) used to display the results of PA. As shown in Supplemental Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison with the Compliance Certification Application Calculations, p. 7-5 [Docket: A-93-02, II-G-28], the contribution to the CCDF that was made by radionuclide transport through the Culebra was dwarfed by the contribution made by spallings. EPA believes that it is highly improbable that this relationship would be significantly changed if dissolution of the Culebra had been explicitly modeled in the CCA. Because of the results of DOE's uncertainty analysis and its consideration of factors that change Culebra permeability, EPA believes that additional analysis of this subject is unwarranted.

Issue X: Miscellaneous modeling issues

1. There are a number of processes that will act to limit releases which were not included in the calculations. Principal among these are controls imposed by the drilling operator, and the inherently massive nature of the waste itself. As a builder of models, I can assure you that these are very difficult processes to capture in a computer code, and that is the only reason they are not

included in the models used to date. As an engineer, I can also assure you that these processes will mitigate releases to the surface. (179)

2. We are talking about models, computer models and the assumptions that they go into it. Everyone knows they are not perfect. Furthermore, when you know there are erroneous assumptions built in and we cannot afford to accept the models and the assumptions that go into it given the incredibly serious consequences of the likely errors that were, in fact, the many known and unknown errors that are found in that model and in the assumptions to that model. (344)

3. While feasible, extending PA calculations beyond 10,000 years is not necessary to demonstrate compliance with Federal regulations 40 CFR part 191 and 40 CFR part 194, which is the purpose of the CCA. (929)

4. Overall, in the CCA many statements concerning the need, or not, to represent processes in the analyses are not sufficiently supported, e.g., by site-specific and experimental evidence, reasoned arguments and references to natural analogues. (1063)

Response to Comments 5.X.1 through 5.X.4:

In promulgating the Compliance criteria, EPA recognized that conceptual models are subject to uncertainty. [61 FR 5234-35] Therefore, EPA required DOE to subject all conceptual models to peer review for validation. [40 CFR 194.27(a)(1)] The purpose of this requirement was to "enrich DOE's process of selecting and developing conceptual models with a broad spectrum of scientific viewpoints." [61 FR 5228] DOE met these requirements by subjecting all applicable conceptual models to peer review. [CARD 23, Models and Computer Codes, section 7, requirement Section 194.23 (a)(3)(v) at 23-39 - 23-46, Docket: A-93-02, V-B-2] EPA evaluated each of the findings of the Conceptual Models Peer Review panel, and determined that DOE's conceptual models were appropriate for use in performance assessment. Therefore, EPA believes that the assumptions and approach to modeling for the CCA PA are appropriate. In 40 CFR Part 191 and 40 CFR Part 194, the Agency specifies that the PA be conducted over a 10,000 year time frame; EPA agrees that it is not necessary to look at a longer time period (Comment 5.X.3). EPA does not concur that the conceptual models had "erroneous assumptions built in." Moreover, without specific examples of deficiencies in the conceptual models, the Agency cannot further address the commenter's general statement about errors in the models and their assumptions (Comment 5.X.2 and 5.X.4).

EPA concedes that, during its initial review of DOE's conceptual models, the Agency identified many concerns about specific aspects of the modeling, particularly the conceptual models for spallings and chemical conditions and specific parameters used in modeling. The Conceptual Models Peer Review Panel eventually found all the models except the spallings model to be adequate for use in PA. The Peer Review Panel also concluded that the results calculated by the spalling conceptual model are "reasonable" for use in the PA, and in fact overestimate the actual waste volumes that would be expected to be released by the spallings process Comment 5.X.1. [Docket: A-93-02, Item II-G-22] EPA evaluated these findings by the Peer Review Panel and concluded that they were correct. [CARD 23, Models and Computer Codes, Sections 194.23(a)(1) and (3)(v), Sections 1 and 7, pp. 23-13 and 23-44; and Section 7 of the Technical Support Document for Section 194.23: Models and Codes, Docket: A-93-02, Items V-B-2 and V-B-6]

In addition, the Agency extensively reviewed the parameter values used in modeling. [Section 194.23(c)(4), Section 12 of CARD 23, Models and Computer Codes, pp. 23-62 through 23-69 and the Technical Support Documents for Section 194.23: Parameter Report, Sensitivity Analysis Report and Parameter Justification Report, Docket: A-93-02, Items V-B-2, V-B-12, V-B-13 and V-B-14] EPA required DOE to: improve records in the SNL Record Center; adequately provide a detailed listing of the code input parameters; list input parameters sampled; provide a description of parameters and the codes in which they are used; discuss parameter correlations and parameters important to releases; describe data collection procedures, sources of data, data reduction and analysis; and describe code input parameter development and an explanation of quality assurance activities. DOE provided all this additional information. In addition, EPA required DOE to use revised parameter values for the parameters having the largest potential impact on results of PA and perform the Performance Assessment Verification Test (PAVT) with these revised values.

The Agency believes that the results of the Performance Assessment Verification Test indicate that the CCA PA modeling shows the WIPP complies with the containment requirements of 40 CFR 191.13, even when substantial conservative changes are made to the major parameters used in modeling. EPA found the CCA, DOE's additional documentation, and the Agency's own analyses to be sufficient to support representing processes in the Department's analyses precisely because the additional information was based upon information such as modeling results, experimental results, and references to analogues (Comment 5.X.4). EPA believes that the models and the assumptions going into them are acceptable for determining compliance.

Section 6 Waste Characterization -- Section 194.24

Issue A: How is the waste characterized?

1. EPA did not use real waste characterization inventory and repository limit information. (232)

2. Because this material has been stored for so many years, nobody knows exactly what is contained in some of those containers. They may know --they may know 80 percent of them, but what happens to the other 20 percent. We don't know. You don't know what reaction of those chemicals, what happens when those chemicals come together, they form gases. (238)

3. Most of the waste placed at WIPP have not been characterized and EPA cannot know if releases might occur. (269)

4. EPA, if there's anything that they have stuck to their guns on, it's been the waste characterization problem. You've got all this super high pressure stuff being mixed together down there and you guys have consistently insisted at the DOE's objections that you've got to sort that stuff more carefully. You've got to keep particular types of toxic chemicals, hazardous wastes and things that could react severely, away from each other and I'm just asking you to stick to your guns on that. (317)

5. Without knowing the specific characteristics of the waste drums that will be placed into WIPP, the EPA cannot know if the existing waste conforms to the waste streams that are assumed in the Compliance Certification Application submitted by the DOE. Neither the DOE nor the EPA know the characteristics of the waste that is to still be generated which constitutes the majority of the waste that is proposed to go into WIPP. With this lack of information, it is absurd o say that safety of WIPP can be guaranteed. (326)

6. Questions that we've been asking since I began to study the WIPP project eight years ago like what's the characteristics of the waste. Because we know at least since 1991, when the EEG found evidence that there is an enormous amount of explosivity to a lot of the waste in the cans, because we have evidence that some of the cans have actually exploded. (347)

7. Another thing is that if you don't know what's in the drums at the generation site, I don't see how any of your calculations can be relied upon what our exposure will be through transportation of the waste. (358)

8. In the TSD, EPA notes that DOE's records are incomplete, particularly for older waste. EPA also notes that when, and this is a quote, the information regarding physical nature is incomplete or inaccurate, these limitations, that is on the accuracy of the waste characterization process, may be considerable. Failure to require accurate characterization of the individual drums is serious and could result in failure to comply with the WIPP limitations which the Department of Transportation and Regulations and the WIPP Land Withdrawal Act parameters. Yet EPA's evaluation of the technical knowledge, personnel and procedure fail to impose specific limitations on DOE's quality of acceptable knowledge documentation use for a specific waste stream. (502)

9. EPA needs to label the waste with its specific characteristics: What radionuclides are in the drums, the qualities and forms: What other liquids, flammables, corrosive chemicals are there

before they put them into drums to travel to WIPP. Neither EPA or DOE knows exactly what is in the drums and their calculations of the same characteristics cannot suffice New Mexican citizens. (521)

10. Your permitting WIPP to open without full knowledge of the contents to be stored there. How can you know what to expect without knowing what the characteristics of the waste are? (557)

11. You don't know what they are going to put in there, they don't know what they are going to put in there. The waste is now --early on we found out it wasn't all radioactivity. There's a lot of very serious other types of environmental hazardous waste mixed in with it. They don't really know what they've got. (578)

12. What are the characteristics of the waste, how will this be tested and monitored? How is it known that the specific waste can be safely stored in canisters and place at the WIPP site without corrosion and release of radioactive? (585)

13. If you do decide to go ahead and authorize the opening, I would like you to maintain the most stringent requirements, including the examination of what's in the barrels, the characterization of what's in the barrels. (629)

14. For many of the drums there is no information on exactly what substances they contain. (824)

15. What specifically will be in the drums destined for WIPP burial? Does DOE or EPA know? (830)

16. They say they don't need to know what is in the drums now because they will characterize the drums before they are shipped. Yet their characterization process also has many unknowns and is yet another new technological process which has never been used on this scale before. Much of it relies on process knowledge (so-called acceptable knowledge) which in itself has too many unknowns. (899)

<u>Response to Comments 6.A.1 through 6.A.16:</u>

Section 194.24 begins by requiring DOE to describe all the waste to be sent to the WIPP. This description of the waste must include the waste components (e.g., metal waste containers, plastic material) and their approximate quantities in the waste. This information was included in the Baseline Inventory Report (BIR). Waste limits based on the BIR were used in the performance assessment (PA) to identify and assess waste properties that affect disposal system performance. The waste to be shipped to WIPP must meet these waste component limits. The methods to quantify the waste component limits must also be identified. [CARD 24, Sections 24.A, B, C, and D; TSD V-B-15; CCA, Section 4.0]

At this point, Section 194.24 shifts from overall waste inventory information and limits to focus on the waste generator sites. First, DOE must show that the acceptable knowledge (AK) used to quantify the waste components at generator sites will conform with quality assurance (QA) requirements of Section 194.22. Then, to ensure that the generator sites ship only waste that conforms with the waste component limits, a system of controls must be implemented that tracks and measures the waste components destined for the WIPP. This system of controls must also comply with the QA requirements of Section 194.22. [CARD 24, Sections E, F, G, H, and I; TSD, V-B-15; CCA, Section 4.0]

The approval process for site-specific waste characterization controls and QA programs includes a Federal Register notice, public comment period, and on-site EPA audits or inspections to evaluate implementation. [Condition 2, Condition 3, and 40 CFR 194.8] Prior to an EPA audit or inspection, EPA expects to receive from DOE certain documents. To determine that the procedures used to characterize waste (e.g., measuring and testing, sample control, equipment assessments) are based on good technical practices, and the personnel are qualified to perform the task, EPA expects to receive the following general types of documents which conform with the requirements of Section 194.22: Site-Specific Quality Assurance Program Plan (QAPP) and a report or reports from CAO's QA organization that verifies the establishment and implementation of the Nuclear Quality Assurance requirements identified in Section 194.22 (document titles may vary from site to site). [CARD 22, Section 22.A; Audit of CAO QAPD, Docket: A-93-02, Item II-A-43; CCA, Appendix QAPD]

Likewise, EPA will examine detailed technical documents during an audit or inspection to verify the methods for quantifying and tracking waste. Such technical documents may include information on the two main components of waste characterization (AK and measurement methods). The first is measurement equipment such as Non-Destructive Assay (NDA), Non-Destructive Examination (NDE), and Visual Examination (VE). The second major component is the AK package. The AK package typically includes information on the areas and buildings from which the waste stream was generated, the waste stream volume and time period of generation, the waste generating process described for each building, the process flow diagrams, and the material inputs or other information that identifies the chemical and radionuclide content of the waste stream and the physical waste form. In addition, the following supplemental information may also be provided for AK records: process design documents, standard operating procedures, preliminary and final safety analysis reports and technical safety requirements, waste packaging logs, site databases, information from site personnel, standard industry information, previous analytical data relevant to the waste stream, material safety data sheets or other packaging information, sampling and analysis data from comparable or surrogate waste streams, and laboratory notebooks that detail the research processes and raw materials used in experiments. [CARD 24, Section 24.G; CCA, Section 4.4.1.1]

The fundamental objective of EPA's review of DOE's waste characterization at waste generator sites is to assure that the proposed system of controls can quantify and track both the radionuclides and the four waste component limits important for the repository performance. Because DOE's defense missions varied at the sites, the waste generated and the methods to characterize waste vary accordingly. These variations in practices and methods result in the need to review two general areas: (1) AK packages and (2) the system of controls, including measurement methods and tracking procedures. Therefore, EPA finds that it is important to clarify what is entailed by both general areas.

Thirty-five percent of WIPP waste is currently classified as "retrievably stored waste," which is TRU waste generated after the 1970's but before the implementation of the TRU Waste Characterization QAPP. Retrievably stored waste containers will be classified into waste streams using acceptable knowledge[27]. All retrievably stored waste containers will be examined using radiography or visual examination to confirm the physical waste form (or "Summary Category Group"), to verify the absence of prohibited items, and to determine the waste characterization techniques to be used. To confirm the results of radiography, a statistically selected number of the Contact-Handled Transuranic waste container population will be visually examined by opening the containers to inspect waste contents to verify the radiography results. Representativeness of containers selected for visual examination will be validated by reviewing documents that show that true random samples were collected. Repackaged retrievably stored waste may be handled as newly generated waste, with the Summary Category Group confirmed by using visual examination instead of radiography. Retrievably stored waste will be assayed using NDA[28], and will undergo headspace-gas sampling and analysis for volatile organic compound concentrations[29]. [CARD 24, Section 24.F; TSD V-B-15; CCA, Section 4.4.1.2]

Acceptable knowledge, NDA, radiography (with confirmatory visual examination as discussed above), and headspace-gas sampling and analysis are used to characterize homogeneous solids and soils/gravel wastes. In addition, a statistically selected portion of homogeneous solids and soils/gravel wastes will be sampled and analyzed for total volatile organic compounds, semi-volatile organic compounds and metals. Container representations selected for sampling and analysis will be validated by reviewing documents that show that true random samples were collected.

Acceptable knowledge, NDA, radiography (with confirmatory visual examination as discussed above), and headspace-gas sampling and analysis are used to characterize legacy debris waste.

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27 AK is used by DOE to (1) delineate waste streams to facilitate further characterization; (2) identify radionuclide content as a basis for further radioassay (NDA) determinations, and identify the combustible and metal content to determine the radionuclide content as a basis for radiography and/or visual examination (NDE/VE); and (3) make hazardous waste determinations for RCRA-listed wastes.

28 All waste containers will undergo NDA techniques to allow an item to be tested without altering its physical or chemical form. NDA techniques approved for use on WIPP waste containers can be classified as active or passive. Passive NDA methods measure spontaneously emitted radiations produced by radioactive decay of the radionuclides inside the waste container. Active NDA methods measure radiation produced by artificially generated reactions in waste material.

29 All waste containers are sampled and analyzed for volatile organic compounds in the headspace gas. A statistically selected portion of homogeneous solids and soil/gravel is sampled and analyzed for Resource Conservation and Recovery Act (RCRA)-regulated volatile organic compounds, semi-volatile organic compounds and metals. Results of headspace gas and chemical analyses are compared with acceptable knowledge determinations to assess the accuracy of acceptable knowledge.

Sixty-five percent of all WIPP waste is to-be-generated TRU waste. To-be-generated waste characterization will begin with verification that processes generating the waste have operated within established written procedures. Waste containers will be classified into waste streams using acceptable knowledge.

Verifying that the physical form of the waste (Summary Category Group) corresponds to the physical form of the assigned waste stream is accomplished by visual examination during packaging of the waste into the drums. This process consists of operator confirmation that the waste is assigned to a waste stream that has the correct Summary Category Group for the waste being packaged into the drums. If confirmation cannot be made, corrective actions will be taken. A second operator, who is equally trained to the requirements of the Waste Acceptance Criteria (WAC) and TRU Waste QAPP, will provide additional verification by reviewing the contents of the waste container to ensure correct reporting. If the second operator cannot provide concurrence, corrective actions will be taken. To-be-generated waste will not undergo radiography, as the waste will be identified by visual examination during packaging. All to-be-generated waste containers will undergo headspace-gas analysis for volatile organic compound and their concentrations, and NDA for radioisotopes and their activities.

Acceptable knowledge, visual examination during packing, NDA and headspace-gas sampling and analysis are used to further characterize homogeneous solids, soils/gravel, and legacy debris waste. In addition, newly generated streams of such wastes will be randomly sampled a minimum of once per year and analyzed for total volatile and semi-volatile organic compounds and metals.

The system of controls for WIPP waste has two phases for DOE's internal process. Phase I entails Waste Stream Screening and Verification, which will occur before waste is shipped to the WIPP, and is a three-step process. First, an initial audit of the site will be conducted by DOE's Carlsbad Area Office as part its audit program before the WIPP could begin the process of accepting waste from a site. The audit provides on-site verification of characterization procedures, data package preparation and recordkeeping. Second, the generator site personnel perform the waste characterization data package completeness/accuracy review and either accept or reject the data. Third, if the data is accepted, the site waste characterization data is transferred manually or electronically via the WIPP Waste Information System (WWIS) to the WIPP. At the WIPP, screening includes verification that all of the required elements of a waste characterization data package are present and that the data meet acceptance criteria required for compliance. Waste stream approval or rejection to ship to the WIPP is the outcome of Phase I.

Phase II includes examination of a waste shipment after it has arrived at the WIPP, and is a three-step process. First, upon receipt of a waste shipment, the WIPP personnel determine manifest completeness and sign the manifest before the driver may depart. Second, WIPP personnel determine waste shipment completeness by checking the bar-coded identification number found on each TRU waste container. The bar-coded identification number is noted and checked against the WWIS. The WWIS maintains waste container receipt and emplacement information. Third, waste shipment irregularities/discrepancies are identified and resolved. If there are discrepancies, the generator is contacted for resolution. Finally, WIPP personnel compare the container identification number with a list of those approved for disposal at the WIPP. Waste shipment approval or rejection for disposal at the WIPP is the outcome of Phase II. [CARD 24, Section 24.H.2]

In summary, all waste sent to WIPP will be appropriately and thoroughly characterized. First, the acceptable knowledge provides essential waste content information that later determines the waste categories. The AK process undergoes quality assurance checks to confirm good technical practices and qualified personnel. Then, the measurement techniques (NDA, NDE, VE) confirm the AK data, and further define the content and limits of the waste. Further confirmation of the accuracy of the waste characterization is provided by the extensive tracking system. Again, quality assurance checks are applied to the tracking and measurement controls. The waste characterization process, if implemented accordingly, provides complete and thorough characterization of the waste. DOE has committed to implementing this process. No generator site will be allowed to ship waste to the WIPP until the waste characterization process detailed above is met at every generator site for every waste stream(s) proposed.

Issue B: Problems with acceptable knowledge

1. Identification of radioisotope curie content and volume is dependent on what EPA calls "acceptable knowledge" (AK) and what DOE calls "process knowledge." Both terms refer to the ability of the waste certification team to ascertain the physical nature of the content of the drums being assayed using a review of records and institutional knowledge about what process produced the waste in the drum. . . In the TSD, EPA notes that DOE records are incomplete, particularly for older waste. EPA also notes that "[w]hen information regarding the physical nature is incomplete or inadequate, these limitations [on the accuracy of the waste characterization process] may be considerable." TSD Attachment 2, 3-6. Failure to require accurate characterization of the individual drums is serious and could result in failure to comply with the WIPP WAC limitations, Department of Transportation regulations, and the WIPP Land Withdrawal Act parameters. (1215)

2. AK documentation is suspect prior to LANL's adoption of the 1991 Waste Profile forms. Without the documentation required by these forms, waste generation information reverts to the same uncertain guesstimates that produced the year to year wildly varying site assessments of total volume and curie content that DOE used as the basis for its Performance Assessment calculations. (1216)

Response to Comments 6.B.1 and 6.B.2:

Prior to 40 CFR Part 194, waste characterization at DOE facilities was not emphasized. DOE indicates in Appendix WAP that AK is used to delineate waste streams to facilitate further characterization, to make hazardous waste determinations for debris waste, and to determine if homogeneous solids and soil/gravel are hazardous wastes. [CCA, Appendix WAP, p. C-21] With respect to Part 191/194 requirements, AK will be used to determine the radionuclide content as a basis for radioassay, and the combustible and metal content will be used to determine the radionuclide content as a basis for radiography and/or visual examination. All acceptable knowledge records must include the following information for each waste stream:

- Areas and buildings from which the waste stream was generated;
- Waste stream volume and time period of generation;
- Waste generating process described for each building;
- Process flow diagrams; and
- Material inputs or other information that identifies the chemical and radionuclide content of the waste stream and the physical waste form. [CCA, Appendix WAP, pp. C-3 through C-5]

In addition the following supplemental information may also be provided for AK records:

- Process design documents;
- Standard Operating Procedures;
- Preliminary and final safety analysis reports and technical safety requirements;
- Waste packaging logs;
- Site databases;
- Information from site personnel;
- Standard industry information;
- Previous analytical data relevant to the waste stream;
- Material Safety Data Sheets or other packaging information;
- Sampling and analysis data from comparable or surrogate waste streams; and

- Laboratory notebooks that detail the research processes and raw materials used in experiments.

If the acceptable knowledge mandatory information is not available for a given waste stream, that waste stream cannot be shipped to WIPP on the basis of AK alone. Sites may submit additional sampling and analytical data to provide the required waste characterization data. [CCA, Appendix WAP, p. C-3] Each site is required to prepare written procedures outlining the specific methodology used to assemble AK records, including document origination, how documents will be used, and any limitations associated with the information. [CCA, Appendix WAP, p. C-7] The generator sites must also develop procedures that describe how AK is evaluated and how discrepancies in the documentation are resolved. [CCA, Appendix WAP, p. C-8] All AK information is confirmed; each generator site must establish procedures for re-evaluating AK if radiography or visual examination results in the assignment of a new waste category. The generator site procedures must describe how waste is reassigned, AK re-evaluated, and appropriate characterization codes assigned. [CCA, Appendix WAP, p. C-9] EPA finds that DOE's AK process is well documented and sufficiently rigorous to provide the basis upon which more detailed characterization will be made.

DOE provided extensive information pertaining to the waste characterization process, including that in Appendix WAP of the CCA [Docket: A- 93-02, II-G-01], the QAPP [Docket: A- 93-02, II-G-01, Ref No. 210] and Methods Manual. [Docket: A- 93-02, II-G-01, Ref. No. 210] EPA has examined this information and has participated in site audits wherein the waste characterization process was observed and evaluated in detail. [Docket: A- 93-02, V-B-15] EPA determined that all waste containers will be subject to physical form and waste material parameter characterization, beginning with AK, continuing through confirmatory radiography and non-destructive assay.

Issue C: Acceptable knowledge problems at Los Alamos National Laboratory

1. What specific steps did EPA take to certify the waste stream at LANL given the "acceptable knowledge problem" cited in EPA correspondence to DOE in August? (3)

2. DOE still doesn't know what radionuclides are in the waste, knowledge that is crucial in calculating the releases. You left it at extrapolations and assumptions about the waste in the CCA. Supposedly this be taken care of when individual drums are characterized before transport. The characterization process is barely working at Los Alamos, and it's based way too much on process knowledge. (416)

Response to Comments 6.C.1 and 6.C.2:

To certify the Los Alamos National Laboratory (LANL) legacy debris waste stream, EPA reviewed all of LANL's quality procedures and detailed technical procedures related to the characterization and quality assurance activities associated with LANL's Transuranic Waste Characterization and Certification Program, which included LANL's AK procedure. [TWCP-QP-1.1-021, R.2] As part of this review process, EPA also attended three waste certification audits conducted by the Carlsbad Area Office (CAO). EPA documented its observations of the three audits in the following documents: "Technical Support for Evaluating DOE's WIPP Waste Characterization Program: Inspection Report, Los Alamos National Laboratory, Waste Characterization Certification Audit," May 12-16, 1997; [Docket: A-93-02, Item V-B-15] "Inspection Report for Los Alamos National Laboratory, Waste Characterization Certification Follow-up Audit," August 18-22, 1997 [Docket: A-93-02, Item V-B-15]; and "Inspection Report for Los Alamos National Laboratory, Waste Characterization Certification Follow-up Audit," September 10-12, 1997. [Docket: A-93-02, Item V-B-15] During the first waste certification audit conducted on May 12 through 16, 1997, EPA observed CAO's auditing of the following quality assurance project description (QAPD) elements:

- ♦ Organization
- ♦ QA Program Implementation
- ♦ Personnel Qualification and Training
- ♦ Quality Improvement
- ♦ Documents and Records
- ♦ Work Processes
- ♦ Procurement
- ♦ Inspection and Testing
- ♦ Measuring and Test Equipment
- ♦ Assessments
- ♦ Sample Control
- ♦ Data Documentation, Control, and Validation
- ♦ Software Requirements.

EPA also observed CAO's auditing of the following Waste Characterization QAPP technical elements:

- ♦ Acceptable Knowledge
- ♦ Sampling Process Design

- Sampling-Headspace Gas
- Testing - non-destructive assay (NDA) and real-time radiography (RTR)
- Visual Examination
- Analysis - Headspace Gas
- Data Validation, Usability, and Reporting
- Performance Demonstration Program (PDP).

For a complete description of EPA's audit observations, see "Technical Support for Evaluating DOE's WIPP Waste Characterization Program: Inspection Report, Los Alamos National Laboratory, Waste Characterization Certification Audit," May 12-16, 1997. [Docket: A-93-02, Item V-B-15]

The two follow-up audits, on August 18-22, and September 10-12, 1997, respectively, were much more limited in scope than the initial waste characterization certification audit of May 1997. The August 1997 follow-up audit focused on the waste characterization issues identified during the May 1997 audit (i.e., NDA, AK, waste container tracking, software quality assurance, miscertification rates, and random selection) as well as the waste stream profile data and the manual data entry and transmission of LANL waste characterization data to the WIPP site via the WWIS. [Docket: A-93-02, Item V-B-15] The September 1997 follow-up audit focused on three waste characterization issues identified during the August 1997 follow-up audit (i.e., NDA AK, and the WWIS). [Docket: A-93-02, Item V-B-15]

In regard to the commenter's specific concern regarding the "acceptable knowledge problem," EPA notes that during the May 1997 audit, EPA observed that the CAO auditors found that LANLs AK for radionuclide distribution was not adequate to support passive-active neutron (PAN) assay. EPA further observed that the CAO auditors found that although sealed containers larger than four liters are prohibited waste items (in accordance with the QAPP and LANL's Certification Plan), AK personnel do not check for this prohibited item. [Technical Support for Evaluating DOE's WIPP Waste Characterization Program: Inspection Report, Los Alamos National Laboratory, Waste Characterization Certification Audit," May 12-16, 1997, Docket: A-93-02, Item V-B-15] In response to these issues, LANL added the gamma technique, Fixed Energy Response Function Analysis with Multiple Efficiencies (FRAM) Assay, to its procedures to support the PAN assay AK, and revised the AK procedures and checklists to include a step to ensure that AK personnel check for sealed containers larger than four liters.

During the August 1997 follow-up audit, EPA observed that the CAO auditors found that AK pertaining to radionuclide distribution was still lacking despite the addition of the gamma assay using the FRAM. [Inspection Report for Los Alamos National Laboratory, Waste Characterization Certification Follow-up Audit, August 18-22, 1997, Docket: A-93-02, Item V-B-15] For example, AK documentation listed neptunium (Np) as a potential radionuclide. This radionuclide was never presented in the AK summary report, and the FRAM did not identify the Np. Also, the CAO auditors reviewed the revised procedure including the checklist and AK summary report. Both the procedure and checklist were found to include a provision for the AK personnel to check for sealed containers larger than four liters, and the AK summary report provided objective evidence that the procedure and checklist were being implemented properly. [Inspection Report for Los Alamos National Laboratory, Waste Characterization Certification Follow-up Audit, August 18-22, 1997, Docket: A-93-02, Item V-B-15]

During the September 1997 follow-up audit, EPA observed that the CAO auditors found that AK pertaining to radionuclide distribution was properly presented in the AK summary report, and the FRAM identified the Np. [Inspection Report for Los Alamos National Laboratory, Waste Characterization Certification Follow-up Audit, September 10-12, 1997, Docket: A-93-02, Item V-B-15]

EPA notes that after the September 1997 follow-up audit, all Corrective Action Responses and observations from May 1997 and August 1997, audits were verified as closed and corrected. [Inspection Report for Los Alamos National Laboratory, Waste Characterization Certification Follow-up Audit, September 10-12, 1997, Docket: A-93-02, Item V-B-15] CAO rated the adequacy of LANL's program as satisfactory, implementation of its program as satisfactory, and the effectiveness of LANL's program as satisfactory. EPA, based on both its participation in the three waste certification audits and its review of LANL's quality procedures and detailed technical procedures concluded that LANL's process for characterizing legacy debris waste was satisfactory as it complies with all of the 40 CFR 194.24 requirements for waste characterization and quality assurance.

Issue D: Problems with measurement methods (Non-Destructive Assay, Non-Destructive Examination, Visual Examination)

1. Contrary to CARD 24 (p.24-8), RTR cannot identify the liquid content of waste in barrels to be transported to the WIPP. (6)

2. Another gray area exists around the actual contents of waste drums. Even though DOE x-rays drums to figure out what's inside, liquids cannot always be detected by this method. And at least one drum that was accepted by the Waste Acceptance Criteria contained in a full can of flammable liquid. In fact, 80 drums that the DOE had certified as fitting the Waste Acceptance Criteria for shipment to WIPP, 58 percent were found to be miscertified. (539)

3. The National Transuranic Program, which is part of the DOE based here in Carlsbad, works directly with the DOE sites where the waste is stored to make sure our requirements are met before the waste is shipped. Each container is put through a battery of requirements and tests before being certified for shipment and disposal. . . First we accurately measure the radioactivity in every container of the waste, and we use a technique called radioassay. . . Every container of stored waste will be radiographed before shipment to verify its physical form and to make doubly sure

that none of the prohibited items I discussed earlier are present. In addition, a limited number of these containers will also be opened and visually examined to verify the accuracy of the radiography. . . Finally, all the waste will be sampled before it's sent to WIPP for the presence of flammable or toxic gases. . . So I urge the EPA to carefully review the DOE's waste characterization program. I am confident when you do so, you will agree with me that it is entirely adequate to the task. (214)

4. EPA has proposed to certify waste characterization of a debris waste stream at Los Alamos National Laboratories (LANL). Such characterization includes quantification of the waste components that have limiting values (See CARD 24 at 24-50). Methods available to perform characterization include non-destructive assay, non-destructive examination (NDE) (radiography), visual examination (VE), headspace gas sampling and analysis, and solid waste sampling and analysis (id. 24-54). Methods to quantify waste components are NDE and VE (id.), which are both “semi-quantitative.” (id. 24-56). . . The rulemaking record shows that NDE and VE are insufficient to quantify waste components. For example, TSD V-B-15 Att. 2 states that radiography (NDE) can “confirm” a drum's contents but has “inherent limitations,” and the document makes no mention of its use to quantify waste components (at 6-4). The TSD states that VE also has “limitations”; again the ability to quantify is simply assumed and not shown (at 6-6). Documentation of VE capabilities at LANL provides no basis to assume the ability to quantify waste components (Att. 6 at 9-11). Likewise radiography was not shown to be capable of quantification (id. 12-13). (956)

5. Non-destructive examination (NDE) is not sufficient to quantify waste components even though that is the method DOE specifies in the CCA (at 4-55), although the CCA also states that NDE “is basically a qualitative determination” (at 4-54). (1154)

<u>Response to Comments 6.D.1 through 6.D.5:</u>

The Agency disagrees with the characterization of the limitations discussed in both the CARD 24 document and the TSD. The Agency also believes that an evaluation of the entire waste characterization program is necessary to determine whether the wastes can be quantitatively characterized adequately.

First, as discussed in Section 3.2.4.2 of the TSD No. V-B-15, a WIPP Waste Certification Audit Team member did find that the radiography system has difficulty in detecting cellulosics, which may be found in a lead-lined drum, because a higher energy X-ray must be used to scan through the lead lining, it also scans past the cellulosics as well. The TSD went on to say that “[T]o compensate for the inability of the higher energy X-ray to scan the cellulosics, the operator must examine the waste container data sheet. This data sheet contains acceptable knowledge information as to what types of wastes are expected to be in the container. If the items listed on the sheet are not observed when performing the analysis of a lead-lined drum, the operator will tag the drum for visual examination.” Thus, if the acceptable knowledge documentation indicates the presence of certain waste components not identified by radiography, visual examination must be employed to determine the contents of the waste container. [Transuranic Waste Characterization

Sampling and Analysis Methods Manual, Revision 1 contains Procedure 310.1, Physical Waste Form Characterization Using Radiography, p. 310.1-1] Waste characterization and quantification is made using AK, VE, Real Time Radiography (RTR), and the Transuranic Waste Baseline Inventory Report; these processes/systems complement each other and compensate for any inherent limitations associated with a specific process.

Second, as discussed in the TSD No. V-B-15, a WIPP Waste Certification Audit Team member noted that there were several limitations associated with LANL's VE process. These limitations, however, were related to the application of the miscertification rate and the number of drums requiring VE using random selection to the entire annual waste population instead of to each waste stream. The WIPP Waste Certification Audit Team member did not identify any problems associated with either the VE process or the ability of the VE process to characterize and quantify waste components. Thus, the commenter's implied conclusion that the identified limitations of VE results in an inability to quantify waste components is not supported by the TSD.

Third, although the Agency agrees with the commenter's statement that NDE and VE are semi-quantitative, EPA disagrees with the commenter's assertion that these methods are insufficient to quantify waste components. Each site is required to develop reference tables of standard weights for waste material parameters in order to estimate weights based on radiography examination. [WIPP Waste Characterization Sampling and Analysis Methods Manual, p. 310.1-5 (Reference 210)] Thus, properly conducted NDE and VE should result in reasonably accurate quantification of these materials.

Visual examination will also be performed on all to-be-generated waste and all retrievably stored waste (i.e., existing waste) that requires repackaging. Waste material and packaging weights and quantities may be determined through use of reference tables or through weighing of items, based upon the ability to ascertain contents through unopened bags or packages. [WIPP Waste Characterization Sampling and Analysis Methods Manual, p. 310.2-4 (Reference 210)]

Fourth, with regard to the commenter's implied concern that DOE cannot characterize and quantify waste components that have limiting values, EPA notes that the minimum limiting values for ferrous and non-ferrous metals will easily be met through consideration of the ferrous and nonferrous metal contributed by waste containers and lead shielding. See DOE's TWBIR, Revision 3 and EPA's review of the TWBIR [Docket No: A-93-02, Item V-B-15] for a complete description and accounting of the ferrous and nonferrous metals to be placed in the WIPP. EPA also notes that an additional margin of safety will be realized through contribution of the significant, additional (but not considered) quantities of both ferrous and nonferrous metals associated with the waste itself (e.g., tools, piping, lead-lined apparel, and metallic sludges).

Lastly, with regard to the commenter's implied concern that DOE cannot characterize and quantify the other waste component that has a maximum limiting value (i.e., water), EPA believes that DOE can successfully use Radiography, especially when combined with VE, to identify the presence of free liquids. Specifically, as discussed in the CCA on p. 4-53, Radiography is used to verify the absence of liquids. The container-based limits are <2 liters total residual liquid per 55-

gallon drum, <8 liters total residual liquid per standard waste box, and <1 inch of liquid in the bottom of any container. As part of operator training, the operator must identify various items in a test drum. These items include an empty bottle, a full container, an aerosol can with liquid, a one-gallon bottle with three tablespoons of liquid, and a one-gallon bottle with one cup of fluid (upside down). [Transuranic Waste Characterization Sampling and Analysis Methods Manual, Revision 1 contains Procedure 310.1, Physical Waste Form Characterization Using Radiography, p. 310.1-8] Therefore, the operator will have training to identify the presence of liquids. In addition, the procedure states the waste container will be jogged by starting and stopping the turntable (dolly). The operator will look for wave motion (a sign that liquids are present). In cases where Radiography does not allow for adequate characterization of the contents of a container (e.g., a lead-lined container), visual examination of the container contents is required. The operator will describe the location, container, and estimated volume of any liquids. [Transuranic Waste Characterization Sampling and Analysis Methods Manual, Revision 1 contains Procedure 310.1, Physical Waste Form Characterization Using Radiography, p. 310.1-3] Therefore, this procedure includes steps to identify the presence of liquids.

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6. EPA's general waste characterization approval fails to explain how the following problems identified in the September audit have been addressed. The software used in the neutron Non Destructive Assay system is heavily dependent on waste matrices and the specific configurations or spatial arrangement of the waste drums. Where waste matrices include materials which produce anomalies in waste calibrations, the percentage of visual examination checks should be more frequent than the one-year approved by EPA. Moreover, because of these anomalies, the percentage of visual examination checks should be calculated for each waste stream, not generally. Yet EPA has not imposed any such requirement on DOE's certificate rate procedure. (503)

<u>Response to Comment 6.D.6</u>:

EPA interprets this comment to refer to the September 1997 audit of LANL. Based on the results of this audit, the waste characterization process was approved only for legacy debris waste. The commenter's first point is that relying on waste matrices and specific configurations of waste drums will produce anomalies in waste calibrations, and therefore should require more frequent visual examination checks. The LANL audit evaluated the NDA program and concluded that the systems, methods, and procedures in place at LANL were capable of meeting the TRU assay requirements found in the Quality Assurance Project Plan only for the legacy debris waste. [Docket No. A-93-02, Item V-B-15]

The LANL NDA instruments (a combination of gamma spectroscopy and passive-active neutron counting) were found to provide precision and accuracy within the required limits over the range of neutron moderating and absorbing properties expected for the legacy debris waste stream. Therefore, EPA concluded that the NDA system and associated software was acceptable for the specific waste summary category that was certified. For more information on the frequency of VE checks see Issue D and the Response to Comment 6.D.8.

The commenter's second point is that VE should be applied to each waste stream, and not generally applied. This issue deals with the waste drum miscertification rate. The RTR of waste drums has a certain miscertification rate that occurs when a drum is determined to meet the WIPP WAC and TRAMPAC (TRUPACT II Authorized Methods for Payload Control) criteria by the RTR operator, but the drum does not meet those criteria based on visual examination. The miscertification rate can be estimated by visually examining a random sample of drums and computing the fraction of miscertified drums in the sample.

EPA considered whether or not a stratified sampling (i.e., VE applied to each waste stream) approach should be used to take into account the (type of) waste stream. Under this approach, separate random samples would be taken from each waste stream. The overall sample would be guaranteed to have a representative number of drums from each waste stream; for example, a simple random sample might by chance have all the drums from the same waste stream. DOE has proposed a sampling method, whereby a sample number of drums is randomly selected for characterization without substituting another drum from a different waste stream. However, the selection does not take into account any information about the waste streams for drums.

EPA finds that DOE's procedure is valid, and properly reduces the chances of making an erroneous decision about the true, unknown, miscertification rate. The sample sizes will be large enough to control the probability of making an incorrect decision based on the sample population. The acceptability of DOE's approach can be illustrated using the following example scenarios:

- An example scenario consists of a large waste stream A with a low miscertification rate and a small waste stream B with a high miscertification rate. A random sampling of the drums would contain proportionately fewer drums of the waste with the high miscertification rate. However, this does not introduce a bias because the overall population of waste stream B drums is small in comparison with the total population of drums.

- Another example scenario consists of a large waste stream A with a high miscertification rate and a small waste stream B with a low misrecertification rate. A random sampling of the drums would contain proportionately more drums with the high miscertification rate and therefore have a higher probability of finding miscertified drums.

Additionally, a stratified sampling program would likely reduce the overall sample population in comparison to the simple random sampling approach proposed by DOE if the miscertification rates are known and if there is sufficient variability in the miscertification rate among the waste streams. If the waste stream miscertification rates are not known and do not vary significantly, then the stratified approach will not offer an improved efficiency.

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7. The overview of waste characterization methodologies does not satisfy 40 CFR 194.24(c)(2). There is a lack of information about nondestructive examination/ nondestructive assay techniques

and process knowledge in particular. Further, how will each component be identified and quantified in waste characterization? (959)

Response to Comment 6.D.7:

Section 194.24(c)(2) requires that DOE identify and describe the methods used to quantify the waste components identified in accordance with Section 194.24(b). Section 194.24(b) requires that all waste characteristics influencing containment of wastes be identified and assessed, and that all waste components influencing waste characteristics be identified and assessed. DOE identified waste components expected to have a significant effect on disposal system performance in Appendix WCA, Tables WCA-2 and WCA-3 of the CCA. [Docket: A-93-02, Item II-G-1] DOE identified waste components for which limiting values were determined in Appendix WCL, Table WCL-1, as:

- ♦ Ferrous metals (iron) -- minimum of 2×10^7 kilograms;
- ♦ Cellulosics/plastic/rubber -- maximum of 2×10^7 kilograms;
- ♦ Free water emplaced with waste -- maximum of 1684 cubic meters; and
- ♦ Nonferrous metals (metals other than iron) -- minimum of 2×10^3 kilograms.

Methods used to quantify each waste component

Chapter 4.4 [p. 4-44] of the CCA identifies NDA, NDE (i.e., radiography), and VE), as the methods to quantify the limiting value of waste components.

- ♦ Radiography is a nondestructive, semi-quantitative technique that involves x-ray scanning of waste containers to identify and verify waste container contents (including cellulosics, plastics, and rubbers).
- ♦ VE is a semi-quantitative method that confirms/determines the matrix parameter category and waste material parameter weights through visual examination of wastes. It is used to quantify waste components such as cellulosics, plastics, and rubbers.
- ♦ NDA, a nonintrusive technology, employs radiation detection techniques to determine the waste's isotopic content and activity.

Chapter 4.4.1 [p. 4-50] of the CCA indicates that radiography and VE are qualitative methods for physical waste characterization that will be employed to quantify physical waste components, including cellulosics, plastics and rubbers.[30] Chapter 4, Sections 4.4.1.2 [p. 4-54] and 4.4.1.3 [p. 4-55], refer to QA guidelines in Chapter 10 (radiography) and Section 5.4.2 (VE) of the Transuranic Waste Characterization Quality Assurance Program Plan [CAO-94-1010], and Methods 310.1 (radiography) and 310.2 (VE) in the Transuranic Waste Characterization Sampling and Analysis Methods Manual. [CCA Reference #210] The QAPP [Chapter 10, pp. 1 to 6] describes radiography and VE as qualitative and semi-quantitative. Sections 4.4.2 and 4.4.2.1 [pp. 4-55 to 4-57] identify NDA as a methodology to quantify radionuclides and their activity. Chapter 4.4.2 [p. 4-55] refers to the Transuranic Waste Characterization Quality Assurance Program Plan for QA guidelines for NDA. [CAO-94-1010, see Chapter 9]

Procedures

DOE provided the following description of radiography procedures in its Methods Manual. [CCA Reference #210, p. 310.1-1] Waste containers are moved into the shielded vault, X-rays are projected through the container onto a fluorescent screen/image intensifier, and the resultant image is transferred by a camera to a remotely located television screen. A description of the contents of the waste container is video recorded and documented on a data form. The description should clearly identify all discernable waste items, residual and packaging materials, and/or waste material parameters whenever possible so that waste can be classified according to the waste material parameters specified in Table 1. This classification based on radiography information will be confirmed by visual examination. [Procedures 310.2 of this Methods Manual]

DOE provided the following description of visual examination in its Methods Manual. [CCA Reference #210, p. 310.2-1] The TRU waste that is designated for the program is visually examined, weights determined or estimated, and video recorded. A description and estimated or measured weights of the contents of each waste container is also recorded on audio/video tape and a visual examination data form. The description should clearly identify all discernible waste items, residual materials, packaging materials, or waste material parameters so that all of the waste in each container can be classified according to the waste material parameters. Opening individual bags/packages may be necessary in order to ensure the quality of the examination data. If individual bags/packages are not opened, estimated weights of waste items, residual materials, packaging materials, or waste material parameters within the bags/packages are recorded. If it is necessary to open individual bags/packages, then actual weights of waste items, residual materials, packaging materials, or waste material parameters are recorded.

The CCA does not identify procedures for NDA, but the QAPP [CAO-94-1010] provides QA guidelines which must be met in site-specific NDA procedures. In addition, the QAPP [Chapter 9,

30 Quantification using these methods will occur as follows: various materials are identified by name and quantity (such as “tyvek protective suits”). This information is then compared to known”quantitative” information (such as a tyvek suit consist of 250g of cellulosic material and 80g of ferrous metal) to come up with the quantitative measure of the waste component groups.

p. 8] recommends the use of American Society for Testing and Materials (ASTM) procedures and Nuclear Regulatory Commission (NRC) standard practices and guidelines.

Instrumentation used and sensitivity

DOE described the equipment and facilities typically found in a radiography system in the Methods Manual, Method 310.1, Section 5.0, Apparatus and Materials. [CCA Reference # 210] DOE described the equipment typically associated with radiation containment facilities for VE in the Methods Manual, Method 310.2, Section 5.0, Apparatus and Materials. The radiography equipment and facilities at Rocky Flats Environmental Technology Site(RFETS), and the radiography and VE equipment and facilities at LANL were examined by DOE during the previously noted audits. The CCA did not discuss sensitivity of instruments, since analytical instrumentation for which instrument sensitivities would apply are not used.

As described in the Methods Manual [CCA Reference #210, pp. 310.1-3], a typical radiography system consists of the following equipment and facilities:

- Shielded room that is properly ventilated and lighted
- X-ray head and associated equipment
- Drum turntable dolly assembly
- Fluoroscopic screen and accessories
- Closed-circuit television equipment and monitors
- Safety interlocks
- Data management system.

DOE discussed NDA instrumentation in the CCA, Chapter 4.4.2.1 [pp. 4-56 to 4-57] and the QAPP, Chapter 9. [CAO-94-1010] Chapter 4.4.2.1 and the QAPP list NDA instrument systems that can be classified as belonging to one or more of four types of measurement categories. DOE indicated that the list of instrument systems is neither complete nor limiting, but shows the breadth of choices available. DOE proposed to use any type of NDA instrument system, modification, combinations or hybrids as long as the quality assurance objectives (QAOs) can be met. NDA instrumentation at RFETS and LANL was examined by DOE during the previously noted PDP and audits.

As described in the Methods Manual [p. 310.2-3, CCA Reference #210], sites develop radiation containment facilities for VE and provide the following equipment:

- Drum, waste bag, and waste handling equipment

- Video cameras and audio equipment
- Mass balances and calibration standards
- Bag opening unit
- Data input station
- Safety equipment.

DOE discussed the minimum detectable concentration (MDC) for NDA, also known as the detection limit, in the QAPP, Section 9.1. The MDC corresponds to a level of activity that is practically achievable with a given instrument, analytical method and analyte/matrix combination. The MDC considers not only the instrument characteristics (background and efficiency), but all other factors and conditions which influence the measurement. The MDC is 60 nCi/g.

As described in Chapter 4.4.2.1 [p. 4-56], typical NDA instrumentation includes:

- Gamma ray measurements
  - -- low-and high-resolution spectroscopy using a sodium iodide and intrinsic germanium detector, respectively
  - -- transmission-corrected gamma ray measurement using a segmented gamma ray scanner
  - -- transmission-corrected gamma ray measurement using a computed tomographic gamma ray scanner
- Passive neutron measurements
  - -- passive neutron coincidence counter
  - -- advanced matrix-corrected passive neutron counter (add-a-source)
  - -- shielded neutron-assay probe totals counter
- Passive and active neutron measurements
  - -- americium-lithium source-driven coincident counter
  - -- californium delayed-neutron counter (shuffler)
  - -- neutron generator differential die-away counter
  - -- combined thermal and epithermal neutron counter
- Thermal neutron capture
  - -- californium delayed-neutron counter
  - -- neutron generator differential die-away counter

-- combined thermal and epithermal neutron counter.

Acceptable knowledge

All waste is first characterized using acceptable knowledge. Acceptable knowledge is used to (1) delineate waste streams; (2) identify radionuclide content as a basis for some NDA determinations; and (3) make hazardous waste determinations. Used for these purposes, acceptable knowledge balances the requirements for providing definitive chemical and physical characterization of waste streams when it is difficult to obtain as a representative sample because of the physical waste form and/or composition of the waste (e.g., metal, glass, combustibles). However, acceptable knowledge procedures should be specific, detailed, and consistent between generator sites.

Generator sites will use acceptable knowledge to sort waste containers into waste streams for the purposes of grouping waste for further characterization. It is advantageous for the generator site to separate its waste based on acceptable knowledge into the most detailed and accurate break-down possible, particularly for homogeneous solids and soils/gravel wastes. The type of analyses performed will not differ based on the waste stream, only on the physical form of the waste (e.g., sludge, soil). Both existing and to-be-generated wastes will be separated in this fashion, though the types of acceptable knowledge used to separate waste streams for existing versus to-be-generated waste, may differ.

How each method will be used to quantify the amounts of waste components

DOE described how radiography and VE will be used to quantify the amounts of waste components in the following documents: Chapter 4.4.1, 4.4.1.2, and 4.4.1.3 [pp. 4-50 to 4-55]; Chapter 10 (radiography) and Section 5.4.2 (VE) of the Transuranic Waste Characterization Quality Assurance Program Plan [CCA Reference #210]; and Methods 310.1 (radiography) and 310.2 (VE) in the Transuranic Waste Characterization Sampling and Analysis Methods Manual. [CCA Reference #210]

Radiography is used to determine the physical form of the waste (i.e., matrix parameter category, waste inventory, TRUPACT-II Content Code, Item Description Code, waste packaging configuration) and the weight of the waste material parameters in order to quantify waste components such as cellulosics, plastics and rubbers. The results of radiography are verified through VE, or VE can be performed in lieu of radiography.

DOE described how NDA will be used to quantify the radionuclides and their activity in Chapter 4.4.2 and 4.4.2.1 [pp. 4-55 to 4-57] and described QA requirements for NDA in the Transuranic Waste Characterization Quality Assurance Program Plan. [CAO-94-1010]

DOE indicated that TRU nuclides emit several types of ionizing radiation (alpha particles, beta particles, gamma rays, and neutrons). Several technologies have been developed to measure one or more of these radioactive emissions as they emerge from the waste container. Although most alpha and beta particles are not able to penetrate the walls of the waste container, both gamma rays and neutrons can penetrate the waste matrix as well as the waste container to varying degrees. NDA techniques can be classified as active or passive. Passive NDA is based on the observation of spontaneously emitted radiations created through radioactive decay. Most active NDA is based on the observation of gamma rays or neutrons that are emitted from a target isotope when that isotope undergoes a transformation resulting from an interaction with stimulating radiation provided by an external source. Special techniques, instrumentation, and detectors have been developed to measure gamma ray energies. Because there can be gamma rays with different energies originating from any one radionuclide, with unique rates of occurrence characteristic of the radionuclide from which it originated, the resulting distribution or spectrum of gamma ray energies provides a fingerprint or signature of that particular radionuclide. [CCA, Section 4.4.2, p. 4-55]

Demonstration of the ability to quantify each waste component

DOE's ability to quantify cellulosics, plastics, and rubber by VE and radiography was addressed during generator site audits. The LANL audits of May 1997 and August 1997 included VE and radiography. The RFETS audit of July 1997 included only radiography; VE was not in the audit's scope. DOE concluded as a result of the audits that the sufficiency of RFETS and LANL's VE and/or radiography programs was adequately demonstrated. [Docket: A-93-02, Item V-B-15]

DOE's ability to quantify radionuclides and their activities by NDA was also addressed during audits of generator sites. DOE conducted NDA audits at LANL in May 1997, August 1997 and September 1997, and conducted a PDP at RFETS in November 1996 and an audit of NDA at RFETS in July 1997. DOE concluded that the certification for NDA at LANL could be authorized as a result of these audits, but NDA at RFETS could not yet be authorized. [Docket: A-93-02, Item V-B-15] These procedures and EPA's compliance evaluation are discussed in greater detail in CARD 24, Section 24.F.

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8. EPA's general waste characterization approval fails to explain how the following problems in the September audit have been addressed.

- "Software used in the neutron Non Destructive Assay (NDA) systems is heavily dependent on waste matrices and the specific configuration or spatial arrangement of the waste drum contents." Attachment 2, 308. Where waste matrices include materials that produce anomalies in waste calibrations, the percentage of visual examination checks should be more frequent than the on-year [sic] interval approved by EPA. Moreover, because of these anomalies, the percentage of visual examination checks should be calculated for each waste stream. Yet EPA has not imposed any such requirement on DOE's miscertification rate procedure.

- Concerns about manual entry of data are not addressed. Attachment 1, 20. Not only are inaccuracies likely, but evidence exists that LANL QA procedures for supervisory review of documentation have not been complied with. (1217)

Response to Comment 6.D.8:

EPA performs on-site audits of each generator site prior to allowing that site to ship waste to the WIPP. Included in the scope of these audits is a detailed review of the software and hardware systems being used at the site for NDA. Prior to using any system for NDA, the site must show that the system is capable of meeting the standards imposed by the TRU Waste Characterization Quality Assurance Program Plan [CAO-94-1010] and the Waste Characterization Performance Demonstration Program. [CAO-94-1045] The EPA review verifies that the site has determined the NDA system provides adequate performance over the range of waste characteristics expected in the waste streams being certified. The September LANL audit encompassed the concerns of the commenter regarding waste matrices and specific configuration on spatial arrangements. EPA, at LANL, evaluated the softwares for PC/FRAM v2.3, PAN and MAESTRO v3.00 and concluded that the software demonstrates the ability to support measurement of total alpha activity and the activity of all individual isotopes present. EPA also ensures, as part of the site audit, that NDA systems are being operated by properly trained personnel, that procedural controls over the NDA process are adequate, and that data entry is both controlled and independently verified.

The LANL waste certification inspections performed in August and September1997, [Docket: A-93-02, V-B-15] included the EPA review process. The September inspection was performed to review changes made by LANL in their NDA methods and in their data entry controls. These changes were made as a result of issues raised, as identified by the commenter, during the August inspection. Specifically, EPA required further evidence that the NDA system in use at LANL could quantitatively determine radionuclide assays for the waste stream in question. EPA also required further evidence that the manual entry of data into the WIPP Waste Information System was procedurally controlled and independently verified. Both requirements were met in the September audit. [Docket: A- 93-02, V-B-15] Similar requirements will be imposed upon all generator sites prior to those sites being certified to ship waste to the WIPP. EPA examined imposing visual examination checks on a waste stream basis and concluded that this process would actually decrease the number of containers examined by visual examination. [CARD 24, Section 24.F.5] Specifically, EPA verified that persons responsible for verifying that activities affecting quality have been correctly performed must have sufficient authority, access to work areas, and organizational freedom to: (a) identify quality problems; (b) initiate, recommend, or provide solutions to quality problems through designated channels; (c) verify implementation of solutions; and (d) assure that further processing, delivery, installation, or use is controlled until proper disposition of a nonconformance, deficiency, or unsatisfactory condition has occurred. [NQA-1, Basic Requirement 1: Organization, also see CARD 22, Section 22.A]

For the EPA response to the issue of the percentage and frequency of visual examination checks and whether or not such checks should be calculated for each waste stream, and DOE's miscertification rate procedure see Issue D and Response to Comment 6.D.6.

Issue E: Sending other waste streams from Los Alamos National Laboratory

1. Now that DOE has been certified for a single waste stream at LANL, can it send similar waste streams from other facilities (e.g., Rocky Flats, INEL) to the WIPP? (2)

2. The EPA has already evaluated and determined the appropriateness of the DOE's site certification process in its valuation of the Los Alamos Laboratory program. (201)

Response to Comments 6.E.1 and 6.E.2:

The certification at LANL applies only to the process used to characterize legacy debris waste at one waste generator site -- LANL. EPA has clearly identified this waste stream using the systems and processes documented in the May 12-16, 1997, August 18-22, 1997, and September 10-11, 1997 site certification audits. [Docket: A-93-02, Item V-B-15] DOE has not demonstrated compliance with the requirements of Section 194.24(c)(3)-(5) for any other waste stream at LANL, or at any other waste generator site. EPA's certification also states that DOE has established and executed the required QA programs at LANL. No other process for characterizing waste streams at LANL, or at any other waste generator site, is yet found to be in compliance with 40 CFR Part 194. Therefore, DOE is not authorized to send waste to WIPP from any other waste stream or waste generator site.

Before any other DOE facility can send any waste to WIPP, the facility must, among other things, comply with Section 194.24(c)(3)-(5) for each waste stream(s). Sections 194.24(c)(3)-(5) require that DOE (1) submit specific information demonstrating that the use of AK used to quantify components in the waste conforms with the QA requirements in Section 194.22; (2) demonstrate that a system of controls has been and will continue to be implemented to confirm that the waste in WIPP will not exceed the upper limits or fall below the lower limits calculated in accordance with Section 194.24(c); and (3) demonstrate that this system of controls conforms with the QA requirements in Section 194.22.

EPA will provide the relevant information for the public comment and then will conduct an audit or an inspection of a DOE audit at each site to evaluate the use of AK and the establishment of a system of controls for each waste stream(s), including the demonstration of the WWIS and application of the relevant QA requirements.

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3. There is the further problem that the certification in its present form is based on assumptions that certain types and quantities of waste will be brought for disposal, including waste that is not allowed to be brought because characterization methods have not been approved. Thus, waste from the ten major sites, it is assumed, will be introduced, even though EPA has found that only one such site has acceptable characterization facilities, and those are limited as to waste type. (1067)

4. Based on what is included in the proposed rule, the only wastes that could ever be allowed for disposal at WIPP are the LANL debris wastes, since no other waste stream has been certified at

LANL and no other site has been certified for any waste stream. Yet, EPA is proposing to certify WIPP to receive dozens of other waste streams from many other sites. EPA is apparently even proposing to certify WIPP for remote-handled wastes that DOE has not asked to be certified.

SRIC believes that EPA must repropose its certification rule to address how it can certify WIPP for RH wastes with no certification information (a violation of 40 CFR 194.24) or to propose certification of WIPP only for CH wastes and require major changes to the CCA to reflect that substantial change. (1115)

Response to Comments 6.E.3 and 6.E.4:

EPA believes that these two commenters have misunderstood the Agency's compliance determination. EPA's proposed determination of compliance is limited to only the legacy debris waste streams that can be characterized using the systems and processes audited by DOE, inspected by EPA, and found to be adequately implemented at LANL. EPA does not find, however, that DOE has demonstrated compliance with Section 194.24(c)(4) for any other waste stream at LANL, or with Sections 194.24(c)(4) and (5) at any other waste generator site. As such, no waste other than this may be accepted, and RH waste cannot be accepted until the information required in Section 194.8(b) is submitted. See Issue J, How Much Contact Handled and Remote Handled Transuranic Waste Will Be In WIPP. No waste for which "characterization methods have not been approved" (Comment 6.E.3) can be accepted without EPA's explicit approval. EPA is not certifying the receipt of "dozens of other waste streams" (Comment 6.E.4).

EPA further notes that in order to ship transuranic waste from other waste generator sites for emplacement at the WIPP, DOE will have to demonstrate compliance with the requirements of Section 194.24(c)(3)-(5). As waste generator sites establish waste characterization programs for new waste streams (or groups of waste streams), EPA will assess their compliance with these requirements. EPA will conduct an audit or inspection of a DOE audit at each waste generator site to evaluate the use of process knowledge and the establishment of a system of controls for each waste stream or group of waste streams. In order for a site to demonstrate the implementation of a system of controls, the WWIS must be demonstrated to be functional at the waste generator site before any waste stream(s) may be shipped from that site for disposal at the WIPP. In order for EPA to confirm that a system of controls has been adequately executed in accordance with Section 194.24(c)(4), DOE must demonstrate that measurement techniques and control methods can be implemented for each waste stream or streams that DOE plans to emplace in the WIPP. As described in the final rule, EPA's decision to approve site-specific plans -- and thus to approve a site to transport a waste stream for disposal at the WIPP -- would be made only after public comment has been solicited and after EPA has conducted an audit or an inspection of a DOE audit of the waste generator site.

Issue F: What is legacy debris waste and derived waste?

1. What exactly is Legacy Debris Waste? (5)

2. In addition, so-called "derived waste" that is generated at WIPP and included in the RCRA Part B permit application is not discussed or described in the CCA. (152)

Response to Comments 6.F.1 and 6.F.2:

EPA assumes that these comments request clarification regarding the specific type of waste that Los Alamos National Laboratory has been certified to ship to WIPP. As such, it should be noted that DOE's certification stated that "retrievably stored (legacy) debris waste" may be shipped. The retrievably stored waste is defined by DOE as "waste generated after the early 1970s but before implementation of DOE's TRU Waste Characterization Quality Assurance Program Plan (QAPP)." [CCA, p. 4-5] DOE defines legacy waste as "any waste within a complex that was generated by past weapons production or research activities and is in storage awaiting treatment or disposal," and "debris" waste as any waste stream classified with a series 5000 waste matrix code (e.g., RCRA S5000 - S5900). Therefore, legacy debris wastes are transuranic wastes that were placed in retrievable storage facilities (i.e., berms with earthen cover, buildings, or in the case of remotely handled wastes in underground canisters) since 1970, and includes materials such as: asbestos debris, legacy debris, inorganic debris, metal debris, concrete debris, organic debris, asphalt debris, and heterogeneous debris. [DOE's 1996 Baseline Environmental Management Report," Volume III, p. New Mexico 40 (discussing legacy wastes) and DOE's 1994 Transuranic Waste Baseline Inventory Report (TWBIR), Revision 0, CAO-94-1005 (listing of all the waste matrix codes)]

The description of the "derived waste" is included in the CCA, Appendix WAP, p. C-17 under the heading Waste-Generating Processes at the WIPP Facility. The "derived waste" is generated from off-site facilities (i.e., locations from the waste generator site to, and including, the WIPP). Derived waste is waste generated from the on-site cleanup of any leak, spill, breach, or other type of release from a TRU mixed waste container received from an off-site facility. Derived waste is also generated from swipes sampled on-site and used to detect external radioactive contamination during receipt inspection of containers from an off-site facility.

Issue G: Characterizing waste to identify cellulosics, plastics, rubber and iron

1. Is EPA assuming that DOE will characterize each drum of waste to identify cellulosics, plastics, and iron? (p. 24-33) (62)

2. Where is it shown that waste characterization methods will quantify cellulosics, plastics, rubber and water? (P. 24-57) (65)

3. There is considerable uncertainty in the inventory in the current as well as the future waste at the DOE sites. There is also uncertainty in the accuracy of estimating the amounts of cellulosics, rubber and plastic in the waste, and this may cause problems in meeting the repository limits which have been set to control carbon dioxide production in the repository. If the inventory, the overall characteristics and the distribution of the waste and repository are significantly different

than those assumed in the CCA, the actual behavior of repository will be different than those assumed in the CCA. (487)

4. The expected amount of CRP [cellulosics, rubber, and plastic] in the repository is 2.1 x 10^7 kg (see CARD 24-38). EEG is concerned about the ability to measure CRP in the waste with enough accuracy to ensure that this limit will be met. . . EEG has not found a reference to the uncertainty in determining the weight of CRP in waste containers in either the DOE or the EPA reports. The EPA needs to point out where this uncertainty has been addressed, if it has been, or address the issue at this time. (704)

Response to Comments 6.G.1 through 6.G.4:

DOE states, and EPA has based its certification, in part, on the understanding that all waste containers will be subject to characterization by AK in addition to radiography and/or visual examination. The characterization and examination process includes identification of iron metals and alloys from waste containers and waste, plastics, and cellulosics. Each waste container will be examined via AK, radiography and/or visual examination, and every waste component will be tracked through the WWIS data management system. [CCA, Appendix WAP, pp. C-23 and C-25, and Tables C-6 and C-7] The DOE WIPP Waste Characterization Sampling and Analysis Methods Manual [CCA Reference 210] contains methods for Physical Waste Form Characterization Using Radiography [Method 310.1] and Physical Waste Form Characterization Using Visual Examination. [Method 310.2] These methods specify that iron based metals/alloys, plastics, and rubber will be subject to weight determination. All retrievably stored (i.e., existing waste) waste containers will be subject to radiography and a certain percentage of the retrievably stored waste containers will also be subject to visual examination. [CCA, Appendix WAP, pp. C-38 through C-40] All to-be-generated waste will be subject to visual examination as part of the packaging process. [Section 5.0 of the CCA Reference 201] In addition, waste limits will be imposed based upon iron and cellulosics/plastic/rubber contents which require that each component be identified for adequate tracking. DOE has also indicated that the WWIS is capable of tracking these components, meaning that they will be characterized at the generator sites. DOE will characterize these important waste components. It must also be noted that the iron content within the WIPP will be maintained via emplacement of steel containers that include a necessary quantity of iron to promote anoxic conditions in the subsurface, and the actual iron content within the waste itself will also be tracked. [CARD 24, Section 24.F.1 through 24.F.5]

For a discussion of the uncertainty associated with the measurement of CRP see Issue 6.I "What is the Limiting Value?" and Issue 6.R "Waste Inventory Uncertainty and Future Changes."

5. [T]here is considerable uncertainty in the inventory of the current as well as the future waste at the DOE sites. The DOE plans to treat, process, or repackage 85% of the waste to be shipped to WIPP are not reflected in the inventory. There is uncertainty in the estimation of the amount of cellulosics, rubber, and plastics in the waste and this may cause problems in meeting the limits for CO_2 production in the repository. These factors affect the computations for the containment requirement. If the inventory, the overall characteristics, and the distribution of the waste in the

repository are significantly different than those assumed in the CCA, the actual behavior of the repository will be different than that predicted in the CCA computations. (720)

Response to Comment 6.G.5:

DOE has not provided any information in the CCA, or in supplementary information, indicating that any of the transuranic wastes to be disposed at WIPP in accordance with the instant certification will be treated or processed (although the commenter does not make this explicit, EPA assumes, for the sake of this response, that the commenter is referring to waste treatment/processing methodologies, such as vitrification). EPA agrees that, if the overall characteristics of the wastes are significantly different from those upon which the CCA calculations are based, the actual behavior of the repository may be significantly different from that predicated in the CCA. In accordance with 40 CFR 194.4(b)(3), DOE is required to report any planned or unplanned changes in activities or conditions pertaining to the disposal system that differ significantly from the CCA. Upon such notification by DOE, EPA shall determine whether to revoke, suspend, or modify the certification. 40 CFR 194.4(b)(3)(vi). Thus, should DOE plan to emplace any treated or processed waste in the repository, EPA must be notified for a determination of whether such emplacement would fail to comply with the terms of the current certification. For a discussion of the uncertainty associated with the measurement of CRP see Issue 6.I "What is the Limiting Value?"

Issue H: Iron content of the drums

1. Does the reference to iron mean the iron content of the drums themselves, or iron inside the drum? (p. 24-42) (63)

2. For at least the past 10 years, the question of gas production in the repository has been a concern and it is common knowledge that reduction of the amount of iron in the repository will help meet compliance with the EPA standards and is therefore a desirable goal. The EPA should therefore explain the following response:

> The amount of iron introduced into the disposal system by rock bolts is inconsequential since there is no upper limit on the amount of iron that can be emplaced in the repository. The DOE did specify a minimum amount of iron that must be emplaced into the repository within Appendix WCL, Table WCL- 1, which is based on the quantity of iron within the waste containers to be emplaced at the WIPP and does not rely on the amount of iron contained in the roof support system to meet this minimum requirement. (CARD 14-95).

Does EPA now believe in a *minimum* amount of iron that must be emplaced in the repository? (1298)

Response to Comments 6.H.1 and 6.H.2:

The reference is to iron that makes up the drum. DOE has indicated that the waste containers (drums) themselves contain iron, and the quantity of iron within these containers is sufficient to meet the minimum iron waste limit of 2.1 x 10^{7} kg specified in the CCA (CARD 24). DOE will track the quantity (weight) of ferrous iron by tracking the quantity of iron-bearing containers emplaced in the WIPP, as well as through determination of iron content in the waste itself via acceptable knowledge, and visual examination and/or radiography.

DOE identified waste components for which limits were required. The waste components with limiting values are:

Ferrous metals (iron)—minimum of 2x107 kilograms.

Cellulosics/plastic/rubber—maximum of 2x107 kilograms.

Free water emplaced with waste—maximum of 1684 cubic meters.

Nonferrous metals (metals other than iron)—minimum of 2x103 kilograms.

The amount of ferrous metal (iron) contained in the repository was calculated according to the total number of drums expected to be emplaced in the repository. DOE demonstrated through these calculations that the ferrous metals (iron) content will not fall below the minimum limit of 2x107 kilograms. Therefore, EPA agrees with DOE's assertion that further quantification is not necessary, particularly since DOE must track the number of waste containers emplaced in the WIPP (See CCA, Chapter 4.2.2 and Appendix BIR (Chapter 1, pp. 17-20; Chapter 2, pp. 6-7; Appendix M, pp. 1-3) for the calculations provided by DOE regarding ferrous metal content).

DOE stated that ferrous iron was required to ensure oxygen reducing conditions within the repository, and that the quantity of iron in WIPP containers would be sufficient for this purpose. The established ferrous iron limit is therefore consistent with the quantity of ferrous iron of which WIPP waste containers are comprised (WCL.2, p. WCL-4).

EPA concluded that the calculated quantity of ferrous iron was reasonable and traceable, and that DOE's calculated waste limit quantities were included in other parameters that were input to PA. For example, Appendix WCA states that reducing conditions will be maintained through the reaction of iron in WIPP waste containers themselves. EPA concluded, given the quantity of ferrous iron in waste containers identified by DOE, that a number of parameters used in the PA—including the oxidation state distribution parameter (Appendix PAR, p. PAR-148)—incorporated the effects of reducing conditions.

Issue I: What is the limiting value?

1. Does the term "limiting value" refer to an upper end of an uncertainty value? (24-52). (64)

2. Support for the assertion that no limiting values need be imposed has not been presented. Such an assertion must be based upon determinations as to the upper and lower limits for waste components and uncertainties related thereto. Plausible combinations of upper and lower limits must be shown, and the limits must be justified. It must appear that the combinations of limits selected result in the greatest projected release. Such information does not appear in the CCA or Appendix WCL. The CCA must also show that performance was modeled at the upper and lower limits and that compliance is achieved at the limits. No such showing appears. (958)

3. 194.24(c)(1) requires a demonstration that upper and lower limits including uncertainties are considered and that "plausible combinations of upper and lower limits" that result in the greatest releases are considered. Such demonstrations have not been done in the CCA or in the proposed rule. (1153)

Response to Comments 6.I.1 through 6.I.3:

As described in 40 CFR 194.24(c), the term "limiting value" refers to an upper or lower limit on waste components and the associated uncertainty (upper and lower bounding value). DOE is required to set limits on all significant waste components identified in accordance with Section 194.24(b)(2), and to demonstrate that the WIPP complies with Sections 194.34 and 194.55 based on these limits. DOE also must describe the basis for setting these limits and demonstrate that when all of the waste component parameters are set at their upper or lower limits, the mean CCDFs obtained will meet the containment requirements of 40 CFR 191.13 at the 95% confidence limit. [Criteria for the Certification and Re-certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations -- Background Information Document for 40 CFR Part 194, at 4-63, Docket: A-92-56, Item V-B-1]

The limiting value is expressed as an upper or lower limit of mass, volume, curies, or concentration. The limiting values identified are minimum or maximum threshold limits for the waste material parameters based on performance assessment requirements for the disposal system. [Docket: A-93-02, II-G-02] For example the amount of ferrous components in the disposal system must be sufficient to ensure a reducing environment. [CCA Appendix WCL, pp. WCL-4 and WCL-5 for a general discussion of the limiting factors] Examples of assumptions and the qualitative uncertainties that were made in developing limiting values are found in the CCA, Appendix SOTERM, p. 35. DOE stated that the waste component limits are fixed values with no associated uncertainties. DOE also stated that the plausible combinations of upper and lower limits are equivalent to the fixed values selected and included in the CCA performance assessment calculations. Therefore, DOE asserted the combination of selected limits that result in the greatest estimated release was used in the analysis.

EPA evaluated the waste limits provided by DOE in Appendix WCL and determined that the appropriate components requiring limitation were identified and the waste limits applied were sufficient. EPA believes that DOE adequately addressed questions regarding uncertainties, the presentation of upper/lower limits, and plausible combinations of these limits. [CARD 24, p. 24-48] EPA examined and agreed with DOE's approach to uncertainty that a limiting value can be a fixed value without an associated uncertainty, or that a limiting value is imposed to ensure compliance and in fact incorporates uncertainty. EPA reviewed several CCA Appendices, including SOTERM, SA, WCA, and WCL to ascertain how the uncertainty issue was addressed by DOE in the determination of limiting values. Although uncertainties are not directly associated with limiting values, EPA concurred that DOE took uncertainties into account in determining the limiting values. [CARD 24, p. 24-52]

In the CCA, DOE did not specifically address plausible combinations of upper and lower limits of waste components and associated uncertainties and the rationale for the selection of these combinations. In response to EPA's March 19, 1997 request for additional information addressing these requirements [Docket No. A-93-02], DOE stated that the plausible combinations of upper and lower limits are equivalent to the fixed values selected and included in the CCA performance assessment calculations. [U.S. DOE, Response to EPA's Request in EPA's March 19, 1997 letter on the WIPP CCA, April 15, 1997 (Docket No.II-I-24) and U.S. DOE Response to EPA's Request in EPA's March 19, 1997 letter on the WIPP CCA, May 2, 1997 (Docket No.II-I-28)] Therefore, DOE asserted that the combination of selected limits that result in the greatest estimated release was used in the analysis. EPA examined DOE's response in concert with a detailed examination of the PA and PAVT results and concluded that DOE adequately addressed the issue of plausible combinations of upper and lower limits and their associated uncertainties through implementation of the PA, wherein multiple combinations of parameters are used that capture the spectrum of plausible PA results and associated uncertainties. [CARD 24, p. 24-52] The emplacement limits for waste components that are expected to have an impact on the repository performance are found in Appendix WCL, Table WCL-1.

EPA has examined thoroughly all components and characteristics [CARD 24, pp. 24-27 to 24-33] and determined that DOE indicates those waste characteristics and components expected to have a significant impact on the PA calculations. [CCA, Appendix WCA Table WCA-2] The waste characteristics and components included in the PA are expected to have a negligible impact on the repository performance based on the Sensitivity Analysis [p. WCL-1, Appendix WCL and Appendix WCA, p. WCA-12). Each waste characteristic that was expected to have a negligible impact on repository performance and was not included in the PA calculations can be found in Table WCA-4 of Appendix WCA [p. WCA-12] Table WCA-4 includes specific Appendix WCA and SCR section references that supports the assertion that the characteristic has a negligible impact on repository performance. EPA examined all references and data used to determine upper and lower limits and concluded that these were determined appropriately. Limitations on cellulosic/rubber/and plastics are based upon the quantity of MgO that can be emplaced in the WIPP to ensure that the quantity of MgO can react with CO_2 generated from biodegradation of the emplaced cellulosics, plastics, and rubber. EPA concurred that using the quantity of iron from the containers as the minimum limiting value is an appropriate and easily traceable waste limit, and also recognizes that iron within waste will add to that of the containers as well as add other components. [CARD 24] The WAC limitations will ensure that water within the waste will be less than 1% of total volume, and EPA believes that the quantity of water in waste will likely be well below the maximum limit imposed by DOE. [CARD 24] EPA also examined DOE's PA modeling, and concluded that because upper and lower uncertainties are encompassed in the PA modeling process and values, and PA is a probabilistic determination, DOE met the requirements of Section 194.24(c)(1). [CARD 24]

Issue J: How much contact handled and remote handled transuranic waste will be in WIPP?

1. Only a certain percentage of the remote handled waste is even really known what it is. What is it, only 15 percent of it is known? That leaves 85 percent is unknown. The same thing with the content handled waste, 80 percent is known. That leaves 20 percent unknown. That's too many unknowns. (370)

2. [In its proposed rule EPA did not use:]

  * the elimination of all RH wastes from the inventory and the waste unit factor. (1144)

3. [T]here is no characterization information provided for remote-handled (RH) wastes. Nonetheless, the proposed rule does not eliminate all RH-TRU waste from the repository, as it is required to do. The final determination must clearly and specifically eliminate any RH-TRU from disposal at WIPP. (1155)

4. Removing RH from the CCA substantially changes many aspects of the application, including the waste inventory, the waste unit factor, and the containment limits. If EPA is not going to exclude RH wastes from the certification, it must ask DOE to revise the CCA to reflect that RH wastes are excluded and to change all aspects of the application that would be affected by that fact. Then, EPA should request public comment on the revised application and reissue its proposed decision for public comment. (1156)

5. DOE's [waste unit factor] value is not conservative since it projects 1.2 million curies of RH-TRU (CARD 24-106), which cannot be allowed for disposal because DOE has not demonstrated compliance with waste characterization requirements for RH-TRU. (1161)

Response to Comments 6.J.1 through 6.J.5:

In the CCA [Appendix BIR], DOE provided radionuclide activity information for RH-TRU waste on a waste stream level in current version of the Transuranic Waste Baseline Inventory Database (TWBID) that had been updated to reflect revised estimated inventories of several key radionuclides at some of the major waste generator sites. EPA reviewed DOE's inventory information to determine whether it provided a sufficiently complete description of the chemical, physical, and radiological composition of the existing and to-be-generated wastes (including both CH-TRU and RH-TRU) proposed for disposal in the WIPP. EPA also reviewed DOE's description of the approximate quantities of waste components for both existing and to-be-generated wastes. [Docket: A-93-02, Item V-B-15] EPA found that DOE provided comprehensive data for hundreds of waste streams based upon characterization techniques such as sampling, analysis, and acceptable knowledge. [Docket: A-93-02, Item V-B-15] While a large percentage of the waste intended for WIPP is to-be-generated, projected waste inventories included the generator's best determination of future waste characteristics. [Refer to Appendix BIR, Appendix P, Docket: A- 93-02, II-G-1] EPA concludes that DOE's development of the stored, projected, and disposal inventory of RH-TRU waste was sufficient for PA because it provides thorough, site-specific information regarding waste components important to repository performance.

The RH-TRU wastes were included in PA assessments [Appendix WCA, pp. WCA-16 to WCA-30] and the resulting CCDFs are below EPA standards. [Docket: A- 93-02, II-G-01, Chapter 6.5] EPA, therefore, believes it is unnecessary to recalculate the waste unit factors and associated CCDF because RH wastes will eventually be emplaced in the WIPP, and compliance was demonstrated assuming RH-TRU wastes would be present. EPA notes that the RH-TRU component of the total activity (22,800 curies at 1995) constitutes less than 1 percent of the total activity of TRU-waste (4,280,000 curies at 1995) projected to be emplaced in the WIPP. [CARD 31, Application of Release Limits, Table 2 - Calculation of WIPP Disposal Radionuclide Activity]

In accordance with the strict requirements of EPA's certification, DOE shall not emplace RH-TRU wastes from any waste generator site in the repository unless it demonstrates that such waste generator site can adequately characterize the RH-TRU wastes to ensure that the RH-TRU waste inventory assumptions incorporated in the PA and PAVT are not violated.

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6. DOE says that the isotopes in RH-TRU will decay rapidly enough that its radiological effects will, in several hundred years, be similar to that of CH-TRU. DOE cannot credibly make such a statement because the radionuclide content of the waste scheduled for WIPP is unknown. (1179)

Response to Comment 6.J.6:

EPA disagrees with the commenter's assertion that the radionuclide content of the waste scheduled for WIPP is unknown. See the Response to Comments 6.M.4, 6.M.5, and 6.M.6.

DOE stated that the total RH contribution to the WIPP-Scale inventory of total TRU curie load is about two orders of magnitude less than that presented for the CH-TRU wastes -- because the majority of the curie content of the RH-TRU waste is due to shorter-lived non-transuranic radionuclides. Specifically, as the shorter-lived components decay away the remaining RH-TRU waste will have a lesser curie content than CH-TRU waste (i.e., as the RH-TRU waste decays, it becomes "simpler" than CH-TRU waste). This is evident from the RH Study which showed that after about 150 to 250 years that CH-TRU waste has a higher specific activity than that of RH-TRU waste. [CCA, Appendix WCA, Attachment WCA.8.2, Table 3]

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7. Testimony on Monday further confused the receipt of contact-handled waste and remote handled waste. . . We had at the WIPP a contingency to overpack any container that we believed could pose a radiological threat to workers, the public or the environment. For RH transuranic waste this overpacking capability is in a hot cell which provides a shielded environment for performing the necessary steps. Since the WIPP waste generators are not yet prepared to ship RH TRU waste and they will not likely be ready until some time during the next decade, we are not now focusing on the

operational readiness of RH facilities. When the time comes, the RH facilities will undergo the same rigorous operations of scrutiny we are now applying to contact handled facilities. (374)

Response to Comment 6.J.7:

Section 2(12) of the WIPP LWA defines "remote-handled transuranic waste" as transuranic waste with a surface dose rate of 200 millirem per hour or greater. Pursuant to the WIPP LWA "[n]o more than 5 percent by volume of the remote-handled transuranic waste received at WIPP may have a surface dose rate in excess of 100 rems per hour." [Section 7(a)(1)(B)] Further, the total curies of RH-TRU that can be received at WIPP cannot exceed 5.1 million curies. [Section 7(a)(2)(B)]

After reviewing the CCA, EPA determined that DOE did not provide any waste characterization methods for RH-TRU waste, nor was there discussion specific to how DOE will quantify the RH-TRU waste. All of the waste characterization discussions in the CCA's Chapter 4 are geared toward CH-TRU waste, except for Chapter 4, Table 4-13 [p. 4-49], which is entitled "Applicable CH- and RH-TRU Waste Component Characterization Methods." Furthermore, there was no discussion provided regarding the applicability of traditional CH-TRU waste characterization methods to RH-TRU waste. Therefore, EPA's certification decision addresses emplacement of RH-TRU wastes in the repository since it is included in the PA and PAVT. However, should DOE determine that it intends to emplace RH-TRU wastes from a waste generator site in the repository at some time in the future, it will have to demonstrate that such waste generator site can adequately characterize the RH-TRU wastes to ensure that the RH-TRU waste inventory assumptions incorporated in the PA and PAVT are not violated.

Issue K: Enforcing the "limits" with the system of controls

1. DOE does not demonstrate that it will enforce limits on the waste that may be brought to WIPP. Specifically, there is non showing of a system of controls to enforce waste limits that EPA's regulations require. (149)

Response to Comment 6.K.1:

The system of controls for WIPP waste has two phases for DOE's internal process. Phase I entails Waste Stream Screening and Verification, which will occur before waste is shipped to the WIPP, and is a three-step process. First, an initial audit of the site will be conducted by DOE's Carlsbad Area Office as part its audit program before the WIPP could begin the process of accepting waste from a site. The audit provides on-site verification of characterization procedures, data package preparation and record keeping. Second, the generator site personnel perform the waste characterization data package completeness/accuracy review and either accept or reject the data. Third, if the data is accepted, the site waste characterization data is transferred manually or electronically via the WWIS to the WIPP. At the WIPP, screening includes verification that all of the required elements of a waste characterization data package are present and that the data meet acceptance criteria required for compliance. Waste stream approval or rejection to ship to the WIPP is the outcome of Phase I.

Phase II includes examination of a waste shipment after it has arrived at the WIPP, and is a three-step process. First, upon receipt of a waste shipment, the WIPP personnel determine manifest completeness and sign the manifest before the driver may depart. Second, WIPP personnel determine waste shipment completeness by checking the bar-coded identification number found on each TRU waste container. The bar-coded identification number is noted and checked against the WWIS. The WWIS maintains waste container receipt and emplacement information. Third, waste shipment irregularities/discrepancies are identified and resolved. If there are discrepancies, the generator is contacted for resolution. Finally, WIPP personnel compare the container identification number with a list of those approved for disposal at the WIPP. Waste shipment approval or rejection for disposal at the WIPP is the outcome of Phase II. [CARD 24, Section 24.H.2]

Section 194.24(c)(4) requires DOE to demonstrate that a system of controls has been and will continue to be implemented to confirm that the waste components emplaced in the disposal system will not exceed the upper limits or fall below the lower limits calculated in accordance with Section 194.24(c)(1). Section 194.24(c)(5) requires that the system of controls conform to the QA requirements specified in Section 194.22. DOE described a system of controls over waste characterization activities, such as the requirements of the TRU QA Program Plan (TRU QAPP) and the WAC. EPA found that the TRU QAPP established appropriate technical quality control and performance standards for sites to use in developing site-specific sampling plans. If implemented as proposed, EPA believes that the TRU QAPP, WAC, and WWIS are adequate to control important components of waste emplaced in the WIPP. However, DOE did not demonstrate in the CCA that the WWIS is fully functional and did not provide information regarding the specific system of controls to be used at any waste generator site.

After receipt of the CCA on October 29, 1997, EPA received information regarding the system of controls (including measurement techniques) to be used at LANL. The Agency confirmed through inspections that the system of controls is adequate to characterize waste and ensure compliance with the limits of waste components, and also that a QA program had been established and executed at LANL in conformance with NQA requirements. [Docket: A-93-02, Item V-B-15] Moreover, DOE demonstrated that the WWIS is functional with respect to LANL -- i.e., that procedures are in place at LANL for adding information to the WWIS system, and that information can be transmitted from LANL to the central WWIS in DOE's Carlsbad Area Office. And incorporated into the central database, and that data in the WWIS database can be compiled to produce the types of reports described in the CCA for tracking compliance with the waste limits. Therefore, EPA finds that DOE demonstrated compliance with Sections 194.24(c)(4) and (5) for the legacy debris waste streams at LANL that can be characterized using the systems and processes audited by DOE and inspected by EPA as documented in Docket: A-93-02, Item II-I-70. EPA does not find, however, that DOE has demonstrated compliance with Section 194.24(c)(4) for any other waste stream at LANL, or with Sections 194.24(c)(4) and (5) at any other waste generator site.

Issue L: Waste inventory uncertainty and future changes

1. This inventory keeps changing markedly. The last two reports by DOE indicate that the existing transuranic waste at a number of sites have changed by a factor, in one case 10 to the 3, and in other cases by a factor of 5. This isn't fine tuning. This does suggest there is some major concern with the existing inventories that we have on our hands. (192)

2. The EPA has concurred with the DOE's contention that there is no uncertainty in the waste inventory. EEG's view is that : (1) there is considerable uncertainty in the stored inventory; (2) there is uncertainty in the volume of newly generated waste and the processes at the generating sites have changed significantly since the stored waste was generate; and (3) DOE plans to treat most of the waste at INEEL and the RFETS (residues) and repackage, and treat for size reduction, at other facilities. These plans are not reflected in CCA inventory. EPA should recognize this uncertainty and either not accept the DOE inventory and Waste Material Parameter (WMP) values or not permit DOE to bring in waste that differ significantly from the values in the CCA until more accurate inventory data have been developed and used in the PA calculation. (703)

3. DOE does not assert that there is no uncertainty in the waste inventory. Rather, DOE has acknowledged all those uncertainties and developed appropriate approaches to obtain the best estimates of waste inventory (DOE/CAO, TWBIR, 1996). The PA calculations are based on the values documented in Transuranic Waste Baseline Inventory Report (DOE/CAO, 1996), which is the best source so far available for waste inventory. The waste inventory and waste form may change in the future, but those changes will be taken into account in WIPP every-five-years re-certifications.

In addition, the repository performance is very robust. For example, the PA calculations show that brine release for most radionuclides will be solubility-limited; therefore, an increase in the radionuclide inventory will not significantly increase releases of radionuclides in brine. Furthermore, the quantity of MgO emplaced in the repository is enough to control repository chemistry, even if all waste drums are fully filled with cellulosics, plastics, and rubbers. Due to the robustness of WIPP repository, there is no perceivable changes (or uncertainty) in waste inventory or waste form that can degrade the performance of WIPP repository. (924)

4. Initially, the waste brought to WIPP will not be treated in any fashion. This is entirely in conformity with the PA accomplished in the CCA. The CCA conservatively did not employ any credit in the performance assessment using knowledge of the many waste streams that DOE intends to treat prior to shipment to WIPP. It is presumed that the EPA's pending certification of the WIPP will allow only waste types discussed in the CCA to be emplaced until a recertification application is prepared and submitted that includes the effects of emplacement of alternative forms of waste. If necessary, concerns at WIPP raised by proposals to dispose of alternative forms of waste will be addressed systematically in future recertification applications and in revised operating procedures at the WIPP. (933)

Response to Comments 6.L.1 through 6.L.4:

DOE did not provide the associated uncertainty for the waste component limits in the CCA. EPA had questioned the omission of associated uncertainties [Docket: A-93-02, Item II-I-17], and DOE responded by stating that the waste components limits are fixed with no associated uncertainty. The Agency examined this logic, together with how uncertainties are dealt with throughout DOE's performance assessment process. EPA concluded that DOE's approach captured the intent of the regulation, in that the limiting value is indeed conservative. DOE also stated that the plausible combinations of upper and lower limits were included in the performance assessment, particularly for 57 waste parameters that underwent Latin Hypercube Sampling (LHS). DOE asserted, and EPA concurs, that the combination of selected limits that result in the greatest estimated release was used in the analysis.

Although DOE has made minor changes to the volumes of wastes reported in the last two versions of the TWBID for several generator sites, the overall volume of waste has not changed significantly. Moreover, the Land Withdrawal Act caps the total volume and activity of waste to be disposed at the WIPP. Rather, the variation in the total curie content of the waste to be disposed of at the WIPP noted by the commenter was caused when DOE corrected its procedures for calculating both (1) the scaling factor used to scale the volume of the to-be-generated waste to fill the repository and (2) the waste unit factor at the time of disposal.[31]

Specifically, based upon waste emplacement and decay information, DOE initially concluded, in the CCA, that the waste unit factor would be 4.07, if closure occurred in 1995. [Appendix WCA of the CCA, Table WCA-5, p. WCA-21] To account for decay and ingrowth of radionuclides at the time of disposal, DOE used the EPAUNI computer code (Version 1.01). DOE thereby obtained a revised waste unit factor of 3.44 at the time of disposal (2033).

EPA, however, was not able to corroborate DOE's waste unit factor value of 4.07 for 1995. EPA's analysis of DOE's data led EPA to conclude that the value should be 4.28, instead, which is about 5% greater. DOE reviewed its work, and thought that it had resolved the discrepancy. [WPO #046766, Memorandum from Sayan Chakraborti, SAIC/CTAC to M. Chu, SNL, "Assumptions and Methodology Involved in the Estimation of the WIPP Disposal Radionuclide Inventory in the CCA," dated August 8, 1997] EPA reviewed DOE's August 8, 1997 memorandum and continued to believe that the correct value was 4.28. After one more round of discussions, DOE realized that it had failed to consider the contribution of TRU waste at an off-site facility of the Savannah River Site when calculating the scaling factor and total curie content. DOE agreed with EPA that the correct waste unit factor was 4.28, and when processed by the EPAUNI computer code so as to apply to a closure date of 2033, the TRU waste factor became 3.59.

EPA finds that the error is of little consequence, and that it, in fact, drives the values of computed normalized releases downward. Specifically, the error will bring about a roughly 5% *decrease* in all normalized releases, with a resulting shift to the left of any CCDF curve by that amount. That is, the correction of the error shows that the WIPP is even more capable of preventing releases, relative to

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[31] One *unit of TRU waste* is defined as that amount of radioactive waste that contains exactly one million curies of alpha-particle-emitting TRU radionuclides (with half-lives greater than 20 years) with a net TRU concentration of greater than 100 nCi/g -- regardless of the amounts of other radionuclides present.

the containment standard, than had been thought previously. This is discussed in greater detail in CARD 31, Application of Release Limits.

For purposes of this certification, the CCA did not incorporate any treatment of WIPP waste. It is reasonable to expect that, over time, the certain basic assumptions about the wastes will change. When changes occur, DOE is required to report to EPA any planned or unplanned changes in activities or conditions pertaining to the disposal system that differ significantly from the most recent compliance application. Moreover, if DOE should determine to engage in waste treatment prior to emplacement that would require a modification of the certification which would be accomplished through a rulemaking procedure in accordance with Section 194.67.

Issue M: Waste inventory data test for performance assessment sufficiency

1. What test did EPA apply to determine that the waste inventory data was "sufficient for PA purposes?" (p. 24-8) (60)

2. As a taxpayer, and with respect to WIPP, I do not want to pay for the collection of information that is not of direct relevance to ensuring either safe, long-term repository performance or operational safety, so knowing the exact contents of waste containers, for instance, may not be necessary. (442)

3. In a meeting with citizens on December 10, 1997, EPA admitted that the waste characterization information used by DOE and EPA in the performance assessment was unreliable and unverifiable. EPA's explanation for accepting this data was that EPA would take particular care to be sure that each drum that goes to WIPP would not fall outside DOE'S self proposed waste sense element. . . In other words, the PA was considered to be conceptual but the criteria imposed by EPA and the waste certification of each drum would be verifiable and specific. The problems which plague the conceptual data used in the PA, however, have not been eliminated from the waste characterization of specific drums. (501)

Response to Comments 6.M.1 through 6.M.3:

EPA did not apply a specific "test" to support its determination that waste inventory data were sufficient for purposes of performance assessment. Rather, the Agency undertook an extensive review of the TWBIR, Revision 3 in making its determination. The data contained in TWBIR were used by DOE to demonstrate compliance with 40 CFR 191.24(a), which requires DOE to describe the composition of all existing and projected wastes proposed for disposal in the WIPP, and to provide sufficient overall waste inventory information for use in the PA, specifically for those components deemed important to repository performance.

The objective of EPA's evaluation of the TWBIR was to document the traceability of key parameters used in the WIPP Performance Assessment. Specifically, EPA evaluated the completeness with which

DOE met the requirements of 40 CFR 194.24(a), as documented by its description of the wastes currently held in inventory and the wastes projected for disposal at the WIPP. EPA's review of the inventory data contained in the TWBIR was restricted to DOE's process for gathering and representing the information obtained from the generator sites. EPA used four criteria to conduct its review:

- ♦ Adequacy: EPA reviewed the TWBIR to ensure that DOE's description of wastes and waste components was adequate to allow the Agency to conduct a qualitative assessment of the adequacy of the chemical, physical, and radiological characteristics of the waste and waste components proposed for disposal at the WIPP.

- ♦ Traceability: EPA reviewed the TWBIR to ensure that the data were traceable to the data submitted by the generator/storage sites.

- ♦ Representation: EPA's analysis was designed to ensure that DOE provided a description of the chemical, physical, and radiological characteristics of the waste and waste components that truly represents the wastes currently stored, and to the extent practicable, the wastes to-be-generated that are proposed for disposal at the WIPP.

- ♦ Sufficiency: EPA reviewed the data contained in the TWBIR to determine if DOE: (1) provided sufficient documentation of its methodologies; (2) provided information at a level of detail that would enable the Agency to have a high level of confidence that DOE accurately represented the inventory; and (3) identified and characterized all components of the waste that could significantly affect repository performance.

As documented in Technical Support Document for Section 194.24: Analysis of TWBIR, Revision 3 [Docket No: A-93-02, Item V-B-15], EPA applied the four criteria described above to its review of DOE's submission to determine whether it had provided a reasonably complete description of the chemical, radiological, and physical composition (and quantities) of the existing and to-be-generated wastes proposed for disposal in the WIPP. (DOE provided descriptions of the chemical, radiological, and physical components of the waste in the CCA, Section 4.1, pp. 4-5 through 4-24 and TWBIR Rev. 3.) EPA reviewed this information and concluded:

- ♦ Chemical: DOE's discussion of both the retrievably stored and to-be-generated waste included descriptions of process chemicals likely to be present in the waste, other added components (neutralizers, stabilizers, solidifiers, etc.), approximate total quantities, and the chemical properties of other items present in the waste that could impact performance.

- ♦ Radiological: DOE's waste stream profile forms in Appendix BIR and other references [Sanchez, et.al, 1997, Appendix WCA] presented sufficient information on the species and quantities of individual radioisotopes in the waste to develop radiological descriptions on the species and quantities of the radioisotopes present in the waste and types of radiation emitted from the waste. EPA notes that other information, such as estimates of curie distribution per container, and surface dose rate, while not explicitly provided in the CCA, can be calculated using the information contained in CCA, Appendix BIR, Appendix P.

- Physical: DOE's physical description of waste included the types of items, articles, and materials present in the waste (void space is inferred by waste porosity values used in PA), physical forms, and types of containers used in disposal. (Although liquid content was not included, EPA notes that this will be acquired for each drum using real-time radiography, when DOE characterizes each drum prior to shipment.)

For a complete discussion of EPA's review of the chemical, radiological, and physical properties of the waste intended for disposal at the WIPP, see Docket No: A-93-02, Item V-B-15.

The Compliance criteria at 40 CFR 194.24(a) requires DOE to include a description of the waste including "a list of waste components and their approximate quantities." EPA expected DOE to provide a description of waste composition that is "semi-quantitative" and sufficiently detailed to "enable EPA to have confidence that no component that is present in transuranic waste and has significant potential to influence releases of radionuclides has been overlooked." [Compliance Application Guidance for WIPP, Docket: A-93-02, Item II-B-29] EPA has determined that DOE adequately identified waste components for purposes of performance assessment.

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4. EPA should not certify WIPP because there is not adequate waste characterization information, which is essential for a credible certification. . .Thus the CCA is fundamentally flawed as relates [sic] to many important aspects, including: radionuclide inventory, repository loading, and synergistic effects of radionuclides and hazards [sic] chemicals on repository performance. 194.24 (1108)

5. [In its proposed rule EPA did not use:] Real waste characterization, inventory, and repository limits information, based on actual data and including such information as that DOE and contractor personnel falsified records at Rocky Flats as disclosed by the FBI raid on and investigation of Rocky Flats. (1144)

6. [N]either DOE nor EPA has done an analysis in which, for example, all Rocky Flats residues and scrub alloys were put into a room through which there is direct drilling. In such a case, the containment limits would be exceeded. Thus, PA runs must be redone assuming such waste loading and reissued for public comment. (1160)

<u>Response to Comments 6.M.4 through 6.M.6:</u>

The Agency disagrees with the commenters' concern that the CCA is flawed because it does not contain adequate (or accurate) waste characterization information. EPA notes that DOE provided descriptions of the chemical, radiological, and physical components of the waste in Section 4.1, pp. 4-5 through 4-24 of the CCA and in the TWBIR Rev. 3 that describe the radiological and physical characteristics of each waste stream (both existing and to-be-generated) proposed for disposal at the

WIPP. DOE's waste profiles contain specific information on the species and quantities of individual radioisotopes in the waste. Additional information, such as curie distribution per container, and surface dose rate, while not explicitly provided in the CCA, can be calculated using the information contained in CCA, Appendix BIR, Appendix P. Descriptions of the chemical components of the waste streams are provided as cross references to EPA hazardous waste codes and are located in Appendix BIR. [Appendix P]

EPA reviewed TWBIR Rev. 3 [Docket: A- 93-02, II-G-1], which includes the best information available to DOE to date. Specifically, the TWBIR is a collection of waste profile forms that include isotope data, waste material parameter densities, hazardous waste codes, final waste form descriptions, waste stream source, stored and projected waste volumes, and detailed descriptions of container contents. These data were assembled by the generator sites based upon a variety of information, including sample analysis information and acceptable knowledge. Therefore, information used by EPA to assess the WIPP waste inventory is based on data provided directly by the generator sites. EPA concludes that it is sufficiently comprehensive and accurate to meet the requirements of 40 CFR 194.24(a). [Technical Support Document, Docket: A- 93-02, V-B-15]

Therefore, based on the above discussion, EPA believes that the commenter's concern that the CCA is fundamentally flawed as relates [sic] to many important aspects, including: radionuclide inventory, repository loading, and synergistic effects of radionuclides and hazards [sic] chemicals on repository performance is unfounded. For a complete discussion regarding EPA's review of the radionuclide inventory, see CARD 24, "Waste Characterization" and Technical Support Document. [Docket: A-93-02, V-B-15] For a complete discussion of EPA's analysis of repository loading, see CARD 24, "Waste Characterization", Section 24.J. For a complete discussion of EPA's analysis of the synergistic effects of radionuclides and hazardous chemicals on repository performance, see Technical Support Document for Section 194.32: Scope of Performance Assessments. [Docket: A- 93-02, Item V-B-13]

Lastly, with regard to the commenter's concern that some of the waste analysis data was potentially falsified, EPA is unaware of instances where waste form, matrix parameters, or content codes were falsified and notes that each container of TRU waste will undergo complete analysis, including headspace gas sampling, radiographic examination, and non destructive assay using certified systems at the generator and/or storage site prior to being accepted for disposal at the WIPP. [Appendix WAP, Docket: A- 93-02, II-G-1, pp. C-21 through C-30] This suite of analyses will ensure that each container meets waste limit requirements and that the necessary waste material parameters, including radionuclides, are characterized.

Issue N: Waste acceptance criteria changes

1. Relying on the WIPP Waste Acceptance Criteria (WAC) to define the limits of the waste characteristics for WIPP waste is disingenuous at best. The WIPP WAC is constantly changing which reflects generator site requirements for waste removal, not the physical limits of the WIPP site. To be complete, the CCA must include a better assessment [sic] the characteristics of all waste, with limiting values for each component. In addition, the CCA should include a description of quality

assurance controls for sampling technologies, measurement techniques, chain of custody records, record keeping systems, waste loading schemes, inventory control, and generator site approval and certification processes, including audits and monitoring of the records. (1211)

Response to Comment 6.N.1:

DOE indicates that the WAC are founded on transportation requirements, safety analysis criteria, and regulatory requirements. [CCA, 4-30] DOE also acknowledges that the current WIPP WAC [1996] does not contain restrictions based upon performance assessment criteria. [CCA, p. 4-30] The CCA, not the WAC alone, is where the waste limits evaluated by EPA are contained. [Appendix WCL] Physical limits for waste characteristics are not based on WAC criteria but tabulated from container specific information obtained from Real Time Radiography or Visual Examination, documented on Waste Stream Profile Forms and tracked in the WIPP Waste Information System. [Appendix WAP, pp. C-22, C-23, C-35, and Figure C-4] The Site Project Manager at each generator site will be responsible for determining that the waste material parameter weights are available for each waste stream. [Appendix WAP p. C8-21] The WWIS structure indicates that waste material parameters and weights are tabulated for each container. [Appendix WAP p. C13-11]

EPA has found that quality assurance controls are specified in CCA Appendices and references as follows:

Sampling Techniques

- ♦ Sections 7-8 of Transuranic Waste Characterization Quality Assurance Program Plan [Reference 201]
- ♦ Sections C8-2 and C8-3 of Appendix WAP [pp. C8-4 through C8-8]
- ♦ Section C4-1b [pp. C4-7 through C4-9], Section C4-2b [pp. C4-14 through C4-16]
- ♦ Section C4-3b [pp. C4-18 through C4-22] of Appendix WAP
- ♦ Sections 110.1, 110.2, 110.3, 110.4, and 120.1 of the WIPP Waste Characterization Sampling and Analysis Methods Manual [Reference 210]

Measurement Techniques

- ♦ Sections 9-15 of Transuranic Waste Characterization Quality Assurance Program Plan [Reference 201]
- ♦ Sections C8-4 through C8-8 of Appendix WAP [pp. C8-8 through C8-13]

- Sections 310.1, 310.2, 430.1 through 430.7, 440.1 through 440.3, 510.1, 520.1, 610.1, 620.1, 630.1, 640.1, and 650.1 through 650.7 of the WIPP Waste Characterization Sampling and Analysis Methods Manual [Reference 210]

Sample Chain of Custody

- Sections 6.1 through 6.3 of the Transuranic Waste Characterization Quality Assurance Program Plan [Reference 201]

- Section C4-4 [pp. C4-22 through C4-23] of Appendix WAP

WIPP WWIS Data Reporting (encompasses inventory control, waste loading schemes, monitoring of records, and record keeping systems)

- Pages C13-1 through C13-12 of Appendix WAP (The WWIS Data Dictionary details field specific limits, edits, and range checks that serve as quality control functions for data entry)

- Sections C8-10 through C8-13 of Appendix WAP [pp. C8-15 through C8-27] details validation, review, and corrective action processes

- Section 3 of the Transuranic Waste Characterization Quality Assurance Program Plan [Reference 201]

Generator site approval and certification processes (including audits)

- Section 2 of the Transuranic Waste Characterization Quality Assurance Program Plan [Reference 201]

- Pages C11-1 through C11-5 of Appendix WAP details audit requirements for site generator facilities.

Issue O: Unannounced audits

1. [I]f DOE proceeds to dispose of nonmixed TRU waste without a RCRA permit, it becomes even more critical that EPA carefully assess and closely monitors all waste characterization and certification activities at the various DOE generator and storage facilities. We specifically recommend that EPA use unannounced comprehensive site audits of those facilities throughout the early years of WIPP's operation life. (409)

Response to Comment 6.O.1:

For the compliance certification and all subsequent re-certifications, EPA has the authority under 40 CFR 194.21 (Inspections) to have "unfettered and unannounced access to inspect any area of the

WIPP, and any locations performing activities that provide information relevant to compliance application(s), to which the Department [DOE] has rights of access." Furthermore, EPA will be allowed to obtain samples, monitor and measure the disposal system and waste proposed for disposal, and review records by DOE pertaining to the WIPP.

Issue P: Waste analysis

1. The CCA does not contain the waste analysis of characteristics influencing the containment of waste, with limiting values, plausible combinations of limiting values, and a showing of compliance at the limits – all as required by EPA's regulations. (148)

2. The waste description in CCA Chapter 4 and the associated appendices is not sufficient to determine whether all waste characteristics and components have been identified and evaluated. Section 194.24(b)(l)-(3) requires an analysis of all waste characteristics and associated components for their impact on disposal system performance, except as to characteristics and components whose exclusion is justified. The sensitivity analysis in Appendix SA does not cover the items required. (957)

Response to Comments 6.P.1 and 6.P.2:

Section 194.24(b) of the Compliance Criteria requires that all waste characteristics influencing containment of wastes be identified and assessed, and that all waste components influencing waste characteristics be identified and assessed. Section 194.24(c) requires that all for all waste components identified and assessed in accordance with Section 194.24(b), limiting values be determined. Section 194(c) and (c)(1) require that for each waste component identified in accordance with Section 194.24(b)(2), the DOE must specify the limiting value (expressed as an upper or lower limit of mass, volume, curies, concentration, etc.) of the total inventory of such waste proposed for disposal in the disposal system. The CCA must demonstrate that, for the total inventory of waste proposed for disposal, WIPP complies with the numeric requirements of 194.34 and 194.55 for the upper or lower limits, and for the plausible combinations of upper or lower limits of such waste components that would result in the greatest estimated releases.
EPA expected the compliance application to provide a detailed description of a waste characterization analysis that identifies a list of waste characteristics retained as a result of the analysis and explains the rationale for excluding any others. [See CARD No. 24, Section 24.B.1 for a detailed discussion of EPA's evaluation of this analysis] DOE first identified those waste characteristics pertinent to the WIPP as part of its screening of features, events, and processes (FEPs). Those FEPs screened into performance assessment served as the basis from which waste characteristics and associated components were identified and further analyzed. [Docket: A- 93-02, II-G-01, Appendix SCR]

Performance assessment modeling and sensitivity analysis were performed by DOE, with verification testing mandated by EPA. [Docket: A-93-02, Item II-I-25] EPA examined the waste characteristic and component parameters that were determined to be important for performance assessment, and EPA concluded that the waste limits proposed by DOE are appropriate and capture the limitations necessary to ensure containment capability of the WIPP. [Docket: A-93-02, Item V-B-13]

DOE performed a thorough analysis of the waste characteristics and associated components that may be present in WIPP waste. This analysis included the full spectrum of possible characteristics and components. [CARD 24, Section 24.B] EPA examined this analysis, and determined that all possible waste characteristics within WIPP waste had been identified and assessed by DOE to determine those which impact WIPP performance. [62 FR 58813]

DOE presented the results of its waste characteristic and components analyses pursuant to Section 194.24(b)(1) in a number of documents, including Chapter 4 of the CCA [CCA, Table 4-7. p. 4-27] and Appendix WCA. [CCA, Table WCA-12] DOE developed a thorough listing of waste characteristics that could impact WIPP performance. DOE indicated [CCA, Table 4-7, p. 4-27] that the following characteristics were expected to have a significant effect on disposal system performance and were used in performance assessment (i.e., parameters were identified for each):

- Solubility (including redox state and redox potential);
- Formation of colloidal suspensions containing radionuclides;
- Production of gas from the waste (hydrogen, and microbial substrate/ nutrients for methane gas generation);
- Shear strength, compactibility (waste compressibility), and particle diameter;
- Radioactivity in curies of each isotope; and
- TRU radioactivity at closure.

EPA reviewed information on waste characteristics and components in a number of technical documents, including those cited above. References were examined, both individually and in concert, to determine whether DOE presented rational and logical arguments for all characteristic and associated component identifications. EPA considered whether all relevant waste characteristics and components were identified and evaluated. [Docket: A-93-02, Item V-B-15] Screening procedures were used to determine whether or not waste characteristics and components were examined for reasonableness and consistency of application. [CARD No. 24, Section 24.B] Results of DOE experimental programs as they pertain to identified characteristics and components were also examined in detail to determine whether conclusions drawn by DOE, based upon experimental program results, were sound. [CARD No. 24, Section 24.B] In addition, DOE's sensitivity analysis, as well as applicable bounding analysis, were also examined to determine whether the sensitivity analysis includes all applicable components; and to review the application of sensitivity analysis results. [Docket: A-93-02, Item V-B-13] All information was examined relative to the waste inventory and its associated uncertainties. [194.24(a), refer to Docket: A-93-02, Item V-B-15 and CARD No. 24, Section 24.B], as well as to how the results of the analysis impact proposed waste limits [194.24(c), refer to CARD No. 24, Section 24.C]

The identification of significant waste characteristics was an important step in this process, and the CCA was examined to determine whether a complete listing of all possible waste characteristics was identified. [CARD No. 24, Section 24.D] Those waste characteristics already included in PA were also examined to assess whether they were important to disposal system performance (i.e., some characteristics are included in modeling to provide a more comprehensive and realistic presentation of system performance, but sensitivity of system performance to the characteristic or components appears to be minimal). [CARD No. 24, Section 24.D]

3. Certain statements in Compliance Application Review Document (CARD) 24 are incorrect. It is said that "each container of TRU waste will undergo complete radiological and physical waste characterization at the generator and/or storage site prior to being accepted for disposal at the WIPP, which will further refine the current waste characterization understanding on a drum-by-drum basis" (at 24-8). Such characterization is not planned. (953)

4. [I]t is erroneous for EPA to assert that the waste data in the BIR constitute "characterization data" (CARD 24 at 24-112), since DOE recognizes that it is not such (See CCA at 4-12). (954)

5. On page 4-12 of the CCA, DOE states that the BIR is "not a summary of TRU waste characterization data." Nonetheless, EPA is treating that BIR data as waste characterization (CARD 24-112). The CCA does not contain actual waste characterization information on Los Alamos to provide a technical and statistical basis for the reliability and accuracy of waste characterization there. Thus, the CCA has not demonstrated compliance with 194.24(b) for any waste streams at any site. . . (1152)

Response to Comments 6.P.3 through 6.P.5:

EPA agrees with the comments that the data provided by DOE in the BIR does not constitute waste "characterization data," and acknowledges that the response to comment to which the comment refers [CARD No. 24, Response to Comments, Response to Issue B, p. 24-112] was inartfully drafted. The BIR does not provide specific information on individual components contained in individual waste containers to be emplaced at the WIPP, as is required for actual "waste characterization." However, EPA believes that DOE provided comprehensive data for hundreds of waste streams based upon characterization techniques such as sampling, analysis, and acceptable knowledge, and the BIR presents sufficient inventory information to satisfy the requirements of 194.24(a). [62 FR 58813]

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6. The CCA has not provided an adequate explanation of the gas generation rates used, especially those rates resulting from shorter term tests and low pH. (1151)

Response to Comment 6.P.6:

The primary gas expected to be produced in the repository is CO_2(g); a product of the microbial degradation of organic waste materials. The exact amount of microbial activity is not known, hence significant organic degradation was assumed to occur for 50% of the realizations used for in the PA calculations. This approach is described on p. SOTERM-4 of Appendix SOTERM of the CCA. Based on the conceptualization of the repository as being a system in chemical equilibrium, it is expected that carbonation reactions involving the MgO will fix the partial pressure of CO_2(g) to a discrete value imposed by hydromagnesite formation. For the purposes of the PA calculations, the potential concentrations of actinide solids in any infiltrating brines are defined by the solubilities of specific actinide solids under the CO_2(g) partial pressure conditions imposed by hydromagnesite equilibrium. This CO_2(g) partial pressure is used for the PA calculations, hence the calculation are not dependent on any specific gas generation rate in that the presence of CO_2(g) is implicitly assumed.

Issue Q: MgO load

1. An excess of CRP in a waste panel could overload the MgO in that panel and since no interchange of brine between panels is assumed, it is questionable how much benefit would incur from excess MgO in another panel. Estimated concentrations of CRP do vary significantly between generating sites (e.g. at INEEL the average is 1.8 times the total inventory average). (705)(1283)

Response to Comment 6.Q.1:

One of the principal benefits of the MgO backfill plan is that it compensates for uncertainty in predicted rate of CO_2 gas generation in the WIPP. Carbon dioxide generated by microbial degradation of Cellulosics, Rubbers, and Plastics (CRP) will be alkalized and precipitated by MgO.

The Agency believes that the commenter's recommendation that a load management plan be instituted on a per panel bases to ensure that the quantity of MgO is met in each panel is unnecessary. The conceptual model for MgO is built on the following conservative factors:

- 74% excess of MgO emplaced in the repository;
- Ignores the consumption of CO_2 by other materials in the repository (e.g. Portland cement); and
- Entire cellulosics, plastics, and rubbers inventory will completely biodegrade to CO_2 and methane.

With the built-in conservatism, the Agency believes that potential for overloading the MgO in a panel with excess of CRP poses no threat to the repository. The commenter assumes that no interchange of brine will occur between panels, however, the CO_2 gas generated by microbes will interact between panels through disturbed rock zones and anhydrite interbeds.

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2. A management plan that allows emplacement of repository limited parameter quantities that vary significantly from the required average could result in a situation where the required limit could not be met by emplacing the remainder of the inventory. This is a potential problem because the actual content of the waste containers will be known only as the individual containers are characterized and

may be much different than the current estimates. EEG believes that the case for controlling limits on repository basis has not been justified. We recommend control on a per panel basis, at least, until the inventory is known with more certainty. (706)(1283)

Response to Comment 6.Q.2:

The Agency believes that the commenter's recommendation that a load management plan be instituted on a per panel basis to ensure that the limited parameter quantities are met in each panel is unnecessary. Specifically, the minimum required emplacement limits of 2×10^7 kilograms of ferrous metals (iron) and 2×10^3 kilograms of nonferrous metals (metals other than iron) will easily be met through consideration of the ferrous and nonferrous metal contributed by waste containers and lead shielding. Thus, as only containerized waste will be placed in the WIPP, there will always be a sufficient supply of ferrous and nonferrous metals in each panel. EPA notes that an additional margin of safety will be realized through contribution of the significant, additional (but not considered) quantities of both ferrous and nonferrous metals associated with the waste itself (e.g., tools, piping, lead-lined apparel, and metallic sludges). See DOE's Transuranic Waste Baseline Inventory Report (TWBIR), Revision 3 and EPA's review of the TWBIR [Technical Support Document for Section 194.24: Docket No: A-93-02, Item V-B-15] for a complete description and accounting of the ferrous and nonferrous metals to be placed in the WIPP.

Issue R: Condition 3

1. I do not believe the EPA should be expected to regulate waste characterization activities at the generator site facilities by conducting its own independent audits and inspections. This would add no greater protection to the public and the environment but would significantly and unnecessarily increase the life cycle costs of transuranic waste characterization activities and keep the risk where it presently is longer. (197)

2. The EPA now wants to certify each of the some 570 waste streams that are destined for disposal and introduce the 30-day comment period prior to the certification of each waste stream. If we optimistically assume that a certification rule can be compete in three months, it would take the EPA about 142 years to certify all of those waste streams. Even if the EPA does simultaneously certify ten waste streams at a time, the process would take more than 14 years. (381)

Response to Comments 6.R.1 and 6.R.2:

The WIPP LWA requires EPA to, among other things, develop, through informal rulemaking pursuant to Section 4 of the Administrative Procedure Act (APA), criteria by which to certify whether the WIPP will comply with EPA's radioactive waste disposal regulations at 40 CFR Part 191 [LWA, Section 8(c)], and utilize such criteria to certify, through informal rulemaking pursuant to Section 4 of the APA, whether the WIPP will comply with such regulations. [LWA, Section 8(d)(2)] EPA duly promulgated the Compliance criteria [40 CFR Part 194] pursuant to the notice and comment obligations of the APA. [61 FR 5224] Therefore, EPA has a legal obligation to utilize these Criteria in its determination of whether the WIPP will comply with the 40 CFR Part 191 regulations. In other words, EPA has no legal authority to ignore or disregard the requirements of the Compliance criteria in making its determination. Thus, the quality assurance and waste characterization conditions (conditions 2 and 3) imposed on EPA's certification that the WIPP will comply with the Part 191 regulations reflect the fact that DOE did not demonstrate complete compliance with Sections 194.22(a)(2)(i), 194.24(c)(3), 194.24(c)(4), and 194.24(c)(5) of the Compliance criteria where applicable at certain waste generator sites.

In making its certification decision, EPA cannot address such issues as to whether demonstration of compliance with these regulatory requirements will impact DOE's schedule for placing transuranic wastes in the WIPP, is "redundant," or constitutes a "needless duplication of effort." EPA is legally required to determine whether DOE has met the requirements of the Compliance criteria. The waste characterization requirements, including quality assurance requirements applied to waste characterization activities, are necessary to provide enhanced confidence that the bases upon which EPA has certified that the WIPP will comply with the Part 191 radioactive waste disposal regulations remain in effect.

As set forth in the rule, EPA has determined that DOE has only met the specific waste characterization and quality assurance requirements at issue for the identified waste streams at one waste generator site. DOE must also demonstrate that it has met these requirements at other waste generator sites in order for the wastes at those sites to be emplaced in WIPP.

Issue S: The Compliance Certification Application satisfies the requirements of 40 CFR 194.24.

1. Conditions two and three of the proposed rule are predicated on perceived deficiencies in complying with the requirements of 40 CFR 194.24 subsection c paragraphs three, four, and five. Paragraph three requires that the use of process knowledge conforms with the quality assurance requirements of 40 CFR 194.22. By validating in the proposed rule that the requirements regarding process knowledge in 40 CFR 194.24(a) have been met, the EPA has already agreed this paragraph three requirement has been met. The proposed long-term public review and EPA involvement in the detailed site certification process which is done for individual waste containers cannot add any quality assurance to the past use of process knowledge for projecting and analyzing the total inventory. Paragraph four requires that a system of controls be implemented to confirm that the total amount of each waste component that will be placed in the disposal system will not exceed the limits established as safe. DOE utilizes the waste information system and computerized data base to meet this requirement and has fully described the system in the Compliance Certification Application. The EPA has reviewed, observed and audited this system and has approved this system in the proposed rule. Paragraph five requires that the same controls be identified and described and that they are applied in accordance with the quality assurance requirements found in 194.22. Again, the WIPP waste information system is fully identified and described in the Compliance Certification Application, and EPA has validated this system and associated quality assurance controls in the proposed rule. (220)

2. DOE satisfied the requirements of sections 194.24(c)(3)-(4) and 194.22(a) by providing information in the CCA which demonstrates that, unless a site develops and implements the required procedures for waste characterization, waste certification and transportation certification, it will not

be authorized to ship waste to WIPP. DOE/CAO and EPA will use audits and inspections to ensure that sites abide by the terms and conditions of their certification. As discussed above, the terms and conditions of a site's certification will change as new waste streams are readied for shipment to WIPP and new techniques and equipment are used to characterize wastes. (947)

Response to Comments 6.S.1 and 6.S.2:

Conditions 2 and 3 are not perceived deficiencies, rather they are observed deficiencies. Under 40 CFR 194.22 (a)(2)(i), DOE is required to demonstrate that a quality assurance program in accordance with NQA standards, has been "established and executed" for waste characterization activities and assumptions. Also, under Sections 194.24 (c)(3-5), DOE is required to provide information that demonstrate the following: (1) that use of process knowledge to quantify waste components meets the requirements of Section 194.22(a)(2)(i); (2) that a system of controls has been and will continue to be implemented to confirm that the total amounts of waste components to be emplaced at WIPP will not exceed the established limits under Section 194.24(c); and (3) that such system of controls meets the quality assurance requirements of Section 194.22(a)(2)(i).

After evaluating the CCA, additional information provided by DOE, and the results of EPA's inspections of DOE's audits conducted on May 12, August 18-20, and September 10-11, 1997, EPA concluded that DOE did not demonstrate compliance with the requisite requirements for any waste generator sites where waste characterization activities will be conducted, with the exception of LANL, which was found to be in compliance for the category of retrievably stored (legacy) debris waste. [Inspection of Carlsbad Area Office (CAO) audit of Los Alamos National Laboratory, Docket No. A-93-02, item II-A-5; and CARD 24] Five sites have DOE approved QA plans (although these have not been demonstrated to be established and executed) and are in the process of buying and setting up equipment for the characterization activities, other sites have QA plans that have not been finalized, and others are in various stages of development of their QA plans. In addition, DOE did not provide specific information on the use of process knowledge at any waste generator sites (other than LANL).

It is incorrect to assume that EPA's determination that DOE has complied with the requirement of Section 194.24(a) of the Compliance criteria somehow constitutes a finding of compliance with the requirements of Section 194.24(c)(3). Section 194.24(a) requires DOE to provide in the CCA a description of the chemical, radiological, and physical composition of all existing and to-be-generated waste, including a list of waste components and their approximate quantities. The requirement suggests that the list may be derived from process knowledge information, as well as other available sources. Section 194.24(c)(3) requires DOE to provide information which demonstrates that the use of process knowledge to quantify components in waste for disposal conforms with the quality assurance requirements in Section 194.22. DOE did not provide specific information demonstrating establishment and execution of the required QA program for use of process knowledge at any waste generator site other than LANL. The use of the process knowledge information for Sections 194.24(a) and 194.24(c)(3) differs in that in the former process knowledge information is suggested to be used as a tool to generate an estimate of waste component amounts. In Section 194.24(c)(3), however, process knowledge is used to quantify the waste components amounts. Therefore, meeting the Section

194.24(a) has no bearing on whether DOE has demonstrated compliance with Section 194.24(c)(3).

EPA would also like to clarify that EPA's site approval process is different from DOE's certification process. Prior to approving shipment of TRU wastes from a waste generator site for emplacement at WIPP, EPA will assess whether DOE has demonstrated compliance with the requirements of Sections 194.22(a)(2)(i) and 194.24(c)(3-5). Waste generators sites produce relevant information on waste components that is critical to the performance of the WIPP disposal facility. The predictions made by the performance assessments, which were the basis for compliance with the radioactive waste disposal standards, set up limits on waste components that are fixed throughout the duration of this certification. Waste characterization activities will generate critical information on the amount of waste components comprising the various waste streams to be emplaced at WIPP. Evaluation of waste characterization quality assurance activities, waste analysis procedures, waste characterization instrumentation and techniques, etc. are of paramount importance in determining whether DOE has the ability to adhere to the identified waste component limits. Thus, the waste characterization requirements, including quality assurance requirements applied to waste characterization activities, are necessary to provide enhanced confidence that the bases upon which EPA has certified that the WIPP will comply with the Part 191 radioactive waste disposal regulations remain in effect.

It is stated that EPA has reviewed, observed, audited, and validated the WIPP waste information system and database as part of determining compliance with the requirements dealing with the system of controls and that DOE provided a full description of the system. This is correct; however, as stated in the final rule, DOE did not demonstrate that the WIPP waste information system is fully functional nor did DOE provide information regarding the specific system of controls to be used at individual waste generator sites. The evaluation of the execution of the QA program for the waste characterization activities requires EPA to witness actual demonstrations of QA procedures being implemented for process knowledge and systems of control. The evaluation of the waste characterization requirements involve actual implementation of procedures for the use process knowledge for waste characterization. To demonstrate implementation of system of controls, for example, DOE must demonstrate that measurement techniques and control methods can be implemented for each waste stream or waste streams. Further, the WIPP waste information system must be demonstrated to be functional at the waste site before any shipment of waste for emplacement at WIPP, and have procedures in place for data entry, compilation, and reporting.

Issue T: Each waste stream needs to be certified by EPA

1. EPA's certification of site waste characterization techniques and procedures for each waste stream is the only way to verify that waste shipped to WIPP will actually fall within the envelope defined by the performance assessment. EPA, however, fails to require the needed specificity for this check. (1214)

Response to Comment 6.T.1:

EPA must clarify the commenter's misimpression that each waste stream must be separately approved by EPA. EPA will be making determinations as to whether DOE has demonstrated that the requirements of Sections 194.22(a)(2)(i) and 194.24(c)(3-5), concerning quality assurance and waste characterization, respectively, have been met for all transuranic waste to be shipped to the WIPP. With respect to waste characterization, EPA will be determining whether DOE has (1) provided adequate information on the process knowledge to be used, (2) demonstrated application of quality assurance processes to the utilization of such process knowledge, (3) implemented a system of controls to confirm on an ongoing basis the amount of each waste component to be emplaced in the repository, and (4) demonstrated application of quality assurance processes to such system of controls. Thus, to the extent that these waste characterization procedures are applicable to multiple waste streams, EPA will not be conducting separate waste stream-specific approvals. For more information on how waste is characterized, see Issue A.

Issue U: Hydromagnesite and Nesquehonite

1. DOE's experiments never identified hydromagnesite as a reaction product. Nor has EPA verified that hydromagnesite will be the dominant stable species. SNL's 4/23/97 report identifies a poorly characterized $MgCO_3{\cdot}3H_2O{\cdot}MgCl(OH)$ phase as hydromagnesite-like. It is actually more like nesquehonite ($MgCO_3{\cdot}3H_2O$) than hydromagnesite [$(MgCO_3)_4{\cdot}Mg(OH)_2{\cdot}4H_2O$]. (37)

2. Cutting to short on this, DOE is planning a magnesium oxide backfill. The question that occurs is whether chemical reactions will result. In the reciprocated - with nesquehonite rather than hydromagnesite with clear water molecules, or the actinides could be highly soluble in the presence of nesquehonite. (193)

3. Experimental as well as extensive natural analog data have shown that the hydration of a magnesite oxide backfill will produce hydromagnesite and eventually magnesite instead of nesquehonite. The EEG chose to ignore the scientific evidence and decided to use nesquehonite as the chemical mineral in their own calculations. (324)

4. One is the recent issue of nesquehonite that has been raised by several people. I just want to get it into the record that back when we were undergoing the independent peer reviews, Sandia scientists made a fair and candid presentation of all the nesquehonite issues, conceptual model peer review panel. That issue was discussed, and it was documented in their findings and essentially they didn't think it was an issue. (575)

5. Perhaps the most important questionable assumption made in projecting the solubility values used in the CCA and the PAVT is the presence of hydromagnesite as the dominant stable mineral species resulting from the MgO backfill. . . Hydromagnesite was not formed in the experiments reported by DOE (Van Bynum, Docket: A-93-02, Item II-A-39); a hydromagnesite-like unnamed mineral is reported. The chemical structure of this mineral is in fact more like nesquehonite. DOE and the EPA believe that "hydromagnesite will be the metastable hydrated magnesium carbonate phase and nesquehonite will be an intermediate phase." (EPA Technical Support Document V-B-15). There is no experimental data for the length of time that nesquehonite is expected to exist. (684)

6. In the Albuquerque hearings, a member of the EEG stated that actinides are much more soluble in the presence of nesquehonite than the fully reacted MgO products. The individual then stated that more studies were needed to evaluate how much greater the calculated releases would be because of this effect. It appears that the EEG has ignored the experimental evidence presented to them in the DOE MgO efficacy report. This report has also been provided to the EPA and was supplied to the DOE Conceptual Model Peer Review Panel. This report shows that any nesquehonite formed by the chemical reactions will be very short-lived. This conclusion is supported by natural analogs for the backfill found in Australia, and was fully accepted by the Conceptual Model Peer Review Panel. (837)

7. The EEG questions the use of hydromagnesite, rather than nesquehonite, as the equilibrium-constraining mineral phase in actinide-solubility calculations. The EEG refers to experiments conducted by SNL in early 1997 in support of their argument. It is imperative to note that those experiments were conducted to investigate long-term reactivity of MgO with CO_2 to address concerns of the Conceptual Model Peer Review Panel (Papenguth et al., 1997). Those experiments were not designed to define the mineral assemblage used in actinide-solubility calculations.

The choice of magnesium-carbonate mineral phase to constrain equilibrium calculations is clearly shown in the $MgO-CO_2-H_2O$ phase diagram published in Dr. Friedrich Lippmann's definitive treatise on carbonate mineralogy (1973). As illustrated in Lippmann's figure, the only thermodynamically stable magnesium carbonate mineral in the $MgO-CO_2-H_2O$ system is magnesite. . . For actinide solubility calculations, we have elected to use a metastable hydrated magnesium carbonate mineral as the equilibrium-constraining $MgCO_3$ phase.

Generation of CO_2 in the WIPP repository requires the presence of water to support microbial degradation of carbon substrates. If water is available for microbial activity, it will also be available for reaction (hydration) with MgO to form brucite [$Mg(OH)_2$], a relatively fast reaction. As CO_2 is generated, the partial pressure of CO_2; (pCO_2) will begin to increase. On the phase diagram (Figure 1), the reaction path, therefore, begins at 25°C at the left, and moves isothermally to the right. Brucite is present in the system. The pCO_2 continues to increase until the hydromagnesite-brucite join is met, at approximately $10^{-4.2}$ atm pCO_2 (Figure 1). . . Because the moles of emplaced MgO exceeds the maximum possible amount of CO_2 generated by a factor of nearly four,. . . nesquehonite will never be produced in the WIPP. (912)

8. EPA has reported that "DOE has performed experiments that indicate that hydromagnesite is a primary product of reactions between magnesium oxide and brines" (CARD 24 at 24-28) and that "nesquehonite rapidly converts to hydromagnesite in a matter of days to weeks" (TSD V-B-6 at 4-163; see also TSD V-B-17 at 7), and in the stakeholder meeting on December 11, 1997, EPA staff asserted that hydromagnesite was actually observed in experiments. In fact, the cited statements are incorrect, and those experiments did not produce hydromagnesite. As EEG has said, "DOE's experimental efforts with MgO predominantly produced nesquehonite, a magnesium carbonate mineral, with the later appearance of an unidentified phase. Hydromagnesite was not formed in the experiments reported by DOE (II-A-39); a hydromagnesite-like unnamed mineral is reported. The chemical structure of this mineral is in fact more like nesquehonite." (981)

Response to Comments 6.U.1 through 6.U.8:

All of these comments refer to the general issue of the reaction product that will form as a result of reactions between brines and the MgO backfill, and are addressed in a single response. In this response, the following three major issues are discussed:

- Reaction sequence and thermodynamics
- DOE experimental results
- Rates of hydromagnesite and magnesite formation.

Individually and collectively, consideration of the relevant information on these major issues leads to the conclusion that the final assemblage of magnesium carbonate solids that will reside in the repository will initially include hydromagnesite, and eventually magnesite. Many of these issues are also discussed in Docket: A-93-02, V-B-17.

Reaction sequence and thermodynamics

As brines infiltrate into the repository and encounter the MgO backfill, the initial reaction that is expected to occur is the hydration of the MgO to form brucite [$Mg(OH)_2$]; a reaction that removes water from the brine in the solid phase, i.e.,

$$MgO + H_2O = Mg(OH)_2$$

In the repository, the degradation of organic material will generate $CO_2(g)$. As the partial pressure of $CO_2(g)$ builds up, the $Mg(OH)_2$ thus formed will, in turn, react with the $CO_2(g)$ to form hydrated magnesium carbonates, e.g.,

$$Mg(OH)_2 + CO_2(g) + 2H_2O = MgCO_3{\bullet}3H_2O \text{ (nesquehonite)}$$

and

$$5Mg(OH)_2 + 4CO_2(g) = Mg_5(CO_3)_4(OH)_2{\bullet}4H_2O \text{ (hydromagnesite)}$$

The nesquehonite formed by the above reaction is metastable according to experimental results (discussed below) and will convert rapidly to hydromagnesite by reactions such as:

$$MgCO_3{\bullet}3H_2O + 3\ CO_2(g) + 4\ Mg(OH)_2 = Mg_5(CO_3)_4(OH)_2{\bullet}4H_2O + 2H_2O$$

As is indicated by the reactions above, the direct formation of $MgCO_3$ from low-temperature solutions does not occur. Instead, hydrated magnesium carbonates form. The reason for the initial formation of the hydrated magnesium carbonates is related to the high energy of hydrolysis of the Mg^{2+} ion, that makes it difficult to separate the waters of hydration from the ion during solid formation. [Doner and Lynn, 1977; Lippman, 1973, p. 79, 83; Morse and Mackenzie 1990] Consequently, the Mg^{2+} tends to form hydrated carbonates in which the Mg^{2+} ions are still surrounded by their waters of hydration. In an analogous system, the Ca^{2+} ion, which has a comparatively lower energy of hydrolysis than the Mg^{2+} ion, precipitates directly from low-temperature carbonate solutions as $CaCO_3$, i.e., calcite.

However, the hydrated magnesium carbonates (e.g., nesquehonite, hydromagnesite, other forms) are not thermodynamically stable under the chemical conditions expected for the repository, as pointed out in Comment 6.U.7. Consequently, after some period of time, the hydrated magnesium carbonates (e.g., hydromagnesite) can be expected to dehydrate to produce magnesite [$MgCO_3$], i.e.,

$$Mg_5(CO_3)_4(OH)_2{\bullet}4H_2O + CO_2(g) = 5\ MgCO_3 + 5\ H_2O$$

This dehydration step, if it proceeds to completion, would produce the thermodynamically stable assemblage of solids for the expected repository conditions, that is the assemblage with the lowest potential energy for the existent chemical conditions. The dehydration step is promoted by elevated temperatures and low activities of water, such as in brine solutions.

This sequence of reactions has been observed in both experimental and natural systems, as discussed below, and is consistent with the chemical properties of the Mg^{2+} ion and thermodynamic constraints.

<u>DOE experimental results</u>

Researchers at SNL conducted a series of scoping and crystal growth experiments to determine the types of magnesium carbonate solids that would precipitate from solution by reactions between brines and MgO backfill material. Overall, the results of these experimental studies are consistent with the above sequence of reactions, except that the final step of magnesite formation was not observed. [Docket: A-93-02, II-A-39] In the SNL crystal growth experiments, a hydrolysis of the MgO was observed and resulted in an increase in the solution pH. Next, a precipitate of nesquehonite was observed to form on the MgO pellets used in the experiments. The nesquehonite was characterized by acicular, blunt tipped, pseudo hexagonal crystals, and also identified by powder x-ray diffraction analyses.

The nesquehonite was then observed to alter to an intermediate solid with a formula of $MgCO_3{\bullet}\ MgCl(OH){\bullet}3H_20$ that is similar in composition to protohydromagnesite [$(MgCO_3)_4{\bullet}Mg(OH)_2{\bullet}4H_2O$], being comprised of a mixture of magnesium carbonate, magnesium hydroxide, and waters of hydration. The magnesium hydroxide component is not present in nesquehonite. (There are a number of hydrated magnesium carbonates with stoichiometries intermediate between nesquehonite and hydromagnesite, including dypingite and protohydromagnesite, see Table 4-1 of the SNL report. [Docket: A-93-02, II-A-39] The formation of the intermediate protohydromagnesite was clearly evident from a change in morphology of the acicular, blunt tipped, pseudo hexagonal crystals characteristic of the original nesquehonite to fine-grained flaky to platy crystals characteristic of protohydromagnesite. [Davies and Bubela, 1973, p. 291] If the intermediate solid actually had a structure similar to nesquehonite, as suggested in Comments 6.U.8 and 6.U.1, then it would not change its crystal morphology in response to continued reaction. The change in crystal morphology and resultant composition clearly indicates that the nesquehonite had altered to a protohydromagnesite-like phase, as they have been described by Davies and Bubela. [1973, p. 291, 296] Although an absolutely pure precipitate of hydromagnesite was not identified in these crystal growth experiments, hydromagnesite was identified by x-ray diffraction analysis of products from scoping experiments [Docket: A-93-02, II-A-39], indicating that is a primary reaction product (Comment 6.U.8).

Rates of hydromagnesite and magnesite formation

In the laboratory experiments conducted by SNL, the conversion of the hydromagnesite to magnesite was not observed. However, other laboratory results reported in the scientific literature and observations of natural occurrences of magnesium carbonate minerals provide some qualitative information on rates of formation that are applicable to the repository environment.

Magnesite has also been observed to form relatively rapidly in solutions at temperatures greater than 60ºC. [Usdowski, 1994, p. 348-350; Sayles and Fife, 1973, p. 87,89] Elevated temperatures provide the requisite energy needed for dehydration of the Mg^{+2} ion and formation of the crystal structures of dolomite and magnesite. Nesquehonite converted to protohydromagnesite and hydromagnesite in a matter of days to weeks in experiments conducted at 52ºC and magnesium carbonate solutions. [Davies and Bubela, 1973, p. 290] The conversion of the nesquehonite to protohydromagnesite under liquid-saturated conditions was typified by a change in morphology from needles to "curved-flake like masses." [Davies and Bubela, 1973, p. 296] In other experiments conducted at 10 to 28ºC in NaCl brine solutions, nesquehonite converted to protohydromagnesite, hydromagnesite, and huntite over a time period of about 10 months. [Davies et al., 1977, p. 188,197] Two of the important conclusions that can be reached, that are consistent with the SNL experimental results, are: (1) nesquehonite alters to hydromagnesite through intermediate phases (e.g., protohydromagnesite and dypingite) [Bubela and Davies, 1973, p. 299] and (2) the rate of nesquehonite alteration is rapid, explaining why hydromagnesite is more commonly found in nature than nesquehonite. [Bubela and Davies, 1973, p. 289]

In the SNL report [Docket: A-93-02, II-A-39] the rate data for magnesite formation from Usdowski [1994, p. 348-350] for 60º and 180ºC and Sayles and Fife [1973, p. 89] for 126ºC were used to construct an Arrhenius plot of the effect of temperature on reaction rate. From the Arrhenius plot, the required time for magnesite formation can be estimated to take a few hundred years. This result is similar to those obtained by Usdowski [1994, p. 353] of a time of 600 years for the formation of dolomite at 30ºC. The formation of magnesite might be expected to take a comparable amount of time. For instance, assemblages of magnesite plus dolomite have been inferred to form from alteration of aragonite plus hydromagnesite in certain arid, saline, near marine environments, such as sabkhas.[32] [Usdowski, 1994, p. 356] Sabkhas bear some similarities in conditions to the repository, although they are probably hotter and wetter than what might be expected in the repository. Other field observations of carbonate mineral occurrences in recent sediments have been used to infer periods of a few hundred to a few thousand years for magnesite and dolomite formation. [Graf et al. 1961, p. 221; Irion and Müller, 1968, p. 1309,1310]

The estimates of the rates of magnesium carbonate formation made from experimental results are generally consistent with observations of their occurrence in nature. Overall, occurrences of nesquehonite are rare and found primarily in young deposits from precipitation from meteoric waters. [Fischbeck and Muller, 1971, p. 87; Marschner, 1969, p. 1119, Docket: A-93-02, II-A-39] Natural occurrences of hydromagnesite and magnesite are more common and typically found in saline environments, such as the sabkhas, evaporites, and alkaline lake sediments. [Irion and Muller, 1968, p. 1309, 1310; Renaut and Long, 1989, p. 239; Stamatakis, 1995, p. B179, Docket: A-93-02, II-A-39] A good example of the occurrence of magnesium carbonates is provided by Stamatakis [1995, p. B179-B181], who has described a Quaternary age deposit of hydromagnesite, magnesite, dolomite [$CaMg(CO_3)_2$] and huntite [$Mg_3Ca(CO_3)_4$] in northern Greece. The genetic model developed by Stamatakis [1995, p. B183, B184] indicates that the magnesium carbonates formed as magnesium-enriched spring waters, derived from sources in mafic and ultramafic rocks, flowed into an enclosed basin and evaporated. As the solutions became more saline and alkaline with evaporation, the magnesium carbonates were precipitated from solution. It is important to note, however, that while these precipitates include hydromagnesite and magnesite, nesquehonite was not found in the deposit. This finding is consistent with the short-lived nature of nesquehonite in saline environments as a result of its relatively rapid rate of conversion to hydromagnesite and magnesite. This field observation is consistent with the experimental results.

Based on the above discussion, the sequence of events resulting from brine infiltration and reaction with the MgO backfill in the repository may be conceptualized by the following reactions, in order:

- ♦ Rapid reaction (hours to days) between the brine and MgO to produce brucite.
- ♦ Rapid carbonation (hours to days) of the brucite to produce nesquehonite and possibly hydromagnesite.
- ♦ Rapid conversion (days to weeks) of the nesquehonite to hydromagnesite.
- ♦ Slow conversion (few hundred to few thousands of years) of the hydromagnesite to magnesite.

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32 Sabkha is a geological term referring to a sedimentation environment, located above the high-tide level (supratidal environment) in arid to semiarid coastal settings. It is characterized by evaporite deposits.

The available rate data indicate that some portion, perhaps all, of the hydromagnesite will be converted to magnesite over the 10,000-year period for repository performance. The exact time required for complete conversion has not been established for all chemical conditions. However, the available laboratory and field data clearly indicate that magnesite formation takes from few hundred to, perhaps, a few thousand years. Thus, the early repository conditions can be best represented by the equilibrium between brucite and hydromagnesite. These conditions will eventually evolve to equilibrium between brucite and magnesite. In fact, the Salado Formation contains magnesite in its mineral assemblage, hence its brine is saturated with respect to magnesite solubility [Novak et al. 1996], indicating that conditions conducive to magnesite formation from reactions between brine and the MgO backfill are already present in the repository surroundings. This overall conceptualization is also consistent with the thermodynamic approach used to model the actinide source term, in that solution conditions would be expected to be controlled by the metastable hydromagnesite until it is completely converted to magnesite.

In summary, information from the SNL experimental studies, experimental studies reported in the scientific literature, observations of natural occurrences of magnesium carbonates, and peer review panel findings (see response to Comment 6.W.1), overwhelmingly indicate that nesquehonite will not persist in the repository environment, but will rapidly alter to hydromagnesite or hydromagnesite-like solids. The hydromagnesite is eventually expected to alter to magnesite, but this process could take up to a few thousand years. Consequently, EPA considers the conceptual model most appropriate for representing the effects of reactions between brines and the MgO backfill to be the equilibrium chemical conditions imposed by the presence of hydromagnesite.

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Issue V: Organic ligands

1. When calculations that include system effects are performed, based on the conservative upper bound estimate, the results indicate that less than 1% of the actinides will be complexed (i.e., there is insignificant binding between actinides and organic ligands). Thus, there is no justification for revising K_d values based on organic ligands. (109)

2. In the solubility calculations, the CCA inappropriately discounts the role of organic ligands on plutonium solubility. The CCA provides information on the amounts and complexing properties of EDTA and then argues that other organic ligands, such as citrate, will be unimportant despite the fact that citrate is the most abundant water-soluble organic constituent. . .Moreover, DOE and

EPA have each assumed that the actinides and the brine would be evenly distributed and well mixed throughout the repository. The problem with this assumption is that the plutonium and citrate are located in the same drums. . .The solubility of the plutonium for these waste forms must also be calculated as a very stable plutonium citrate complex where other cations in the brine diffusing into the drum cannot compete effectively with the complexed actinides (IV). (683)

3. The EEG incorrectly asserts that the "CCA inappropriately discounts the role of organic ligands on plutonium solubility." This assertion is based on the false premise that the impact of an organic ligand is dependent only on its abundance. EEG appropriately concludes that citrate complexes with the +4 actinides are stronger than with the other major cations expected to be in the WIPP brines (e.g., Ca^{+2}, Mg^{+2}, Fe^{+2}, Ni^{+2}) as was stated in the CCA. The formation of stronger complexes by a bare, highly charged (+4) ion as compared to a lower charged ion (+2) is what would be expected based on the chemical theory and is borne out by experimental data. . . In the CCA, DOE performed bounding calculations which demonstrated that EDTA, with a complexation constant over six orders of magnitude greater than that of any of the other organic ligands with a +4 actinide, will not have sufficient interaction with the actinides to have any appreciable impact on the dissolved actinide source term. These calculations were based on demonstrating that the organic ligands were essentially tied up by complexation with the numerous other metallic species which will exist in the disposal room environment. These calculations and their underlying assumptions were reviewed by the Waste Characterization Independent Peer Review Panel. (911)

4. As for organic ligands, EPA states that their effects may be discounted because of their concentrations, the chemistry attributable to the MgO backfill, and the presence of other cations (CARD 23 at 142). EPA's conclusion is based almost entirely on the effects of EDTA. EEG has pointed out that other organic ligands, such as citrate, can be important factors; also, plutonium and citrate will be found in the same waste drums, arguing for the calculation of a very stable plutonium-citrate complex. (979)

5. The DOE assumption as to the EDTA inventory is insufficiently based. Moreover, other organic ligands are omitted from DOE consideration. (988)

6. DOE should publish a formal sensitivity analysis of the potential impact of organic ligands on aqueous concentrations of radionuclides, using the lists of ligands supplied by EEG. (992)

7. The CCA provides information on the amounts and complexing properties of EDTA and then argues that other organic ligands, such as citrate, will be unimportant despite the fact that citrate is the most abundant water-soluble organic constituent. Citrate forms extremely strong complexes with actinides in the +4 oxidation state [e.g. Th(IV)], but very weak complexes with other cations. Moreover, the DOE and EPA have each assumed that the actinides and the brine would be evenly distributed and well mixed throughout the repository. EEG believes that this is an inappropriate assumption. The plutonium and citrate are probably located in the same drums. (1241)

8. The DOE should conduct and publish a formal sensitivity analysis to examine the potential impact of organic ligands on the aqueous concentrations of the radionuclides. The concentrations of the ligand should be varied by several orders of magnitude, and the full list of ligands provided by EEG should be used. (1277)

Response to Comments 6.V.1 through 6.V.8:

These comments address two major subjects:

- ♦ Lack of a sensitivity analysis on the effects of organic ligands and
- ♦ Organic ligands besides EDTA were not considered.

These two subjects are related with respect to the approach developed by DOE to determine the potential effects of organic ligands on the solubilities of actinide solids, hence a single response is given below to address these comments.

Organic chemicals were expected to be part of the wastes, especially because many were used in the separation of actinides during chemical processing of nuclear materials. [Appendix BIR] Hence, DOE made an effort to determine what kind and how much of the organic chemicals might be present in the waste because, in part, strong complexants, such as EDTA, could potentially affect the solubilities and aqueous speciation of actinides. Using the estimates of the weights of the organic chemicals present in the waste, the potential solution concentrations were calculated by dividing by the volume of brine required to inundate the void volume of the repository after closure. The results of these calculations are provided in Table SOTERM-4 in Appendix SOTERM of the CCA. They indicate the following estimated concentrations: 1.1×10^{-3} m acetate, 4.7×10^{-4} m oxalate, 7.4×10^{-3} m citrate, 4.2×10^{-6} m EDTA. The calculations of the effects of organic chemicals on the aqueous speciation of actinides were based on these calculated organic concentrations.

The key point in this approach is the same as that mentioned in some of the comments, that is, for the calculations of performance, the repository is represented as a completely mixed system with evenly distributed chemical components and conditions. Numerous "what if " scenarios could be imagined in which specific drums are filled with mixtures of chemicals that could maximize actinide mobility, such as a drum with both plutonium and some form of citrate. The consideration of every possible combination of potential events for chemical mixture in specific drums would present an impossible number of hypothetical situations to represent in a performance assessment. However, rather than dismiss this potential problem entirely, DOE conducted a series of bounding calculations to determine the maximum possible effect that the organic ligands might have on actinide concentrations, and also included uncertainties in their representations of actinide solid solubilities for input to PA calculations.

In the bounding calculations, the effects of EDTA complexing of Th(IV) were examined to determine the potential for organic ligands to affect the aqueous speciation of the actinides. The combination of EDTA and Th(IV) was chosen as the bounding case because this reaction, i.e.,

$$Th(IV) + EDTA = Th(IV)\text{-}EDTA$$

has the highest affinity of the possible actinide-organic ligands reactions for producing a high proportion of an organically complexed actinide, simplistically represented in the above reaction as Th(IV)-EDTA. The affinity for organic ligand complexation is proportional to the product of the stability constant and the reactants, i.e.,

$$[Th(IV)\text{-}EDTA] \% \beta[Th(IV)][EDTA]$$

where the brackets refer to concentrations. The substitution in this equation of the estimated EDTA concentration of 4.2×10^{-6} m EDTA, the mid-range value for the stability constant of $10^{16.25}$ for the formation of Th-EDTA from Table SOTERM-5 in the CCA, and any arbitrary concentration of Th(IV) expected for the repository (e.g., 1×10^{-8} m), the product obtained is 747. The same operation can be applied to the other organic ligand complexes, as shown in the following table.

Organic Complex	log Stability Constant	Organic Ligand (m)	Th(IV) (m)	Product β[Th(IV)][EDTA]
Th(IV)-EDTA	16.25	4.2×10^{-6}	1×10^{-8}	747
Th(IV)-acetate	3.93	1.1×10^{-3}	1×10^{-8}	9.7×10^{-8}
Th(IV)-oxalate	7.26	4.7×10^{-4}	1×10^{-8}	8.6×10^{-5}
Th(IV)-citrate	9.75	7.4×10^{-3}	1×10^{-8}	0.4

As shown by these calculations, the affinity for Th(IV) to form an organic complex with EDTA is about 3 orders of magnitude greater than for citrate, which has the next highest affinity. Consequently, it is appropriate to use the Th(IV)-EDTA complex for any bounding calculations to assess the effects of organic ligands on the aqueous speciation of the actinides and solubilities of the actinide solids for the brine solutions expected to infiltrate into the repository over time. There is no reason to consider the other organic ligands (i.e., acetate, oxalate, and citrate) because their potential to complex the actinides is so much less than EDTA.

To assess the effects of EDTA to complex Th(IV) in a brine solution, DOE conducted a series of speciation calculations, considering the probable concentrations of major solutes (e.g., Mg^{2+}) and metals (e.g., Fe^{2+}, Ni^{2+}) expected to be present in the brines and also known to form complexes with EDTA. These calculations are described on pp. SOTERM-40 to 41 in Appendix SOTERM of the CCA. The calculation results indicated that only 3% of the EDTA was complexed with EDTA.

The remainder of the EDTA was tied up with Mg^{2+}, Fe^{2+}, and Ni^{2+}. This finding indicates that even for the organic complex with the highest potential to form an organic complex [i.e., Th(IV)-EDTA] very little of that organic complex will actually be present because of the vast majority of the EDTA will form complexes with other ions present in much higher concentrations than the actinides.

In EPA's review of the actinide source term, an independent calculation of the potential effects of EDTA on the solubility of ThO_2(am) was conducted to determine whether the calculations were sensitive to the EDTA concentration. [Docket: A- 93-02, V-B-17] The solid, ThO_2(am), was used because it is expected to control the Th(IV) concentrations in the repository environment based on experimental investigations and FMT model calculations. [Novak and Moore, 1996; Novak et al. 1996; 1997] Also, as noted above, among the actinides, aqueous Th(IV) has the highest tendency to be complexed by EDTA. Based on these factors, the EDTA-Th(IV)-brine system should provide the greatest possibility for an organic ligand to affect the prediction of the solubility of an actinide solid. The PHREEQC geochemical computer code (version 1.5) [Parkhurst, 1995] was used for the solubility calculations. PHREEQC is a well established computer code that has been used for a variety of problems in aqueous geochemistry for a number of years.

The formulations for activity coefficients incorporated in PHREEQC are not representative of high ionic strength solutions, hence the ThO_2(am) solubility calculations were performed for the SPC (Salado Primary Constituent) brine diluted 10 times. Although this solution composition may not be exactly representative of the repository environment, the resulting calculations still provide a reasonable representation of the effects of EDTA concentration on ThO_2(am) solubility. Additionally, the solubility calculations were conducted for a constant CO_2(g) partial pressure of $10^{-5.5}$ bars, which is the level expected for equilibrium between brucite [$Mg(OH)_2$] and hydromagnesite [$Mg_5(CO_3)_4(OH)_2.4H_2O$] resulting from reactions between the MgO backfill and SPC (Salado Primary Constituent) brine (see Sections 3 and 4). The representative EDTA concentrations expected for the repository is estimated at about 4.2×10^{-6} m. [Table SOTERM-4 in the CCA] Thus, the ThO_2(am) solubility calculations were conducted for an EDTA concentration range of 4.2×10^{-6} m to 4.2×10^{-2} m.

The results of the solubility calculations for ThO_2(am) indicate that the effect of EDTA is negligible at concentrations less than about 4.2×10^{-4} m [Docket: A- 93-02, Item IV-B-17, Figure 7-1, Solubility of ThO_2(am) with pH at 25ºC in SPC brine diluted 10 times predicted with the PHREEQC model for a range of EDTA concentrations], which is 100 times the concentration estimated for the inundated repository. At an EDTA concentration 4.2×10^{-2} m, which is 10,000 times the level estimated for the repository, an increase in Th(IV) concentrations is predicted for pH less than about 7.5. At higher pH, the EDTA has no substantial effect on ThO_2(am) solubility because aqueous Th(IV) speciation is dominated by hydroxyl, carbonate, and sulfate complexes rather than EDTA complexes. The EDTA is predicted to be present primarily as complexes with Ca^{2+} and Mg^{2+} under alkaline conditions.

These bounding calculations clearly show that the organic ligands will not affect the solubilities of the actinide solids for the expected conditions. Thus, there is no need to conduct a formal sensitivity analysis because even the worst case does not show an effect. However, it should also be pointed out that the PA calculations were not conducted with single values for the solubilities of the actinide solids but used a distribution based on an uncertainty range for the solubilities. Within the well-mixed conceptual model, the potential effects of deviations from the average situation, such as the potential scenario of having a drum with both plutonium and citrate, are accounted for by the inclusion of uncertainties and uncertainty distributions in the performance assessment calculations. For instance, in the source-term portion of the performance assessment, the concentrations of actinides were assigned an uncertainty band of 100 times less than (-2.0 log units) and 25 times greater than (+1.4 log units) the calculated solubilities of actinide solids for the expected repository conditions, i.e., the average case. Depending on the uncertainty distribution, some performance assessment realizations would have used actinide concentrations at the outer bounds of the uncertainty range. Because the effects of the organic ligands are so small, it is expected that they would have been included within the uncertainty range, hence incorporated into the overall PA calculation.

In summary, DOE's bounding calculations, independent bounding calculations, and incorporation of uncertainty ranges to represent actinide concentrations in the PA calculations indicate the organic ligands will have only a minor effect on the solubilities of actinide solids under the expected repository conditions. Consequently, there is no substantive information that could be gained by conducting a sensitivity analysis for the effects of the organic ligands or conducting the calculations with citrate rather than EDTA. EPA agrees with the conclusions of the Waste Characterization Independent Review Panel in their supplementary report, which states: "The Panel agrees that under the conditions of MgO backfill, chelating agents will have a negligible effect on repository performance. The Panel notes that, even at the basic pH in the repository, the availability of transition metals may be enhanced due to the formation of soluble halo complexes, making an even stronger case that base metals control ligand chemistry." [Docket: A-93-02, Item V-B-17]

<u>References</u>

Novak, C. F. and R. C. Moore (1996) Estimates of Dissolved Concentrations for +III, +IV, +V, and +VI Actinides in a Salado and a Castile Brine under Anticipated Repository Conditions. Memo to M. D. Siegel, March 28, 1996, Sandia National Laboratories, Albuquerque, New Mexico, CCA Ref. No. 479.

Novak, C. F., R. C. Moore, and R. V. Bynum (1996) Prediction of Dissolved Actinide Concentrations in Concentrated Electrolyte Solutions: A Conceptual Model and Model Results for the Waste Isolation Pilot Plant (WIPP). In *Proceedings of the 1996 International Conference on Deep Geological Disposal of Radioactive Waste*, Canadian Nuclear Society, Toronto, Canada (ISSN No: 0-919784-44-5). CCA Ref. No. 481.

Novak, C. F. (1997) Calculation of Actinide Solubilities in WIPP SPC and ERDA6 Brines under MgO Backfill Scenarios Containing Either Nesquehonite or Hydromagnesite as the Mg-CO_3 Solubility-Limiting Phase. Memo to R. Vann Bynum, dated April 21, 1997, Sandia National Laboratories, Albuquerque, New Mexico. WPO 46124.

Parkhurst, D. L. (1995) User's Guide to PHREEQC -A Computer Program for Speciation, Reaction-Path, Advective-Transport, and Inverse Geochemical Calculations, Water-Resources Invest. Rep. 95-4227, U.S. Geol. Survey, Lakewood, Colorado.

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9. DOE's arguments concerning the limited impact of organic ligands uses stability constants from disparate and unreconciled sources. (987)

Response to Comment 6.V.9:

In Appendix SOTERM of the CCA, the sources of stability constants for complexation of actinides, magnesium, and metal cations are listed in Tables 4-5, 4-6, and 4-7, respectively. The stability constants for the actinides in Table 4-5 represent the results of experimental studies at Florida State University. The stability constants for magnesium also represent the results of experimental studies at Florida State University. The stability constants for the metal cations are from Martell and Smith [1982], which is a standard reference for stability constants. In all of the experimental data that have contributed to the derivation of these various stability constants, even those from different sources, the most important concept is that the constants represent the equilibrium distribution of aqueous species involved in each separate reaction for the examined chemical conditions. Consequently, it is incorrect to refer to the data as "unreconciled." The data are by definition reconciled to represent conditions of chemical equilibrium, otherwise they cannot be referred to as stability constants.

References

Martell, A. E. and R. M. (1982) *Critical Stability Constants, Volume 5: First Supplement*. New York, Plenum Press (cited in Appendix SOTERM of the CCA).

Issue W: MgO chemical processes

1. Concerning the chemistry of the disposal rooms, DOE has assumed that the MgO backfill will react instantly and completely with the waste, gas, and brine in the repository, reacting with CO_2, reducing gas pressure and also reducing the solubility of the radionuclides. However, DOE has

not shown that these processes will in fact take place. DOE's peer review panel has rejected DOE's PA assumption in this respect also. (140)

2. The analytical results of these experiments has [allowed] comparison to WIPP and affirms the results of actinide source term solubility models developed by Sandia National Laboratories that have conclusively shown that release of actinides in the accessible environment will not exceed EPA standards. (597)(888)

3. It has been demonstrated in the memorandum by Wang (1998) included as Attachment 7 that, even if all waste drums are fully filled with CRP, the amount of MgO emplaced in the repository will still be enough to control repository chemistry. Consequently, there is no need for imposing a upper limit on CRP inventory and therefore for accurately quantifying the uncertainty in determining weight parameters of those materials. (925)

Response to Comments 6.W.1 through 6.W.3:

DOE provided additional information on MgO processes and the Peer Review Panel later amended its conclusion to find that MgO processes will indeed take place as initially postulated by DOE. The use of an MgO backfill in the repository offers the potential for limiting the chemical conditions (i.e., pH and CO_2(g) partial pressure) in the repository to a relatively narrow range, as described in Appendix SOTERM of the CCA. This process was described in DOE's Chemical Conditions Conceptual Model. While the peer panel initially rejected DOE's conceptualization of the Chemical Conditions Model, the CMPRP accepted the Conceptual Models Third Supplementary Peer Review Report. [Docket: A-93-02, II-G-22] Thus, the panel concluded that the Chemical Conditions Model: Results of the MgO Backfill Efficacy Investigation [Docket: A-93-02, II-A-39] provided "satisfactory evidence that the laboratory phases produced by DOE will in fact transform well within the time constraints needed for the Chemical Conditions Model." Conceptual Models Third Supplementary Peer Review Report, at p.15-16. [Docket: A-93-02, II-G-22] The report concludes [p.16], "Based on the information presented to the Panel in the written material and in oral discussion, the Panel concludes that the results available provide an adequate basis to determine that the MgO backfill will function according to the Chemical Conditions Conceptual Model, as used in the CCA, with respect to reaction with generated CO_2 gas."

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4. It has been demonstrated in the memorandum by Wang (1998) included as Attachment 7 that, even if all waste drums are fully filled with CRP, the amount of MgO emplaced in the repository will still be enough to control repository chemistry. Consequently, there is no need for imposing a upper limit on CRP inventory and therefore for accurately quantifying the uncertainty in determining weight parameters of those materials. (925)

5. Confidence has not been developed that wastes within individual drums or the brines entering those drums will undergo the rapid chemical conditioning effect assumed, and insufficient attention has been given to the volumetric expansion and other effects due to MgO reactions (at 21). (1061)

Response to Comments 6.W.4 and 6.W.5:

Experiments conducted by DOE, which are described in SNL [1997], show that reactions between MgO and carbonated brines are rapid. Solution pH values were found to increase in a matter of hours, indicating that the MgO backfill-type material is very reactive. [SNL, 1997, p. 8, 11] Also, significant amounts (a few weight percentages) of uptake of carbon were observed to take place after only days to weeks, indicating that the rates of formation of magnesium carbonates are also rapid. [SNL, 1997, p. 10, 12, 15] These rapid rates of reaction are consistent with experimental results of the transformation of nesquehonite to hydromagnesite after three to seven days of reaction at 52ºC. [Davies and Bubela, 1973, p. 290, 291] Also observed, the formation of protohydromagnesite from nesquehonite after 10 months at 10 to 28ºC in a simulated sedimentary column indicates that the formation and recrystallization reactions involving magnesium carbonates occur rapidly. [Davies et al.,1977, p. 188, 189, 197,198] The results of these experiments provide adequate information to conclude that reactions involving the MgO backfill material, brines, and carbon dioxide will be rapid and will produce the geochemical conditions expected for chemical equilibrium between brucite and hydromagnesite and/or magnesite.

As noted in this comment, the conversion of MgO to hydrated products can be expected to result in a volumetric expansion of the materials. For example, the increase in volume of the solids involved in the initial reaction between MgO and water, i.e.,

$$MgO + H_2O = Mg(OH)_2$$

can be estimated from the difference in molar volumes of $Mg(OH)_2$ (molar volume = 24.63 cm^3/mol) [Robie et al.1978, p. 20] and MgO (molar volume = 11.248 cm^3/mol) [Robie et al.1978, p. 20], to give a potential increase with reaction of 13.38 cm^3/mol. Similarly, the conversion of $Mg(OH)_2$ to hydromagnesite (molar volume = 211.1 cm^3/mol) [Robie et al.1978, p. 25], i.e.,

$$5Mg(OH)_2 + 4CO_2(g) = Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O \text{ (hydromagnesite)}$$

might be expected to produce an increase in molar volume of 87.95 cm^3/mol (= 211.1 cm^3/mol - 5*24.63 cm^3/mol), if the reaction were to proceed to 100% completion.

However, the combined potential effects of the removal of water by the backfill material and volumetric expansion of reaction products relative to the original MgO are expected to be beneficial to the backfill performance. Clearly, the removal of water, as in the first reaction above, would limit the amount of water available for transporting actinides downgradient. Also, any volume expansion that might occur may result in the formation of dense layers of cementitious material in and around the waste containers, which will also limit the ability of water to contact wastes and solubilize actinides.

In summary, experimental evidence indicates that the MgO backfill material will produce the desired chemical conditions in a rapid time frame. Secondly, the effects of the backfill reactions with carbonated brines can be expected to reduce the potential for actinide transport relative to a system with no backfill. Based on these considerations, EPA concludes that the emplacement of the MgO backfill material will be beneficial to repository performance.

References

Davies, P. J. and B. Bubela (1973) The transformation of nesquehonite into hydromagnesite. *Chem. Geol*. 12, 289-300.

Davies, P. J., B. Bubela, and J. Ferguson (1977) Simulation of carbonate diagenetic processes: formation of dolomite, huntite, and monhydrocalcite by the reactions between nesquehonite and brines. *Chem. Geol*. 19, 187-214.

Robie, R.A., B. S. Hemingway, and J. R. Fisher (1978) Thermodynamic Properties of Minerals and Related Substances at 298.15 K and 1 Bar (10^5 Pascals) Pressure and at Higher Temperatures. Geol. Surv. Bull. 1452, U. S. Gov. Printing Office, Stock No. 024-001-03065-9., 456 pp.

Sandia National Laboratory (SNL) (1997) Chemical Conditions Model: Results of the MgO Backfill Efficacy Investigation. Prepared for U.S. DOE, Carlsbad Area Office by Sandia National Laboratory, Albuquerque, New Mexico, Docket II-A-39.

Issue X: Plutonium solubility is discounted by other scientists.

1. DOE's assumptions regarding Pu solubility drive the "no releases, no migration" conclusion of the CCA, despite the fact the solubility value used is discounted by other scientists. (27)

Response to Comment 6.X.1:

DOE's solubility model for plutonium includes representations of Pu(III) and Pu(IV) (the higher oxidation states, that is Pu(V) and Pu(VI), are not expected to be stable under the anoxic reducing conditions of the repository environment.) The concentration of Pu(III) is represented by the Fracture-Matrix Transport (FMT) calculation of the solubilities of Am(III) solids (i.e., $Am(OH)_3(s)$ and $AmOHCO_3(s)$), which are based on experimental data for Am(III) and Nd(III) aqueous speciation and solid-phase solubilities. The concentration of Pu(IV) is represented by the FMT calculation of the solubility of a Th(IV) solid (i.e., $ThO_2(am)$). The chemical properties of actinides with the same oxidation state are known to be similar [Silva and Nitsche, p. 379-380, 1995], making it possible for DOE to apply solubility and aqueous speciation data determined for one actinide oxidation state (e.g., Am(III)) to represent the solubility and aqueous speciation of another (e.g., Pu(III)).

The objections of other scientists are not specified in this question. A peer review panel of scientists found that the use of solubility data for Am(III) solids for representing Pu(III) and solubility data for Th(IV) solids for representing Pu(IV) was a reasonable approach (Hrncir and Knecht, 1996). These issues are discussed in CARD 194.24, Docket: A-93-02, Item V-B-2.

<u>References</u>

Hrncir, D. and R. Knecht (1996) Waste Isolation Pilot Plant Waste Form and Disposal Room Data Qualification Peer Review Report. Final Report, U.S. DOE, Carlsbad Area Office, Office of Regulatory Compliance, July, 1996.

Silva, R. J. and H. Nitsche (1995) Actinide environmental chemistry. *Radiochimica Acta* 70/71, 377-396.

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2. Additional PANEL simulations were performed to test the effect of Plutonium solubility on the CCDF calculations in the CCA. The solubility was changed in both the Castile and Salado brine from a ranged parameter to a constant value. Six simulations were conducted that tested the overall effectiveness of the changes, which included changes in the solubility and Castile brine intrusion probability. As expected, the simulations seemed to be more sensitive to the increased solubilities than the increased Castile intrusion probability. The EPA limit suggests that releases remain below 10.0 EPA units at the probability of 10^{-3}, therefore rendering all justifiable Plutonium solubilities conservative with the current amount of brine release. Additional studies should be conducted in which the amount of brine volume increases with the increasing solubility.(1079)

<u>Response Comment 6.X.2:</u>

The comment refers to an analysis conducted and reported in EEG-69 [IV-G-43] section 5.5. EPA disagrees with the comment that it is necessary to conduct additional studies in which the amount of brine volume increases with the increasing solubility. As the comment itself states, in EEG-69 the commenter found "all justifiable plutonium solubilities conservative with the current amount of brine release." EPA interprets this to mean that the commenter believes that changing the plutonium solubility does not greatly affect releases from the direct brine release scenario using brine release volumes predicted in DOE's CCA. EPA's review of DOE's actinide solubility, including plutonium solubility, is discussed in the response to comments for "Hydromagnesite and Nesquehonite" and "Effects of the Mg Carbonate Phase on the Solubilities of Actinide Solids." In summary, EPA's analysis of solubility identified that the actinide solubilities expected for the repository are much lower than those assumed in the commenter's analysis.

Increasing the amount of brine released would be necessary to get additional releases with the plutonium solubilities used by the commenter. EPA does not agree that it is necessary to assume that greater brine releases need to be modeled as is discussed in detail in the response to comments for section 23 in the issue 2D vs. 3D BRAGFLO modeling where commenters raised the following issues:

- 3D BRAGFLO predicts larger brine inflow above the anhydrite fracturing pressure than 2D BRAGFLO;
- 3D BRAGFLO predicts greater brine saturations at high pressure than 2D BRAGFLO; and
- Greater repository saturations at high pressure may result in substantially greater direct brine release than calculated in the CCA.

In the response to comments for Section 23, EPA addresses these issues and provides a detailed explanation on why the direct brine release modeling by DOE is adequate for use in performance assessment.

Since EPA agrees that the current modeling of direct brine releases is appropriate, and that the commenter used solubilities much higher than would be expected in the repository, EPA does not agree that additional studies in which brine volumes released are higher than those used in the CCA need to be combined with higher plutonium solubilities as suggested by the comment.

Issue Y: Oxidation state analogy

1. FMT relies heavily upon analogy, particularly in high pH and high salinity systems. Substantial experimental verification will be needed to establish the limits of this analogy. In addition, the use of Th(IV) values for all actinide(IV) is highly questionable. (35)

2. In summary, the inclusion of all possible oxidation states of the actinides (and therefore the complete range of their solubilities) have ensured that actinide solubilities have not been underestimated in the CCA. (107)

3. In addition to the sound theoretical basis for the oxidation state analogy, direct experimental demonstration under WIPP relevant conditions has been performed. These studies have included ThO_2(am)/UO_2(am) in 6.0 m NaCl (Figure 7)[26], ThO_2(am)/UO_2(am) in various $MgCl_2$ solutions (Figures 8 and 9)[26], Th(IV)/U(IV) in 0.1 M sulfate (Figure 10)[27], Th(IV)/U(IV) as a function of NaHCO)[3] (Figure 11)[27], Th(IV)/U(IV) in 0.01m NaOH as a function of CO_3^{2-} (Figure 12)[27], and Th(IV)/U(IV) as a function of pcH in 0.03m to 6 m NaCl (Figure 13)[27]. . .(910)

4. The key to the oxidation state analogy then lies in understanding the chemical conditions where it is and is not applicable, and also understanding the appropriate use, including limitations, as applied to a real problem. . .

To develop this reasonable model of actinide behavior under WIPP conditions, two general trends were taken advantage of:

> 1. the tendency of actinides in the same oxidation state to exhibit similar behaviors under similar conditions (i.e., the oxidation state analogy), and
>
> 2. the general trend of increasing stability of the actinide solid phases progressing across the series. . .

In developing the Actinide Source Term Dissolved Species Model, the limitations of the oxidation state analogy were a primary consideration. For example, the oxidation state analogy applied to +3 actinides trends very closely and provides for a very good predictive model, including when a model based on americium'" data is used to predict neodymium behavior (Figure 3) or a model based on curium" is used to predict americium (Figure 4) and neodymium data (Figures 5 and 6). . . The area being questioned for utilizing the oxidation state analogy is thus the +4 actinides. The +4 oxidation state exhibits the greatest variations of the actinide oxidation state analogy. These variations are principally due to the proximity of the electron orbitals in the +4 state and the ability of various electronic configurations to exist. However, the general trends that form the basis of the oxidation state analogy still exist, but vary in magnitude in relation to the stability of the various species. The trend of increasing stability progressing across the series is manifested in the +4 actinides and was used to develop a bounding predictive model. . . Therefore the model for the +4 actinides was developed primarily based on thorium data, confident that the solubilities of any other actinides which may exist in the +4 state (i.e. Pu, Np, and U) will have lower solubilities due to the greater stability of the solid phase. (909a)

5. The oxidation state analogy, direct experimental demonstration under WIPP relevant conditions has been performed. These studies have included ThO2(am)/UO2(am) in 6.0 m NaCl (Figure 7)26, ThO2(am)/UO2(am) in various MgCl2 solutions (Figures 8 and 9)26, Th(IV)/U(IV) in 0.1 M sulfate (Figure 10)27, Th(IV)/U(IV) as a function of NaHCO)3 (Figure 11)27, Th(IV)/U(IV) in 0.01m NaOH as a function of CO32-(Figure 12)27, and Th(IV)/U(IV) as a function of pcH in 0.03m to 6 m NaCl (Figure 13)27. . .

Based on the sound theoretical basis, which has been confirmed with direct, WIPP relevant observations, the use of the oxidation state analogy for the construction of the Actinide Source Term Dissolved Species. (909b)

6. The FMT database values for Am(III), Th(IV), and Np(V) were used for all actinides of similar oxidation state (CARD 24 at 24-28). . . there is a consensus that the oxidation state analogy must be used with great caution. The NAS WIPP Committee report states that “deviations from the oxidation state analogy are well known in natural and experimental systems. Substantial experimental verification will be needed to establish the limits of this analogy.” (978)

7. A modeling study has been presented in which the solubilities of actinides in the CCA and PAVT are questioned. . . The modeling of the intermediate phase, Nesquehonite, is much like the modeling of the PAVT, in which Hydromagnesite was assumed to persist throughout the 10,000 years. In addition, No MgO Backfill model solubilities were studied. The consequence of higher solubilities. . . are quite high. The overall mean release for the CCA and PAVT were 0.2 and 0.4 EPA Units at 10^{-3} probability, respectively. The overall mean for the increased solubilities of Nesquehonite and “No Backfill” are 6.0 and 8.0 EPA Units at 10^{-3} probability, respectively. The limit for compliance, according to 40 CFR Part 194 is 10 EPA Units. Therefore, it readily appears that even high solubility values do not cause the disposal to be out of compliance with EPA regulations. However, there is a deeper issue that one cannot dismiss, that is far less superficial than the previous statement. It deals with the consequences in small changes of solubility and variability in the actual values. Are we so certain that the solubility of Plutonium or Uranium, in any oxidation state, is less than the values presented in the CCA or the PAVT? How did we arrive at these numbers? Are there experimental evidence to back up the claims made in the CCA that deals with the oxidation state analogy between Am^{+3} and Pu^{+3}? (1088)

8. Plutonium will account for 82% of the WIPP radioactive inventory 100 years after closure. The CCA maintains that the plutonium will exist either as PU(III) or Pu(IV). However, the plutonium data were not used for developing the FMT model to predict the solubility of Pu(IV). Rather, the CCA relied on data for uranium and thorium as analogs. But there are long recognized concerns about relying entirely on the oxidation state analogy to derive thermodynamic constants for modeling complex electrolyte systems. (1239)

Response to Comments 6.Y.1 through 6.Y.8:

These comments address three related issues regarding the appropriateness of the actinide analogy for representing the actinide concentrations for the actinide source term model. These issues are:

- ♦ Reliance of the FMT code on the actinide analogy
- ♦ Verification of the actinide analogy
- ♦ The use of Th(IV) solids to represent the solubilities of other +IV actinides [i.e., Pu(IV), U(IV), and Np(IV)].

With respect to the first issue, the statement in Comment 6.Y.1 "FMT relies heavily upon analogy...." is incorrect. The actinide analogy is just part of the conceptual model for defining the actinide source term. The FMT (Fracture-Matrix Transport) computer code is only a numerical model for aqueous speciation and solubility. The calculations that can be made with FMT are based solely on the thermodynamic data for individual aqueous species and solids contained in its database not on any empirical or conceptual data, such as the actinide analogies.

With respect to the second issue, the oxidation state analogy is based on standard inorganic chemistry principles. In short, the actinide oxidation analogy means that actinides of the same oxidation state tend to have similar chemical properties under similar conditions. This generalization can be made because chemical reactions involving ionic species are related primarily to the charge densities of the reacting species. [CCA, Appendix SOTERM] Actinides with the same oxidation state have the same core electronic structure [Silva and Nitsche, 1995, p. 379]; hence have similar ionic radii and charge densities, which in turn leads to analogous chemical behavior in solubility and aqueous speciation reactions. Also, as stated by Silva and Nitsche [1995, p. 379]: "Because of the similarities and the fact that actinide ions in the same oxidation state have essentially the same core structure, actinides ions in the same oxidation state will tend to have similar chemical properties." A similar phenomenon occurs for the lanthanide group elements (i.e., rare-earth elements of atomic numbers 57 through 71), which have the same core electronic structure for ionic species. [Silva and Nitsche, 1995, p. 379] In addition to the theoretical basis, DOE conducted experimental studies and analyses that confirmed the validity of the oxidation state analogy, and subsequently employed it in their representation of the solubilities of actinides. [CCA, Appendix SOTERM]

With regard to the third issue, the application of the actinide analogy to the +IV actinides is a good example of its appropriate application to the actinide source term. Besides the oxidation state analogy, another generalization that can be made is that there is decreasing trend in the solubilities of actinide solid phases across the actinide series. [DOE, 1998, p. 5] This generalization is based on the fact that ionic radii of the lanthanides and actinides decrease with increasing atomic number. With decreasing radii, the stabilities of actinide-oxide and actinide-hydroxide bonds are increased, leading to decreased solubility products, which is a direct indication of solubility, for similar compounds. [DOE, 1998, p. 5] This effect is exemplified by the decrease in the solubility products of both hydrous actinide dioxides and crystalline actinide dioxides with increasing atomic number as shown by Rai et al. [1987, p.40] The data from Rai et al. [1987, p.40] show that the solubility product for Th(IV) dioxides, which is the actinide with the lowest atomic number, is about 8 orders of magnitude greater than for U(IV) dioxides, about 9 orders of magnitude greater than for Np(IV) dioxides, and about 10 orders of magnitude greater than for Pu(IV) dioxides. These experiments confirm the validity of the actinide analogy for the +IV actinides in that Th(IV) solids are more soluble than U(IV), Np(IV), and Pu(IV) oxide solids.

The data compiled by Rai et al. [1987, p. 40] are most relevant to low ionic strength conditions. However, more recent experimental data from Rai et al. [1997, pp. 242-243,245] show that the actinide analogy for the order of solubilities of +IV actinides is also relevant to high ionic strength conditions expected for the WIPP. Rai et al. [1997, p. 239] indicate that the solubility products for ThO_2(am) is about 8 orders of magnitude greater than for UO_2(am) in concentrated NaCl and $MgCl_2$ solutions, consistent with the earlier data discussed above.

Based on these established trends for the +IV actinides, DOE used the solubility of ThO_2(am) to represent the concentrations of the other +IV actinides [i.e., U(IV), Np(IV), and Pu(IV)] under the expected repository conditions. The experimental evidence provided by Rai et al. [1997, p. 239] and Rai et al. [1987, p.40] clearly indicate that ThO_2(am) is more soluble than the other +IV actinides as indicated by the solubility products determined for the various solids in the following table (Note: higher solubility products indicate higher solubilities for the same chemical conditions).

Summary of solubility product data for +IV actinides.

Actinide	Solid	Reaction	Solubility Product (25ºC)	Reference
Th(IV)	ThO_2(am)	$ThO_2(am) + 2H_2O = Th^{4+} + 4OH^-$	-45.4	Rai et al. (1997, p. 239)
U(IV)	UO_2(am)	$UO_2(am) + 2H_2O = U^{4+} + 4OH^-$	-53.45	Rai et al. (1997, p. 239)
Np(IV)	$NpO_2{:}xH_2O$(am)	$NpO_2{:}xH_2O(am) = Np^{4+} + 4OH^- + (x-2)H_2O$	-54.5	Rai et al. (1987, p. 35)
Pu(IV)	$PuO_2{:}xH_2O$(am)	$PuO_2{:}xH_2O(am) = Pu^{4+} + 4OH^- + (x-2)H_2O$	-56.85	Rai (1984, p. 97)
Pu(IV)	$Pu(OH)_4$	$Pu(OH)_4 = Pu^{4+} + 4OH^-$	-57.85	Kim and Kanellakopoulos (1989, p. 145)

Pu(IV)	PuO_2	$PuO_2 + 4H^+ = Pu^{4+} + 2H_2O$	-60.20	Kim and Kanellakopoulos (1989, p. 145)

While the concerns of the NAS, as described in Comment 6.Y.6 are noted, EPA finds from evaluations of the available data, consideration of chemical conditions, and theoretical aspects of actinide chemical behavior, that the actinide oxidation state analogy and its application to the +IV actinides (as exemplified by the use of ThO_2(am) solubility, to represent the solubilities of other +IV actinide solids) is an appropriate and verified approach that bounds the potential concentrations that the +IV actinides might reach in any brines that infiltrate into the repository.

References

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Rai, D. and J. L. Ryan (1985) Neptunium(IV) hydrous oxide solubility under reducing and carbonate conditions. *Inorganic Chemistry* 24, 247-251.

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Issue Z: Solubility uncertainty range problems

1. With respect to DOE’s proposed solubility uncertainty range:

- ♦ There were no calculations for Am(VI).
- ♦ EPA itself cited problems with Am(IV) data

- III and V uncertainty distributions were based on Nd(III), Am(III), and Np(V). Pu(III) was not included, although it was used for Pitzer coefficients. Is it reasonable to assume that these analogs can represent uncertainties for Pu actinides?

- Finally, inconsistencies in speciation for Th in FMT suggests that the range of uncertainty is not broad enough. (36)

2. There is no direct basis for the uncertainty ranges for actinides in oxidations states +4 and +6. Moreover, the uncertainty ranges for oxidation states +3 and +5 are derived primarily from non-actinide data. Nonetheless, EPA has accepted the ranges as adequate, commenting "It is not clear that including more actinide state would appreciably change this range" (EPA, V-B-17, p.35). The argument is weak. It also remains unclear that the range adequately brackets uncertainty for a population for which data have not been examined. (682)

3. Solubility uncertainty limits were developed by DOE based on experiments with +3 and +5 actinides. The limits -- +1.4 log units and -2.0 log units -- were applied to each actinide sampled in performance assessment (CARD 24 at 24-16). EPA states that the distribution obtained provides a "reasonable depletion of the uncertainty" and is not "arbitrarily narrowed to exclude the uncertainty that might be expected for +4 and +6 actinides." (CARD 24 at 24-30). However, the TSD is more candid: "Whether or not data from primarily +3 actinides is representative of actinides in other oxidation states is difficult to assess. . . . It would seem logical that the uncertainties for the +4 and +6 actinides must be larger because less of a basis of knowledge is available to depend upon for making predictions." (TSD V-B-17 at 34-35). The uncertainty limits are inadequately based. (982)

4. In its technical support documentation, EPA discusses the shortcomings of the solubility uncertainty ranges advanced by DOE. There is no direct basis for the uncertainty ranges for actinides in oxidations states +4 and +6. Moreover, the uncertainty ranges for oxidation states +3 and +5 are derived primarily from non-actinide data. Nonetheless, EPA has accepted the ranges as adequate, commenting "It is not clear that including more data for the other actinide state would appreciably change this range" (U.S. EPA, 1997c). The argument is weak. It also remains unclear that the range adequately brackets uncertainty for a population for which data have not been examined. (1240)

Response to Comments 6.Z.1 through 6.Z.4:

A brief description of the uncertainty calculation and the histogram for the error distribution is provided in Appendix SOTERM. [pp. SOTERM 28-29] This description is consistent with that provided in Bynum. [WPO41374] As described by these references, the method involved determining the differences between concentrations calculated by the FMT model and those measured in solubility experiments. The calculated and measured solubilities were then plotted, with the differences between each then approximated by measurement using a ruler. The populations of errors from different comparisons were accumulated and used to generate a cumulative distribution of errors. In some cases, differences between concentrations calculated with the NONLIN model (instead of the FMT model) and experimentally measured concentrations were also used. The NONLIN model has been used to determine equilibrium constants from experimental data using nonlinear regression analysis, and the Pitzer-type parameter database for calculating activity coefficients from Harvie et al. [WPO30422], Felmy and Weare [WPO30421], and Felmy and Rai. [1992] This database is also used in FMT and NONLIN, thus, it is logical to conclude that comparisons from NONLIN calculations should be analogous to those obtained from FMT.

Before conducting the uncertainty analysis , Bynum [WPO41374] made an assessment of which solubility data were appropriate for inclusion in the uncertainty distribution. As explained by Bynum [WPO41374], the criteria for inclusion was as follows. If a data set for an actinide oxidation state was determined to be technically deficient or inconsistent, then the whole data set was removed from consideration to avoid making subjective judgments about specific studies. As a result, solubility data for actinides in the +6 oxidation state were not used. This decision seems appropriate in view of the fact that the CCA source term was unable to develop a solubility model for U(VI), which is the only hexavalent actinide species expected under WIPP conditions.

Experimental solubility data for +4 actinides were also eliminated from consideration in the uncertainty analysis because as stated in Bynum [1996b]: “The data available for the +4 model were found to have significant problems in the extrapolated regions and were thus determined to be inadequate for use in this analysis.” This statement seems to contradict the discussion of +4 actinides in Appendix SOTERM [p. SOTERM-26] where it is implied that data for Th(IV) are available from Felmy et al. [1991], Felmy and Rai [1992], and Felmy et al. [1996], and are adequate for describing ThO_2(am) solubility and Th(IV) aqueous speciation in brines. The last sentence on p. SOTERM-26 indicates that Th(IV) solubility has been measured in WIPP brines, implying that there should be experimental data relevant to determining uncertainties in solubilities according to the criteria of Bynum. [1996b] From these statements, it is unclear why the experimental data for Th(IV) were eliminated from consideration in the uncertainty analysis. It is also indicated in Appendix SOTERM that the dissolved Th(IV) solids are more soluble than the other +4 actinides and are used to provide a conservative model of the solubilities of the other +4 actinides [i.e., U(IV), Pu(IV), and Np(IV)]. This statement infers that it would be important to include uncertainties from solubility studies for Th(IV) because it is the model used to represent both U(IV) and Pu(IV).

The exclusion of the +4 and +6 solubility data from consideration left only data for +3 and +5 actinides for the uncertainty analysis. [Bynum, 1996b] Using available data, a total of 150 measurements of differences between predicted solubilities and analytically determined actinide concentrations were made by Bynum. [1996b] Of this total 104 (69% of 150 total) were from experiments on the solubilities of Nd(III) carbonates [$NaNd(CO_3)_2.XH_2O$] in brines for which FMT was used to make solubility predictions. [Bynum, 1996b] Solubility data for Am(III) in carbonated brines [Runde and Kim, 1994, cited in SOTERM] yielded 35 (23% of 150 total) more measurements for comparison to FMT predictions. Eleven data points (7% of 150 total) were obtained from experiments on Np(V) solubility in carbonated brines, 9 of which were conducted in low ionic strength solutions that may not be representative of brines. Solubility data for Pu(III) solids in brines [Felmy et al. 1989] were not included in the uncertainty analysis. On p. SOTERM-25, it is stated that "… an Am(III) model has been parameterized in the Pitzer formalism for the Na, Cl, SO_4, CO_3, and PO_4 systems; Pu^{+3}-Na^{+}-Cl- in Felmy et al. [1989]…" This statement implies that data for Pu(III) solubility must have been available. The reason for their exclusion from the uncertainty analysis is not clear, considering the criteria set forth in Bynum [1996b] that only complete data sets were used or the data sets eliminated in their entirety to avoid making subjective judgments (Comment 6.Z.1).

While the approach used to define uncertainties in the actinide concentrations for the source would appear to provide a reasonable representation of the potential range of error inherent in the FMT model predictions, its implementation is inconsistent. The entire database of uncertainties may be skewed by the prevalence of data for the +3 actinides (93% of the total comparisons), which have the most extensive database of all the actinides [p. SOLTERM-25], and exclusion of data for other oxidation states. Additionally, 69% of the error distribution is derived from studies with Nd(III), which is not an actinide, although its chemical behavior may be argued to provide an analogue for the +3 actinides.

EPA determined that it would have been useful to have uncertainties calculated from comparisons of experimental measurements to model calculations for all of the actinide oxidation states. DOE determined that the available experimental data for the +IV actinides were insufficient for making such comparisons. However, the experimental procedures for determining the solubilities of +IV actinide solids are not substantially different from those used to determine the solubilities of +III and +V actinide solids, hence EPA concludes that the uncertainties determined for the +III and +V actinide solids would be inclusive of those that would be obtained for +IV actinide solids. This expectation is based on the fact that DOE used the outermost limits of the differences between model results and experimental results for all data examined to define the breadth of the uncertainty limits. This procedure greatly expands the size of the uncertainty bounds beyond what might be calculated from statistical treatment of the distribution of the differences. EPA agrees with this analysis because +IV and +III data will include the +IV uncertainty range. [Docket: A-93-02, Item V-B-17, Section 4]

It is true that much of the data used for the uncertainty analysis were derived from experimental studies on the solubilities of a non-actinide solid, that is neodynium [Nd(+3)]. However, this fact does not make the data invalid for representing actinides. Neodynium(+3) is a lanthanide group element with ionic and aqueous speciation properties that are similar to Pu(+3) and Am(+3). Hence, Nd(+3) has been used by numerous researchers to determine the aqueous chemical behavior of the +3 actinides while avoiding the danger of working with a radioactive element. [Khalili et al. 1994; Rao et al. 1995; Rao et al. 1996; Runde et al. 1993; Silva and Nitsche, 1995] Because the experimental procedures followed by researchers for determining the solubilities of

Nd(+3) solids are similar to those used for determining the solubilities of actinide solids, it is reasonable to believe that the uncertainties between measurement computations are also similar in magnitude and distribution.

A fully parameterized Pitzer model for Pu(III) is not included in the FMT model, hence DOE was not able to make a direct comparison of the model calculations with experimental data for the solubilities of Pu(III) solids. Instead, DOE assumed that the uncertainties generated from comparisons of FMT calculations with measured concentrations of Nd(III), Am(III), and Np(V) solids would be representative of uncertainties for Pu(III). Since the +III and +IV data are expected to be similar for actinides of similar oxidation states, EPA concurs with this conclusion.

EPA's review and testing of the FMT model identified a problem in the Pitzer coefficients for Th(IV) species, primarily $Th(CO_3)_5^{-6}$. This problem was corrected in the FMT database by DOE, based on updated information. [Felmy et al.,Table 1,1996] This problem was related to the thermodynamic database for FMT. It is not related to the uncertainty of experimental measurements of the solubilities of actinide solids. The corrected database yielded results that were consistent with expectations of the solubility of ThO_2(am) in high pH, carbonated solutions. With the corrected database, EPA concludes that the uncertainties calculated from the difference between model calculations to experimental results for +III and +V actinide solids should be inclusive of the differences that might be obtained for ThO_2(am) solubility.

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Issue AA: Actinide solubility values adopted by EPA

1. Why did EPA adopt actinide solubilities different from those initially specified in the CCA? (p. 24-27) (61)

Response to Comment 6.AA.1:

There are three reasons why EPA's actinide concentrations are different from the CCA. 1) The solubilities of actinide solids calculated by DOE were based on the assumption that chemical conditions will be controlled by the equilibria between brucite and magnesite. However, magnesite formation was not observed in SNL experiments on reactions between brines and MgO backfill material, and magnesite formation generally requires higher temperatures than expected for the repository. Consequently, EPA recommended that calculations of the solubilities of actinide solids be based on conditions of equilibrium between brucite and hydromagnesite. 2) Between the time of release of the CCA and the conduct of EPA's evaluations of the FMT model, scientists at SNL updated the thermodynamic database of the FMT model to be consistent with recently completed experimental results. 3) During the course of EPA's evaluations of the FMT model, problems in the Pitzer parameters for Th(IV) species, specifically for $Th(CO_3)_5^{-6}$, were identified. Concurrently, SNL identified this error and made corrections to the FMT database. The net result of these assessment and database revisions was generally lower actinide concentrations than in the CCA. [CARD 194-24, pp. 24-27 to 24-30, and Docket: A-93-02, Item V-B-17] More detail on these issues is also presented in this section's responses to comments (e.g., see the discussion on Hydromagnesite and Nesquehonite).

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2. In its proposed rule, EPA did not use realistic solubility values including no backfill solubility. EPA did not use realistic permeability based on actual experimental data partly because DOE and Sandia haven't produced such experimental data. (228)

3. [In its proposed decision EPA did not use:]

* realistic solubility values, using "no backfill" solubilities (see also II-H-12, IV-D-12, IV-F-2). (1133)

Response to Comments 6.AA.2 and 6.AA.3:

The current plan of operations for the repository includes the use of MgO backfill. The presence of the MgO in the repository is a basic premise of the conceptualization of the processes that will control the chemical conditions. The calculations of the solubilities of the actinide solids are based on these chemical conditions and are realistic for those conditions. There is no plan to not use the MgO backfill, hence there was no need or value added to the PA calculations of release rates in conducting solubility calculations in the absence of the MgO backfill.

Issue BB: Effects of the Mg carbonate phase on the solubilities of actinide solids

1. In the CCA dissolved actinide solubility values are based on mistaken assumptions, as EEG has shown, resulting in an underestimate of the amount of radionuclides which will be dissolved in any brine which is released from the WIPP. (144)

2. The DOE and the EPA have selected the values for this important parameter on the basis of assumption on the effect of a magnesium mineral, hydromagnesite, that is assumed to be present as a result of chemical alteration of the magnesium oxide backfill. The reported results of the mineral, nesquehonite, may be present instead. The solubility of plutonium in the presence of nesquehonite, high enough in fact to cause a significance larger computed release, without changing any factor. (353)

3. I believe that the actinide solubilities used in the CCA and PAVT were not characterized properly. The EPA examined this parameter in their evaluation of the performance assessment but a true sensitivity analysis was not investigated thoroughly. . . Using DOE values for solubility with different mineral species that were not considered in the CCA that DOE has said to exist in the repository during its 10,000 year history, complementary cumulative distribution functions (CCDF's) which were used as comparison to the EPA's 40 CFR 194, come very close to the limit. (366)

4. The reported results of the DOE laboratory experiments on the magnesium oxide backfill, however, indicate that another mineral, nesquehonite, may also be present. Solubility of plutonium in the presence of nesquehonite is several orders of magnitude higher than the hydromagnesite, and this will cause a significantly larger commuted release if indeed its present. (486)

5. With respect to solubility values, increasing solubility values because of nesquehonite is not justified because nesquehonite is only a transient phase that will exist on a scale of days to years.(497)(666)

6. The EEG has investigated the effect of actinide solubilities on the mean CCDF plots, using the EPA's PAVT releases, and making no other changes. The investigation (Enclosure 1) included the "CCA" solubilities, "no backfill" solubilities, and "nesquehonite" solubilities. The overall mean CCDF curve for "nesquehonite" solubility moved one order of magnitude closer to the compliance limit at 10^{-3} probability compared to the CCA solubilities. (Enclosure 1, Fig. 1).194.24 Solubilities (685)

7. The solubility of plutonium in the presence of nesquehonite is several orders of magnitude higher than with hydromagnesite, high enough in fact to cause a significantly larger computed release, without changing any other factor. (718)

Response to Comments 6.BB.1 through 6.BB.7:

As is noted in these comments, the determination of the magnesium carbonate solid that will form in the repository environment from reactions with the MgO backfill material is an important issue because it affects the solubilities of the actinide solids used in the calculations, which, in turn, translates into an effect on the calculated CCDFs. The importance of the magnesium carbonate solid arises primarily from the differences in the equilibrium partial pressures of CO_2(g) that are calculated for equilibrium conditions. (The presence of CO_2(g) in the repository is expected to result from the degradation of carbon sources in the waste.) For example, equilibrium for the reaction between brucite and nesquehonite yields a CO_2(g) partial pressure of about $10^{-3.84}$ atm for the Salado Primary Constituent (SPC) brine. [Table 4-8 in TSD V-B-17] In comparison, equilibrium for reactions between brucite and the two types of hydromagnesite considered in geochemical modeling calculations described in TSD V-B-17 yield CO_2(g) partial pressures of $10^{-5.39}$ to $10^{-5.50}$ atm for the SPC brine. [Table 4-8 in TSD V-B-17] Equilibrium between brucite and magnesite yields a CO_2(g) partial pressures of $10^{-6.92}$ atm for the SPC brine. [Table 4-8 in TSD V-B-17] A similar pattern of results was obtained for the Castile brine as described in TSD-V-B-17. These calculation results show that the partial pressure for CO_2(g) would be expected to be greatest for the case of nesquehonite equilibrium, lowest for magnesite equilibrium, with hydromagnesite at intermediate levels.

For the different CO_2(g) partial pressures, different solubilities of the actinide solids are obtained in equilibrium modeling calculations. Different solubilities are caused by different levels of formation of aqueous actinide-carbonate complexes by reactions, such as

$$Th^{4+} + 5\,CO_2\,(g) + 5\,H_2O = Th(CO_3)_5^{-6-} + 10\,H^+$$

In general, higher CO_2(g) partial pressures lead to higher solubilities of actinide solids, depending on the pH and the concentrations of other complexants, because of the formation of carbonate complexes, such as $Th(CO_3)_5^{-6-}$, shown in the above reaction. As a result, the concentrations of actinides calculated for the solubilities of various actinide solids for the elevated CO_2(g) conditions of nesquehonite equilibrium are greater than the actinide concentrations calculated for hydromagnesite and magnesite equilibrium. Consequently, the CCDFs for the nesquehonite case are closer to the compliance limits than for either hydromagnesite or magnesite cases.

As part of its review of DOE's source term modeling and studies of MgO backfill effects, EPA investigated the potential effects of the different magnesium carbonates on the computed solubilities of the actinide solids. At that time, the determination of which magnesium carbonate solids would predominate under the repository conditions was not clear. However, more recent experimental work by SNL and review of the scientific literature have indicated that hydromagnesite is the most probable phase that will control CO_2(g) and pH conditions in the repository, with eventual control by magnesite (see response to Comments 6.U.7, 6.U.8, 6.U.2, 6.U.1, 6.U.3, and 6.U.5 for more details on this issue). The calculated results for actinide solid solubilities for conditions of nesquehonite equilibrium were included in the EPA review reports for completeness and to show the importance of the issue. Their use in CCDF calculations is interesting for illustrating the importance of knowing the equilibrium geochemistry, but is not considered to be representative of expected repository conditions.

In summary, EPA has concluded that the most likely representation of the equilibrium geochemistry is that controlled by hydromagnesite equilibrium and has based the calculations of the solubilities of actinide solids on the conditions imposed by hydromagnesite equilibrium. The PAVT CCDF results for the case of hydromagnesite equilibrium is the most realistic and representative depiction of the expected result of reactions between brines and the MgO backfill. EPA notes that EEG apparently has investigated the potential releases from the nesquehonite solubility (Comment 6.B.B.6) and determined that it will not result in "significantly large computed releases" (Comment 6.BB.7)

Issue CC: Plutonium (VI)

1. Regarding the oxidation states that will be present in the repository, it has been noted that Pu(VI) dominates at steady-state conditions. (See Letter, Neill to EPA, Feb. 7, 1997, enclosure re plutonium solubility) (II-H-12). Solubility values should therefore be based on the presence of Pu(VI). (976)

Response to Comment 6.CC.1:

In their description of the actinide source in Appendix SOTERM of the CCA, DOE determined that any plutonium that might be dissolved in brines that infiltrate into the repository would exist as either Pu(III) or Pu(IV). As described in Appendix SOTERM of the CCA, Pu(V) and Pu(VI) are not expected to be important oxidation states for plutonium under the expected repository conditions. The issue is potentially important because the solids that incorporate Pu(V) and Pu(VI) tend to have higher solubilities than the solids that incorporate Pu(III) and Pu(IV). Experiments by Reed et al. [1996] indicated that Pu(+6) is stable at a pH of 8 to 10 under oxidizing conditions and in the presence of high carbonate concentrations. Comment No. 6.CC.1

implies that the dominant oxidation for plutonium will be Pu(VI) based on an interpretation of some experimental work conducted by Reed et al. [1996] that was conducted at a pH of 8 to 10 under oxidizing conditions and in the presence of high carbonate concentrations.

However, application of Reed et al. [1996], to the repository is incorrect because the experimental conditions used by Reed et al. [1996] are not representative of what is expected for the repository. The repository inventory includes large quantities of reducing agents in the form of metallic iron, organic matter, and organic chemicals. These reductants are expected to rapidly consume any available oxygen present in the repository atmosphere shortly after closure, producing anaerobic or reducing conditions. Under reducing conditions, plutonium is expected to be stable in either the +3 or +4 oxidation states based on both experimental studies and chemical equilibrium calculations.

The experimental studies considered by DOE in developing their conceptual model for plutonium includes those conducted at SNL by R. Weiner and coworkers. [Weiner, 1996] These studies clearly show that Pu(VI) is reduced by iron in both soluble (i.e., Fe^{2+}) and metallic (i.e., iron powder) forms. In experimental studies of the solubilities of plutonium and other actinides, iron powder is used to maintain reducing conditions, thereby preventing Pu(III) and Pu(IV) from oxidizing to Pu(V) and Pu(VI). [Felmy et al. 1989, p. 30; Rai and Ryan, 1985, p. 248] Other studies have shown that Pu(V) and Pu(VI) are reduced by humic acids even under the oxidizing conditions of seawater. [Choppin, 1991, p. 113, 114] Humic acids and other organic acids are expected to be present in the repository from the degradation of cellulosic waste materials. These empirical observations show that Pu(V) and Pu(VI) will not persist in the presence of reductants, such as iron and organics, that will be present in the repository environment.

Also, it is important to note that the conceptual model that was developed to describe the actinide source term is based on conditions of chemical equilibrium. Under the reducing conditions that will be created by the presence of metallic iron, the stable oxidation states for plutonium are Pu(III) and/or Pu(IV). This conclusion is based on a comparison of the redox conditions (i.e., the Eh or pe) imposed by equilibrium between Fe^{2+} and $Fe(OH)_3$(s) and the Eh-pH conditions relevant to aqueous plutonium species. [Brookins, 1988, p. 73-76, 144-145; Choppin, 1991, p. 110; Rai et al. 1980, p. 417] The $Fe^{2+}/Fe(OH)_3$ stability line in Eh-pH space intersects the Pu(III) and Pu(IV) fields, indicating these are the stable oxidation states for plutonium in the presence of iron. The redox conditions imposed by organic materials are lower than for the iron species [Scott and Morgan, 1990, p. 371-374; Stumm and Morgan, 1996, p. 467-477], providing more information that leads to the conclusion that Pu(VI) will not persist under the expected repository conditions.

In consideration of the extensive empirical and theoretical information that indicates that Pu(III) and Pu(IV) are the stable oxidation states of dissolved plutonium under reducing conditions, EPA concludes that it would be unreasonable to expect that the higher oxidation states of plutonium [i.e., Pu(V) and Pu(VI)] would persist in the repository environment. EPA agrees with DOE's approach of including Pu(III) and Pu(IV) as the predominant oxidation states for plutonium in actinide source term modeling and PA calculations.

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Issue DD: Microbial actinide binding

1. Microbial actinide binding is modeled in PA using a proportionality constant. EPA has noted: “While the mathematical functions used to model microbial actinide mobilization are adequately conceived, the same cannot be said for experiments performed by BNL and LANL researchers to determine the mobile actinide binding parameters.” (TSD V-B-17 at 64). The experiments examine only one microbial strain (id.). (980)

Response to Comment 6.DD.1:

In the PA modeling for the WIPP CCA, the accumulation of actinides on microbes is represented by complete proportionality constants. Considering the large uncertainty in the identities and properties of microbes that will grow in the WIPP, it seems reasonable to adopt this approach. [TSD III-17, Section 8] The proportionality constants were determined from experiments with a microbial strain (archaeal strain WIPP-1A) that is indigenous to the WIPP salt formations (Salado brine). This strain was chosen as the model organism, although it is recognized that other strains may also be present in the repository. However, the identities and potential populations of these other strains are not known and can only be speculated about at the current time. To address the potential level of uncertainty that might be associated with having other microbial strains present in the repository, DOE incorporated an uncertainty of plus or minus one-order-of-magnitude for the concentration of actinides bound by mobile microbes. EPA believes that this uncertainty range is adequate for performance assessment since the microbes are only expected to survive in half the PA realizations and live only for about 2,000 years when they do survive because of limited substrate. In addition, the microbial proportionality constant is an insensitive parameter in EPA's sensitivity analysis.

In summary, EPA finds that, even though there are uncertainties with DOE's characterization of the microbial issues, the selection of an indigenous microbial strain as a model for characterizing the concentration of microbially bound actinides coupled with a broad uncertainty range is an appropriate and reasonable method for bounding the potential effects of microbes on the actinide source term for the purposes of PA calculations.

Issue EE : FMT computer code

1. In evaluating solubilities presented in the CCA, did EPA benchmark the FMT code against another code? (34)

2. The FMT model, not unlike the chemical conditions which exist at the WIPP, is indeed unique. However, FMT has never yielded calculations with the solubility (with all other geochemical conditions being the same) differing between Castile and Salado brine by 19 (nineteen) orders of magnitude as inferred in EEG's comment. Slight differences in the actinide solubilities between Castile and Salado brine are expected in that the concentrations of solubility influencing constituents in the brine (e.g. CO_3^{2-}, Mg^{2+}) vary significantly in these two brines. EEG's unsubstantiated assertion of 19 orders of magnitude difference in solubility is perhaps the result of some typographical error. (907)

3. The FMT code has undergone extensive validation. This included a comparison of problem solutions by FMT with the solutions to the same problem as provided by PHRQPITZ and EQ3/6. The code PHRQPITZ was utilized instead of PHREEQE (the use of PHREEQE was suggested by EEG) since PHRQPITZ includes the Pitzer formalism (which is used by FMT) whereas PHREEQE does not. These validation efforts are extensively documented in FMT Version 2.0 Validation Document Version 1.0. This validation document was placed in the Sandia WIPP Central Files under WPO# 28121 on 11/17/95. (908)

4. EEG has rightly criticized the use of the FMT model. It has shown that model calculations result in a difference in 19 orders of magnitude between solubility of some compounds in Salado and Castile brine. (977)

5. The FMT model is unique to WIPP and is not generally used elsewhere. Calculations using the FMT model result, for example, in a difference of 19 orders of magnitude between the projected solubility of thorium pentacarbonate in the Castile brine versus the Salado brine. This is hard to explain on the basis of differences in the brine compositions. Hence the code becomes suspect. (1238)

6. In reviewing the basis for the selection of actinide solubilities in the CCA and PAVT calculations, the EEG finds that the FMT model is unique to WIPP and is not used elsewhere. Calculations using the FMT model result, for example, in a difference of 19 orders of magnitude between the projected solubility of thorium pentacarbonate in the Castile versus the Salado brine. This is hard to explain on the basis of differences in the compositions. Hence the code becomes suspect. It appears that the EPA verification was limited to an exercise in which EPA used the same computers, codes, and database (after correction of some errors in the database) as DOE, to determine the same numerical values. Verification would require, at a minimum, an analysis and demonstration that the FMT code correctly solves the simultaneous equations, a thorough comparison with the results of calculations using a code that is used more widely in the modeling community, and a demonstration that the calculations are consistent with all relevant published data. For example, as a preliminary analysis, it would have been more informative if a widely used code such as EQ3 or PHREEQE had been used with the FMT database and then FMT had been used with a database from some other modeling group. (680)

Response to Comments 6.EE.1 through 6.EE.6:

The Fracture Matrix Transport (FMT) code solves chemical equilibrium problems using the Pitzer activity coefficient formalism. The Pitzer approach is the most accurate method for calculating activity coefficients for ionic species under conditions of high ionic strength as found in the WIPP brines. The FMT model computes activities and concentrations of constituents in brine solutions based on thermodynamic data and Pitzer parameters from Harvie, Moller, and Weare and Felmy & Weare [Docket: A-93-02, II-G-1, Ref. #286 and Ref. #245] for the following major components; hydrogen, oxygen, sodium, potassium, magnesium, calcium, chlorine, sulfur, carbon, boron, bromine, chlorate, phosphorus. This database has been augmented to include data for Am(III), Th(IV), and Np(V) which are relevant to use of FMT at WIPP. Positions in the database exist for U(VI) species, but no data actually exist in the database for these species, and consequently the FMT code is not used to model uranium chemistry.

For implementation in the PA, the FMT code is used to calculate the concentrations of Am(III), Th(IV), and Np(V) from the solubilities of specified actinide solids under conditions of chemical equilibrium. The code is not actually used for transport calculations as might be implied from its name. The effects on chemical conditions caused by equilibrium with specific solid phases part of the database are also included in the FMT calculation scheme. This capability is important for determining the effects of specific reactions, such as between magnesium hydroxide and magnesium carbonates, that are expected to be important for controlling pH and CO_2(g) fugacity in the repository -- i.e., parameters that strongly affect the solubilities of actinide solids. The FMT model is not used for calculating redox equilibria. Instead, actinides are specified to exist completely in a single oxidation state, i.e., Am(III), Th(IV), and Np(V). Using oxidation state analogies, the results for these actinides are extrapolated to Pu(III), Np(IV), U(IV), and Pu(IV).

A fundamental precept of the representation of the repository environment in the performance assessment is that the actinide source term can be described by chemical equilibrium processes. The FMT code is a model of chemical equilibrium as applied to actinide chemistry that incorporates the Pitzer approach for calculating activity coefficients relevant to the high ionic strength conditions present in the Salado and Castile brines. This conceptualization is summarized in Appendix SOTERM. [Docket: A-93-02, II-G-1, Volume XVII and more detail regarding chemical equilibrium processes are provided in Docket: A-93-02, II-G-1, Ref. #302, Ref. #477, Ref. #479; Docket: A-93-02, II-G-3, Volume 6, User's Manual; Novak, et. al. 1995; and Bynum 1996]

In summary, the chemical equilibrium concept as applied to the repository environment involves the following assumptions:

- The system of brine and wastes is well-mixed [Appendix SOTERM].

- The brine composition entering the repository is constant with time. [Appendix SOTERM]

- The brines are in chemical equilibrium with the common minerals found in the Salado and Castile formations (e.g., halite and anhydrite). [Appendix SOTERM and Ref. #479]

- The brine pH (or pcH) and fugacity of CO_2(g) will be buffered to specific values by the equilibrium between brucite [$Mg(OH)_2$] and magnesite [$MgCO_3$] as a result of brine interactions with the MgO backfill material. [Appendix SOTERM and Ref. #479]

- The concentrations of actinides released to the brines can be represented by the experimentally determined solubilities of the actinide-bearing solids expected to form under the prevailing solution conditions. [Appendix SOTERM, Ref. #477, Ref. #479 and Novak, et. al., 1995]

- The effects of redox reactions can be adequately represented by assuming dominant valence states for the actinides expected to be stable under the reducing conditions of the repository, where reducing conditions are generated from the consumption of oxygen by decaying organic material and ferrous metals. [Appendix SOTERM]

- Oxidation state analogies can be used to represent the concentrations of actinides for which solid-phase solubility data are not available or inadequate, i.e., Am(III) is used to represent Pu(III), where Th(IV) is used to represent Np(IV), Pu(IV) and U(IV), etc. [Appendix SOTERM and Novak, et. al., 1995]

- Solubility and aqueous speciation data are inadequate to model U(VI), hence a model solubility of 8.8×10^{-6} M (in Castile brine) is used to provide a conservative representation of expected U(VI) concentrations based on a variety of empirical measurements. [Appendix SOTERM and Ref. #302]

- The uncertainty in predicted solubilities of actinide solids can be represented by the deviances between solubilities determined in individual experimental studies and concentrations predicted by models used to fit experimental data to aqueous speciation schemes. [Appendix SOTERM, and Bynum 1996]

- The Pitzer approach provides the best representation of activity coefficient for the high ionic strength solutions found in the Salado and Castile brines. [Appendix SOTERM, User's Manual, Ref. #477, Ref. #479, and Novak, et. al., 1995]

To determine conditions of chemical equilibrium for a solid/solution system, the FMT model uses the criteria of minimization of free energy given the constraints of the chemical composition of the fluid in question and principles of mass and charge balance and mass action defined for individual chemical reactions. [FMT User's Manual] This method is entirely consistent with the definition of chemical equilibrium as being the state of lowest free energy. The equations of mass action and mass balance are defined in the thermodynamic database of the FMT model in terms of specific reactions for aqueous speciation and solid phase solubility. [FMT User's Manual]

The FMT model was designed for application to high ionic strength solutions and contains algorithms that incorporate the Pitzer approach to calculating activity coefficients for dissolved species based on the databases developed in Docket: A-93-02, II-G-1, Ref. #245 and Ref. #286. These databases were developed for representing chemical equilibrium in the high ionic strength solutions found in evaporative lakes and are directly applicable to representing chemical reactions in the high ionic strength brines of the Salado and Castile formations.

The response to these questions is split into two parts: (1) difference of 19 orders of magnitude, and (2) code verification.

Part (1) Response to Comments

It is not clear what the basis is for the comments (680, 977) that mention the phrase "...a difference of 19 orders of magnitude between the projected solubility of thorium pentacarbonate...." EPA is unable to find any specific reference to any report that might provide some context. The term solubility refers to how much of a solid can dissolve in a solution under a given set of conditions. In the case of thorium and the WIPP, the solubility of ThO_2(am) is used to calculate the total amount of thorium that can dissolve in the brine solutions for the specified chemical conditions. Thorium pentacarbonate is just one of many aqueous species that the dissolved thorium can form under the specified conditions. Its concentration may be many orders of magnitude less than the total dissolved thorium concentrations, but, in any event, cannot be greater than the total dissolved thorium. No cases of change in the total dissolved thorium concentration of 19 orders of magnitude could be found in the documents on the FMT calculations and actinide source term.

Part (2) Response to Comments

The focus of the work conducted by EPA [Technical Support Document for Section 194.23: Models and Computer Codes, Appendix A1, Docket: A-93-02, V-B-6] on the FMT computer code was:

- ♦ To evaluate the procedures used by DOE to incorporate conceptualizations of geochemical processes to define the actinide source term within the context of the calculation abilities of the FMT code;

- ♦ To investigate alternative conceptualizations of geochemical processes, such as the effects of equilibria conditions with hydromagnesite and nesquehonite rather than magnesite, on the solubilities of actinide solids; and

- ♦ To reproduce independently the results reported by DOE in the CCA, while investigating code behavior for potential errors, such as unrealistic concentrations for a given set of conditions.

As suggested in Comment 680, verification of the FMT calculation results through comparison with results from other computer codes and is also useful for evaluation purposes. However, a validation-verification study of the FMT code had already been conducted by DOE WPO #28121 (WPO #28118, and WPO #40256).

In the validation exercises reported in DOE's studies (see discussion of each FMT validation exercise below), the accuracy of the FMT calculations results were evaluated for providing accurate calculations of elemental mass balance, reaction equilibrium calculations, and activity coefficients. These tests were conducted with the SPC (Salado Primary Constituent) brine composition and no errors were found. [WPO #28121, pp. 188-208] In another test, the FMT calculations were compared to the measured solubilities of various minerals (e.g., galserite, sylvite, halite, kainite, leonite, trona, borax, nahcolite, etc.) expected to be important precipitates in high ionic strength solutions and to test the FMT model's implementation of the Pitzer activity coefficient model and Harvie-Moller-Weare database. The FMT model was found to accurately represent the solubilities of the brine minerals, indicating that it correctly implements the Pitzer activity coefficient model and also represents experimental data for brine solutions. [WPO #28121, pp. 221-278] The FMT model calculations were also compared to experimental measurements of the solubility of $NdAm(CO_3)_2$ in sodium carbonate and bicarbonate solutions and found to provide an accurate representation of those data. [WPO #28121, pp. 326-344]

Additionally, as suggested in Comment 680, the results from FMT were compared to results obtained with PHRQPITZ and EQ3, two well-known geochemical computer models. [WPO #28121, pp. 279-283] The sample problem involved calculations of aqueous speciation of major cations and anions (Na, K, Mg, Cl, SO_4, B, and CO_3) in a brine solution in equilibrium with different solid phases specified as solubility controls. The differences between the FMT and other codes were generally less than 15% for everything but boron from the EQ3 model. [WPO #28121, p.279, 281] The differences in results for boron can be attributed to the fact that the EQ3 model did not contain a fully parameterized set of data relevant to boron at high ionic strengths, hence cannot be expected to produce accurate results for boron speciation under high ionic strength conditions. For all other cases, the FMT model results were in good agreement with the results obtained with PHRQPITZ and EQ3.

Overall, the validation tests designed and conducted for the FMT code by DOE indicated that FMT produces reliable results for aqueous speciation and solubility given an accurate database. Previous comparisons of geochemical computer models have indicated that differences in calculation results are primarily a function of the individual values for various aqueous species and solid phases in each model's thermodynamic data and generally not a function of the mathematical scheme used to obtain the result. [Nordstrom et al. 1979, pp. 867-880, 885] In summary, EPA reviewed DOE's verification studies of the FMT code as part of their assessment of the work related to the development of the actinide source term, and agreed with DOE's conclusions that the FMT code produces reliable results for aqueous speciation and solubility for high ionic strength solutions, depending on the accuracy of the FMT thermodynamic database.

Validation exercises

A series of nine verification and validation model runs or tests are described in the Requirement Document & Verification and Validation Plan (RD/VVP) and the Validation Document (VD) for FMT. [Docket: A-93-02, II-G-3, Volume 6] These verification tests adequately cover the calculation limits of the FMT code used in the CCA PA. They are designed to test the ability of the FMT model to implement its numerical algorithms correctly and produce stable solutions.

The results from the first run verify that the FMT model correctly maintains mass balances for chemical components and accurately reproduces equilibrium constants. [VD, pp. 198-208]

The second test indicates that the FMT model can reproduce the general effect of carbonate concentration on $NaNpO_2CO_3$(s) solubility, although the model calculation concentrations were generally lower than those measured in experiments. [VD, pp. 218-220]

The third test shows that FMT can reproduce the measured solubilities of various solids commonly found in evaporite deposits, such as the Salado and Castile formations, when compared to experimental measurements. These results indicate that the Pitzer ion interaction parameters of references 286 and 245 were entered correctly and provide accurate depictions of activity coefficients in high ionic strength solutions. [VD, pp. 273, 276]

In the fourth test, results from FMT were compared with those obtained from EQ3/6 and PHRQPITZ, which are also models of chemical equilibrium with implementation of the databases of references 286 and 245. The FMT results are in very good agreement with those from the other models except for boron from the EQ3/6 model. [VD, pp. 280-282] However, EQ3/6 did not contain a full boron model and boron is not considered to have any impact on actinide concentrations, hence the small discrepancies are not considered important.

The fifth test involved using FMT to titrate sulfate solutions with HCl to determine the effect on the solubility of $AmPO_4$ for comparison to experimental data and previous FMT calculations. The results show a very good match to the experimental data and replication of the FMT calculations used to represent $AmPO_4$ solubility in a previous FMT application.

In the sixth test, the criteria of mass balance was tested for an Am(III)-containing SPC (Salado Primary Constituent) brine titrated with NaOH. Mass balances for oxygen and hydrogen were examined and found to match starting masses indicating that FMT's numerical solution scheme correctly satisfied the constraint of mass conservation in its calculation of equilibrium solution composition. Calculations of equilibrium constants for various speciation reactions also closely matched the values contained in the FMT database.

For the seventh test, results from FMT calculations were compared to Am(III) concentrations from solubility experiments with $NaAm(CO_3)_2 \cdot 6H_2O$ conducted over a range of carbonate concentrations. The comparison shows that FMT closely reproduces the solubility data, indicating that it provides an accurate representation of experimental results.

The eighth test case was directed at examining FMT calculations of the effects of elevated CO_2(g) fugacity on speciation of the SPC brine. The problem was run for a CO_2(g) fugacity of 60 atm and results were examined for mass balance violations. The results showed that carbon and other elements were conserved.

In the ninth and final test, a number of test cases were run with input values that either represented physically impossible situations and incorrect chemical specifications. In all cases, the FMT code reported an error and stopped execution or produced a solution composition that reflected the errors in the input.

The verification and validation plan for the FMT code as described in the RD/VVP and the VD provides a clear indication that the FMT code provides correct and stable solutions for a variety of chemical equilibrium problems. The tests were appropriate, including checks of elemental mass balance, calculation of equilibrium constants, and comparisons of results with other geochemical codes. Additionally, FMT calculations of actinide-solid solubilities were in good agreement with experimental data. This test is important because FMT is used to calculate actinide concentrations from solubility data for input to the performance assessment.

The only test that was lacking in detail in the verification and validation study was directed at FMTs representation of CO_2(g) equilibria. However, additional execution of the FMT code, that has been conducted as part of other subsequent studies, indicate that FMT does provide accurate calculations of aqueous speciation and solubility in a CO_2(g)-containing system (see below Section d). As a result, this issue is not considered to be a significant omission in the testing of the FMT code.

<u>FMT documentation</u>

The FMT code is documented as specified in NQA-2a-1990 in the User's Manual, the Requirements Document & Verification and Validation Plan, the Validation Document, and the Implementation Document. [Docket: A-93-02, II-G-1, Volume 5]

Although these reports describe the operation and testing of the FMT code, they do not document the generation of the thermodynamic database used by FMT or the modifications to that database planned for the future. This issue is important because calculations of the solubilities of actinide solids with FMT are directly dependent on its thermodynamic database. This database has undergone continuous revision since the publication of the User's Manual and the CCA, and this has undoubtedly resulted in improvements, but the changes have made it difficult to reproduce past results exactly. For example, the database used for the verification studies is indicated to be fmt_hmw_np_am.chemdat in the Script file on p. 29 of the RD/VVP, implying that it does not contain data for Th(IV). However, Table SOTERM-2 of Appendix SOTERM -- which provides the calculated actinide concentrations from FMT for the CCA -- concentrations are given for +IV actinides, i.e., Th(IV). Because Th(IV) is the model for the +IV actinides, a database distinct from that used in the RD/VVP and the VD containing data for Th(IV) species must have been used.

Documentation of the history of changes in the FMT thermodynamic database and implementation for the CCA process is absent in the materials associated with the CCA. However, a complete copy of the data base was provided by Novak 1997.

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WPO #28121. WIPP PA Validation Document for FMT (Version 2.0), Document Version 1.00, November 17, 1995, Sandia National Laboratory, Albuquerque, New Mexico.

WPO #28118. WIPP PA Requirements Document and Verification and Validation Plan for FMT (Version 2.0), Document Version 1.0, November 17, 1995, Sandia National Laboratory, Albuquerque, New Mexico.

WPO #40256. WIPP PA Implementation Document for FMT (Version 2.1), Document Version 1.1, August 15, 1996, Sandia National Laboratory, Albuquerque, New Mexico.

Issue FF: Incorrect reference

1. The reference on page 24-8 (CARD 24) to Section 4.5 of the CCA is incorrect. (7)

Response to Comment 6.FF.1:

CARD 24, [p. 24-8], incorrectly cites to Section 4.5.4 of the CCA. The correct citation should read: Chapter 4.4.2.3, p. 4-12. CARD 24 has been corrected to reflect this change.

Issue GG: WIPP end date for operations

1. Why did DOE use 2033 as an end date for WIPP operations, as opposed to 2160 as indicated in the Supplemental Environmental Impact Statement? (8)

Response to Comment 6.GG.1:

The year 2033 represents the date at which DOE intends to complete the operational phase of the project and begin to prepare the WIPP facility for permanent closure (i.e., the WIPP will have reached design capacity and DOE will no longer receive, handle, or emplace wastes in the repository). The end of the operational phase (or disposal phase) is the base year from which DOE must comply with the containment requirements of 40 CFR 191.13(a) which stipulates that "[The disposal system] shall be designed to provide a reasonable expectation, based upon performance assessments, that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from all significant processes and events...." Further, for the purposes of complying with 40 CFR Part 194, DOE was required to use the 2033 date in the CCA because the regulatory time frame for DOE's demonstration that WIPP will comply with the radioactive waste disposal regulations is the time period beginning at disposal and ending 10,000 years after disposal. [40 CFR 194.2]

Section 7 Expert Judgment -- Section 194.26

Issue A: DOE's assertion that expert judgment was not used in the CCA is incorrect.

1. Many parameters in the CCA are a result of expert judgment, rather than scientific data. The Compliance criteria require specific procedures when expert judgment is used. However, DOE insists that expert judgment was not used at all in the CCA. This is not a credible position, and the Compliance criteria have plainly been violated. (150)

2. The IRG was surprised that the CCA states that expert judgment is not used, whereas it is clear that the judgments of the project staff have had a very important influence on the performance assessment (at 12). (1055)

Response to Comments 7.A.1 and 7.A.2:

A commenter selectively quotes from an International Atomic Energy Agency (IAEA) report. The complete quotation is as follows:

> The IRG was surprised, for example, that the CCA states that expert judgment is not used, whereas it is clear that the judgments of the project staff have had a very important influence on the performance assessment. This arises because the term "expert judgment" has a specific meaning in the EPA regulations, indicating formal elicitation of experts independent of the project. [Docket A-93-02, Item IV-G-40, Enclosure (IAEA Report), p. 12]

DOE correctly stated that no expert elicitation (expert judgment) activities were conducted with respect to the CCA. Expert elicitation is explicitly defined by Section 194.26 of the Compliance criteria and requires adherence to specific rules and requirements that govern its conduct. EPA believes that a commenter's statement that many CCA parameters are the result of "expert judgment" actually refers to DOE's purported use of "professional judgment" for deriving certain input parameters. The CCA identifies a number of input parameters as resulting from "professional judgment." The Compliance criteria, however, do not provide for derivation of input parameters through "professional judgment." Input parameters are to be derived solely from data collection, experimentation, or expert elicitation. EPA identified 149 parameters identified in the CCA as purportedly resulting from "professional judgment" that were not adequately supported by data collection, experimentation, or expert elicitation. EPA requested additional information from DOE on the derivation of these input parameters. [Docket: A-93-02, Items II-I-17, II-I-25, and II-I-27] In the absence of evidence of data collection or experimentation, EPA expected DOE to derive these parameters through actual expert elicitation, in accordance with the requirements of 40 CFR 194.26.

DOE added information to and improved the quality of the records stored in the Sandia National Laboratory (SNL) Records Center to enhance the traceability of the input parameters. On the basis of the new information made available in the SNL Records Center, EPA determined that 148 of the 149 suspect parameters were properly derived for use in the PA. For a comprehensive discussion of the technical review of PA parameters, see CARD 23 -- Models and Computer Codes. [Docket: A-93-02, Item V-B-2] DOE did not provide adequate documentation to support the derivation of the waste particle size distribution parameter. Therefore, EPA required DOE to conduct an expert elicitation to develop the value for the waste particle size distribution parameter.

DOE conducted the expert judgment elicitation from May 5-9, 1997. EPA observed DOE's elicitation process and conducted an audit of the documentation prepared to support DOE's compliance with Section 194.26. The scope of the audit covered all aspects of the expert judgment elicitation process, including: panel meetings, management and team procedures, curriculum vitae of panel members, background documents, and presentation materials. EPA's audit team assessed the compliance of the expert elicitation process, in accordance with the requirements of 40 CFRSection 194.22(a)(2)(v) and 194.26. Based on the results of the audit and review of all appropriate documentation, the Agency concluded that DOE met the requirements stipulated in Section 194.26 for the waste particle size distribution parameter expert elicitation.

Issue B: Specific applications of expert judgment

1. Some examples of expert judgment activities used in the CCA follow. Expert judgment is a part of the passive institutional control development process according to the WIPP Passive Institutional Control Peer Review Report (p. 4-3 and 4-4). A November 14, 1995 R-E/SPEC Inc. memorandum (PE/SPEC's Pfeifle to SNL's Diane Hurtado) outlines as part of a task plan "solicitation of expert opinion" for establishing seals parameter values, and execution of this task plan would seem to fall directly under the Section 194.26, Expert Judgment requirements. (769)

Response to Comment 7.B.1:

The commenter asserts that DOE utilized expert judgment as part of the PICs development process and for establishing seal parameter values, and that such activities were subject to the Section 194.26 requirements. The Compliance criteria entered into effect as of April 9, 1996. 40 CFR 194.7. Expert elicitations conducted prior to that date were not necessarily expected to comply with the Section 194.26 requirements. DOE's development of PICs was informed by two historical expert panels, the Futures Panel and the Markers Panel. These Panels concluded their assignments in 1991, and 1993, respectively. For additional information on DOE's development of PICs, refer to CARD 43, Section 43.A.5. EPA does not consider it necessary that DOE demonstrate that these Panels comply with regulatory requirements promulgated five and three years, respectively, after they were conducted. With respect to the task plan for solicitation of expert opinion for establishing seals parameter values, these parameter values were investigated during EPA's review of input parameters purportedly derived using professional judgment. EPA found that DOE has used data that have been collected either from experimental studies or literature searches for analogous situations (analog data) to develop these specific parameters. An example of the usage of analog data will be, DOE used experimental studies on solubilities of non-actinide solids, Neodymium [Nd (+3)] to represent actinides solubilities. The underlying rationale is that Nd, is a lanthanide group element with ionic and aqueous speciation properties that are similar in nature to Plutonium [Pu (+3)] and Americium [Am (+3)]. So using lanthanides as proxies for actinides is acceptable because of their similar chemical properties. Thus, in accordance with EPA's requirements, because either experimental or collected data was used to derive the seal parameter values, expert elicitation was not necessary. Refer to EPA Technical Support Documents for Section 23: "EPA Parameter Report" [Docket: A-93-02, Item V-B-12] and "Parameter Justification Report." [Docket: A-93-02, Item V-B-14]

Issue C: Use of professional judgment in the CCA

1. EPA's statement that "[t]he Compliance criteria do not provide for utilization of "professional judgment" is incorrect. The scientific use of data always requires judgments of some sort concerning what data should be collected, how data should be used, and how data should be extrapolated or interpolated between or beyond actual measurements. Professional judgment is not a distinct category of information, but a necessary adjunct to the use of all data in any scientific study. Data are never complete, and investigators must always use some amount of judgment in interpolating, extrapolating, interpreting, and applying data. In EPA's background information document for 40 C.F.R. Part 194, the Agency acknowledged that the procedures established in section 194.26 do not apply to every exercise of judgment in the CCA. (939)

2. Numerous parameters used in the performance assessment are justified by "investigator judgment" or "professional judgment." (769)

Response to Comments 7.C.1 and 7.C.2:

The Agency believes that Comment 939 misinterprets the statement cited. As discussed in the preamble to the proposed rule [62 FR 58817], "the Compliance criteria do not provide for derivation of input parameters through "professional judgment." This statement means that input parameters used in the performance assessment are to be derived from data collection, experimentation, or expert elicitation. The Agency, however, recognizes that raw data resulting from data collection or experimentation may require "professional judgment" in the development of input parameters. Professional scientific judgment used when interpolating, extrapolating, interpreting, and applying data can be used provided that it does not substitute for experimental data or data collection. The applicability of Section 194.26 does not extend to professional scientific judgment.

Section 8 Scope of Performance Assessments and Consideration of Drilling Events -- Sections 194.32 & 194.33

Issue A: DOE has not adequately characterized scenarios at WIPP.

1. Appendix SCR states that drilling associated with geothermal energy production, liquid waste disposal, hydrocarbon storage, and archaeology has not taken place in the Delaware Basin, and, therefore, such matters need not to be considered in PA. . . DOE relies upon Section 194.25, the future states rule, but it is an error to assume that the future states rule is tied directly to recent history in the Delaware Basin. (153)

2. To review, it has been postulated that at some future date there exists a remote possibility that a drilling operation may penetrate the site. If several other low probability assumptions are invoked, it could be calculated that degraded waste material spalls into the drill string and out the hole to the surface -- at least theoretically. When taken all together, these contributing assumptions have led to the largest theoretical releases between one and two orders of magnitude below the EPA limit. (180)

3. We have been pressing for two major actions. One: All the implications of the resource exploitation activities be taken into account in projecting the potential scenarios for future inadvertent breach of the site and in computing the effects of those scenarios; in particular, the consequences of air drilling and fluid injection, and mining, including solution mining activities, require additional attention from the EPA. (190)

4. What the proposed rule shows is that EPA did not evaluate at all the impacts of air drilling into the site. EPA did not realistically evaluate the impact of drilling with mud, which again results in releases that violate the disposal regulations. EPA did not evaluate releases from fluid injection

even if it occurs outside the site boundary, which can lead to violations of the standard, let alone fluid injection within the site boundary, also leading to violation of the standard. EPA did not evaluate carbon dioxide injection for over recovery even though that again is another realistic scenario that results in violation of the disposal regulations. (227)

5. Despite decades of concerns about major water intrusion into the WIPP site, the major release scenarios have not been adequately analyzed. Water flooding, drilling, gas or brine intrusion must be better analyzed and better mitigation measures must be developed. The possibility of catastrophic failure at WIPP with the release of 100,000 to millions of curies is still present. Tens of thousands of gallons of fluid injection from oil drilling can move laterally into the site from outside current boundaries. (256)

6. We all know that in the future human beings will be strongly motivated to drill down through the WIPP site. We know that human beings invariably make mistakes. We can deduce this with practically 100 percent certainty that within far less time that the required lifetime of WIPP, human activity will release radioactive material at the surface and into the aquifer. (264)

7. EPA has ignored events that will cause massive radioactive releases that violate the disposal standards. EPA has dramatically underestimated the likelihood that drillers will hit highly pressurized brine reservoirs. EPA has not fully considered that drilling outside the WIPP site boundary would cause radioactive wastes that violate the disposal regulations. (268)

8. All the implications of the resource exploitation activities [must] be taken into account in projecting the potential scenarios for future inadvertent breach of site and in computing the effects those scenarios. In particular, the consequences of air drilling and fluid injection and mining, including solution mining, activities require additional attention from the EPA. (351)

9. I request that you require the DOE to resubmit a compliance [application] that includes the issues of the [Hartman] scenario, modeling air drilling releases from [either] air and mud drilling, and the possibility of drilling into the WIPP site and hitting a brine reservoir. (428)

10. First is that the geologic and hydrologic studies have conclusively shown that the WIPP repository will not be breached by any natural process for times far in excess of 10,000 years. (455).

11. [R]esource exploitation activity should be taken into account in projecting the potential scenarios for future inadvertent breach of the site, in computing the effects of these scenarios. In particular, the consequences of air drilling, fluid injection, mining, including solution mining, activities require additional attention from EPA.(484)

12. Because there are large amounts of potash, natural gas and oil near the site, the repository may be breached by future drilling. Radioactive materials could travel to the surface through the boreholes. If the brine reservoirs below the repository also are breached, the pressurized brine can push the radioactive slurry to the surface with even greater force. (491)

13. Why is EPA willing to summarily reject the carefully examined scenarios brought forth by numerous qualified sources regarding potential drilling releases at WIPP. (510)

14. Major scientific concerns not included in the evaluation: One is the comprehensive modeling of gas, oil and potash. Drilling releases using current technological methods such as forced air and brine injection. The second would be a fully assessed possibility of fractures in the substrata caused by fuel injection and the level of commercial drilling around the WIPP site for the future given the next 10,000 years. (529)

15. What are all the potential scenarios should highly lethal radioactive waste be stored at the WIPP site in terms of environmental contamination and release of deadly poisons? (583)

16. [T]he EEG recommended (EEG-6, May 1996) that at least the actual conditions at the site related to the presence of natural resources be fully and conservatively assumed in projecting compliance with the numerical containment requirements. This does not appear to have been done in the CCA, judging from the DOE resistance to consideration of fluid injection, air drilling, and mining scenarios. (709)

17. All the implications of the resource exploitation activities be taken into account in projecting the potential scenarios for future inadvertent breach of the site and in computing the effects of those scenarios. In particular, the consequences of air drilling and fluid injection, and mining (including solution mining) activities require additional attention from the EPA (716).

18. As described in Section 6.1 of the CCA, scenario uncertainty was assessed by randomly sampling the occurrence of future events that create scenario uncertainty, namely, deep drilling for exploratory boreholes and potash mining. In the three replicates of 100 vectors, there are 3,000,000 individual, explicit scenarios. Each of these 3,000,000 scenarios is unique. If one chooses to view scenarios more collectively, then the CCA considered seven discrete scenario types . . . (1) undisturbed performance, (2) potash mining, (3) deep drilling with brine reservoir intrusion, (4) deep drilling without brine reservoir intrusion, (5) potash mining plus deep drilling with brine reservoir intrusion, (6) potash mining plus deep drilling without brine reservoir intrusion, and (7) potash mining with combinations of deep drilling with and without brine reservoir intrusions. We therefore conclude that the IRG as quoted by Bredehoeft is wrong because conceptual model and scenario uncertainties are presented and discussed in considerable detail in the CCA and supporting documents. (936)

19. Some events and processes not analyzed might deserve consideration from a radiological safety perspective, including water flooding due to nearby brine injection, solution extraction of the salt, solution mining of underground cavities for storage, and extraction boreholes disturbing the flow regime (at 19). (1059)

20. In the past 50 years the area salt beds have been subjected to intense exploration, drilling, and mining by prospectors seeking oil, gas, potash and other minerals from the rich deposits there. The disposal regulations, subparts B and C of 40 CFR 191 determine that "DOE must demonstrate, with reasonable expectation that WIPP complies with the following provisions of the compliance criteria," and the second criteria lists "Containment Requirements, which address methodologies for considering inadvertent human intrusion." The DOE has not sufficiently addressed the inevitability that future drilling and mining could puncture the WIPP storage rooms. (1092)

21. There are numerous scenarios which result in massive releases of radioactivity, far in excess of the limits established in the EPA disposal regulations (40 CFR 191.13). Among those scenarios are direct drilling into waste rooms (by air or conventional mud drilling), drilling through the repository and into the underlying pressurized brine reservoir, fluid injection for oil and gas production in which brine moves through marker beds at WIPP and floods waste rooms, and carbon dioxide injection. (1107)

22. EPA did not evaluate at all the impacts of air drilling at WIPP--though air drilling would result in releases that violate the disposal regulations. EPA did not realistically evaluate the impacts of drilling with mud. (1129)

Response to Comments 8.A.1 through 8.A.22:

Many commenters stated that DOE did not adequately characterize or analyze scenarios that could occur at WIPP or that EPA has ignored events (Comments 8.A.3, 8.A.5, 8.A.7, 8.A.8, 8.A.11, 8.A.14, 8.A.16, 8.A.17, 8.A.19, 8.A.20, and 8.A.21). In addition, Comment 8.A.15 raised the question of what are the potential scenarios at WIPP. Many of the scenarios identified in these comments are related to human activities associated with resource exploitation, with an emphasis on direct drilling into the site; however, commenters are also concerned about indirect effects of human activities, such as fluid injection for secondary oil recovery and potash mining away from the waste panel area. Some comments (8.A.3, 8.A.4, 8.A.8, 8.A.9, 8.A.11, 8.A.16, 8.A.17, 8.A.20, 8.A.21, and 8.A.21) claimed that scenarios which should have been included in DOE's performance assessment were omitted by either DOE or EPA. EPA disagrees with the premise that scenarios were improperly characterized or omitted from DOE's performance assessment. Uncertainties were discussed and accounted for in the CCA using the process discussed below.

In summary, DOE followed an acceptable process for identifying potential features, events and processes (FEPs) that could occur and then narrowed down the events to those that were relevant to WIPP. [Docket: A-93-02, II-G-1, Chapter 6.2-6.4, Appendices DEL, SCR, CCDFGF, SA and

MASS] DOE put the features, events and processes into two groups: those FEPs that would occur if the repository were not disturbed by direct human intrusion, and those FEPs that would occur if there were direct human intrusion into the repository. DOE modeled the case of no human intrusion and identified that radionuclide releases to the accessible environment would be negligible. In the case of human intrusion, DOE identified that releases would be associated with releases to the surface from cuttings and cavings, spallings and direct brine release. DOE identified that additional, but minimal, long-term radioactive releases could occur from brine in the repository moving upward to and through the overlying Culebra and to the accessible environment. DOE also incorporated the potential effects of potash mining at the site. As discussed in multiple sections of CARD 32, Section 32.C, EPA agreed that DOE's process was adequate and DOE appropriately included scenarios that could affect releases from WIPP.

Some Comments (8.A.3, 8.A.4, 8.A.9, 8.A.15, 8.A.16, 8.A.17, and 8.A.21) identified that air drilling was not evaluated. Air drilling was not evaluated in the CCA; however, EPA reviewed the air drilling scenario at WIPP and identified that it was not current practice in the Delaware Basin and did not have to be considered [Docket: A-93-02, V-B-29] in the performance assessment. EPA's analysis also demonstrated that, even if air drilling were to occur at WIPP, releases from air drilling would not result in noncompliance with the disposal regulations. Air drilling is further discussed in this section of the responses to comments.

Since many of the comments indicated a misunderstanding of or questioned DOE's process for incorporating activities or scenarios into the performance assessment, DOE's process, EPA's review of that process and specific responses to comments are provided below.

The radioactive waste disposal regulations at 40 CFR Part 191 include requirements for containment of radionuclides. The containment requirements specify that releases from a disposal system to the accessible environment may not exceed the release limits set forth in Appendix A, Table 1 of Part 191. [Section 191.13] Assessment of the likelihood that DOE's WIPP will meet the Appendix A release limits is conducted through the use of a process known as "performance assessment" (PA). The WIPP PA culminates in a series of computer simulations that attempt to describe the physical attributes of the repository (site, geology, waste forms and quantities, engineered features) in a manner that captures the behaviors and interactions among its various components. The results of the simulations show the potential releases of radioactive materials from the disposal system to the accessible environment over the 10,000-year regulatory time frame. The PA must include both natural and man-made processes and events which have an effect on the disposal system. [61 FR 5228] Section 194.32, "Scope of Performance Assessment," stipulates that the PA shall include both natural and man-made processes and events that may affect the disposal system over the regulatory time period.

In the CCA, EPA expected DOE to consider all FEPs that may have an effect on the disposal system during the regulatory time frame. The terms undisturbed performance and disturbed performance can be applied to the consideration of FEPs. Undisturbed performance is defined in Section 191.12 to mean "the predicted behavior of a disposal system, including uncertainties in predicted behavior, if the disposal system is not disrupted by human intrusion or the occurrence of unlikely natural events." As defined in Section 194.32, the undisturbed performance scenario includes the effects of human activities outside the controlled area. (Comment 8.A.15) DOE identified 67 FEPs that were included in the undisturbed performance scenario. [See Table 6-6, p. 6-65 to 6-68] As mentioned in Comment 8.A.10, natural processes are not expected to breach the repository in the 10,000 year regulatory period. CCA Vol. XVI, Appendix SCR, Section SCR.1 [Docket: A-93-02, II-G-1] identifies some natural processes that could potentially breach the repository (for example, volcanic activity or a large meteorite impact). However, these processes were screened out because of their low probabilities of occurrence. [Docket: A- 93-02, V-B-21] EPA agrees with Comment 8.A.10 that any natural event large enough to disrupt the disposal system would have a very low probability and can thus be screened out. The human activities included in the undisturbed performance scenario outside the Land Withdrawal Boundary are potash mining and fluid injection related to hydrocarbon extraction.

In addition to natural processes and events, Section 194.32 required DOE to consider human intrusion related activities of mining, deep drilling, and shallow drilling that may affect the disposal during the regulatory time frame (creating the disturbed performance scenario). (Comment 8.A.15) DOE listed the events and processes retained for the disturbed performance scenario in CCA Chapter 6, Tables 6.4 and 6.5. As identified by numerous comments, there are natural resources in the vicinity of the WIPP. [CCA Chapter 2.3, pp. 2-145 to 2-161] DOE defined both economic (mineral and nonmineral) and cultural resources that may exist at or beneath the WIPP site. Due to the depth of the disposal horizon, only the mineral resources are of significance to predicting the long-term performance of the disposal system. DOE indicated that some of the geologic formations below the repository area contain oil and gas, resources that are currently being exploited in the Delaware Basin. In addition, potash is found within the Salado that contains the WIPP waste area; however, the waste area lies below an area where there are no economically mineable reserves. According to DOE's analysis, most of the water in the vicinity of WIPP is highly saline, with the closest dependable potable aquifer associated with the Capitan Reef at the edge of the Basin.

EPA expected DOE to consider mining effects on hydraulic conductivity, fluid injection, future development of leases and existing boreholes in the scope of the PA. The PA process also must consider the effects of current activities such as secondary oil recovery methods (water flooding), disposal of natural brine, solution mining to extract brine, etc., in the vicinity of the repository. The CCA was also expected to document which FEPs (or sequences or combinations of FEPs) are included in the PA. DOE is required to document the decision not to include any feature, event, or process in the PA.

<u>Process of identifying and selecting features, events and processes for inclusion into performance assessment</u>

CCA Chapter 6, Appendix SCR, and supporting documents [reference 605; Docket: A- 93-02, II-A-33] illustrated the process used by DOE to select the FEPs and subsequent scenarios relevant to

PA. DOE's methodology for demonstrating compliance with Section 194.32(a) was based on the general requirements for FEP and scenario identification stated in the Section 194.32(e). These requirements include the following:

- Identifying and classifying FEPs relevant to the WIPP -- DOE indicated that the first step in the analysis of features, events and processes was the identification of potential FEPs. DOE initially developed a list of FEPs using a list of over 1,200 FEPs assembled by the Swedish Nuclear Power Inspectorate (SKI). Over the past several years, DOE added and removed FEPs until it developed the Draft Compliance Certification Application (DCCA) FEP list of approximately 900 FEPs. The FEPs on the DCCA list were divided into nine categories: waste, canister, backfill, seal systems, repository/near-field, far field, biosphere, geology/climate, and human influences. During the CCA preparation process, DOE further consolidated the FEPs into 236 FEPs in three major categories [CCA Chapter 6.2]: 1) natural FEPs, 2) waste and repository-induced FEPs, and 3) human initiated FEPs. Of particular importance were those FEPs dealing with mining, deep drilling, and shallow drilling. DOE initiated a Side Effort program to address numerous technical issues. DOE conducted approximately 300 side effort studies as part of this effort. [II-A-33]

- Screening FEPs -- DOE used three criteria to evaluate whether a feature, event and process should be included in the final performance assessment calculations:

  -- *Probability*. Section 194.32(d) indicates that performance assessments need not consider processes and events that have less than a one in 10,000 chance of occurring over 10,000 years. DOE has provided either qualitative or quantitative arguments pertaining to FEPs screened out based upon probability.

  -- *Consequence*. DOE eliminated some FEPs based upon the consequences of those FEPs. DOE used two criterion for screening of FEPs due to consequence:

  1) <u>Insignificant Consequences.</u> DOE has eliminated those FEPs based upon consequences where "there is a reasonable expectation that the remaining probability distribution of cumulative releases would not be significantly changed by such omissions."

  2) <u>Beneficial FEPs.</u> FEPs that are potentially beneficial to performance of the disposal system or subsystem were eliminated, if necessary, to simplify analysis. DOE also states that this argument "may be used when there is uncertainty as to exactly how the FEP should be incorporated into

assessment calculations or when incorporation would incur unreasonable difficulties."

-- *Regulatory*. In the process of developing the 40 CFR Parts 191 and 194, EPA considered and made conclusions regarding FEPs and in so doing allowed for DOE to eliminate some of the FEPs from consideration. For example, relative to human initiated events and processes, DOE need not consider those events in the future that are screened out based on consequence and/or probability in the present or near future.

EPA's evaluation of DOE's FEPs analysis is set forth in greater detail in CARD 32 [V-B-7] and EPA Technical Support Document for Section 194.32: Scope of Performance Assessment, Table 1-1 to 1-40. [Docket: A- 93-02, V-B-21]

- ♦ Combining FEPs to form scenarios -- FEPs were combined by DOE to create scenarios with concurrent conceptual model development; scenarios selected for implementation were the basis for the PA model (e.g., conceptual, numeric, computational) development.

- ♦ Screening scenarios -- DOE retained FEPs in PA calculations for either undisturbed performance (UP) or disturbed performance (DP). UP included the predicted behavior of the disposal system, assuming the disposal system in the controlled area was not disrupted by human intrusion or the occurrence of unlikely natural events. DP included the predicted behavior of the disposal system assuming disruption of the system by human intrusion or other actions, including future drilling and mining activities. A logic diagram [CCA Chapter 6.3, Figure 6-7, p. 6-63] developed within the framework of 40 CFRSection 191.13, 191.15 and 191.24, illustrates the development of scenarios from those FEPs accounted for in PA calculations. DOE used the retained FEPs in conceptual models, mathematical models (equations), and codes (initial and boundary conditions, geometry and material property parameters) or computational models.

- ♦ Selecting scenarios for implementation in the PA -- The CCA included over 70 natural FEPs that were screened to determine those that should be included in the PA. Of these, approximately 26 have been retained for inclusion in the PA. [Appendix SCR, Table SCR-1] DOE also concluded that oil and gas exploration and exploitation and water and potash exploration are the only human-initiated activities that need to be considered for the PA. [CCA, Chapter 6.7.5] DOE divided human-initiated activities into three categories: (1) those that are currently occurring, (2) those that might be initiated in the operational phase, and (3) those that might be initiated after disposal. Human-initiated activities included three different drilling-related intrusion scenarios used in the PA, based upon the screening analysis, designated by DOE as E1, E2 and E1E2. [Chapter 6, p. 6-77] The E1 scenario assumed penetration of a panel by a borehole drilled through the repository, which then struck a brine pocket present in the underlying Castile Formation. The E2 scenario included all future boreholes that penetrate a panel but do not strike an underlying brine pocket within the Castile Formation. The E1E2 scenario was defined as the occurrence of multiple boreholes that intersected a single waste panel, with at least one of the events being an E1 occurrence. Refer to Section 194.33(a) in CARD 33 -- Consideration of Drilling Events in Performance Assessments for additional discussion of the three different drilling-related intrusion scenarios. For mining, also see CARD 32 [Docket: A- 93-02, V-B-7, p. 6-13] and this section of Response to Comments.

<u>EPA's review of DOE's FEP and scenario analyses</u>

EPA reviewed DOE's initial FEP listings to determine whether the listing was comprehensive. In addition, EPA examined information sources used by DOE to compile FEP lists for completeness and accuracy of technical information. EPA also examined listings to determine whether DOE's rationales for reducing listings was appropriate and technically sufficient. As discussed below, EPA also examined sequences and combinations of events.

EPA reviewed the CCA to determine whether the list was comprehensive and included all potential elements that may affect the disposal system. EPA required that FEPs represent all the aspects of the repository, as specified in Section 194.32. DOE was required to identify all the potential processes and events or sequences and combinations of processes and events that may occur during the regulatory time frame and affect the disposal system.

EPA examined DOE's initial list of FEPs and determined that the initial FEP identification and screening performed by DOE was thorough, although poorly documented in the CCA; see EPA Technical Support Document for 194.32: Scope of Performance Assessments. [Docket: A-93-02, V-B-21] Because of the poor documentation of FEP identification and screening in the CCA, EPA reviewed numerous documents in the Sandia National Laboratories Records Center, which were analyzed with respect to identification of scenarios. [Docket: A-93-02, V-B-21] After review of the CCA, associated references, and information in the SNL Records Center, EPA concluded that DOE considered all human-initiated and natural processes and events that may reasonably be predicted to occur within the regulatory time frame in the WIPP area. [CARD 32 and V-B-7, p. 18-24]

DOE identified those events and processes and sequences/combinations of events and processes that may occur during the regulatory time period that may affect the repository. EPA concluded that these FEPs represented those most critical in terms of affecting the disposal system. EPA initially expressed concern that DOE screened out brine extraction (solution mining) without providing the appropriate justification, but supplementary information sent by DOE resolved this concern; see CARD 32, Section 32.C for a detailed discussion.

EPA raised questions about DOE's screening analysis of fluid injection. EPA required DOE to use modified values for some input parameters, and to model the behavior of the disturbed rock zone consistent with assumptions used in the PA. [Docket: A-93-02, Item II-I-17] EPA also required DOE to provide additional information on the frequency of fluid injection well failures. [Docket: A-93-02, II-I-17] In supplemental work on fluid injection, DOE addressed all the issues identified by EPA. Also see the Technical Support Document for Section 194.32: Fluid Injection Analysis. [Docket: A- 93-02, IV-B-22; CARD 32] DOE modified the computer model grid configuration and added a new model to address concerns raised by both EPA and stakeholders. [Stoelzel and Swift, 1997, "Supplementary Analyses of the effects of Saltwater Disposal and Waterflooding on WIPP," WPO # 44158, Docket: A-93-02, II-I-36b] For additional information on fluid injection, see the specific responses below and also see responses to Fluid Injection.

The CCA did not include sufficient information to support certain conclusions relating to scenarios involving the connection of a Castile brine reservoir with repository waste panels. EPA required DOE to submit additional information supporting these conclusions. [Docket: A-93-02, Item II-I-01] In addition, the CCA did not contain adequate information supporting conclusions regarding the behavior of short-term brine flow to the surface if a brine pocket was intercepted. [Docket: A-93-02, Item II-I-17] Supplemental information was provided in two DOE letters. [Docket: A-93-02, Items II-I-24 and II-I-31] The information submitted by DOE addressed EPA's concerns as follows: the process and pressure conditions required to release substantial amount of contaminated brine to the surface are not found to be present in reasonably normal conditions. DOE also stated that the Conceptual Model Peer Review Panel concluded that entrainment of waste in Castile brine discharges during drilling would be minimal because circulation of brine will be limited and volume release will be minimal. EPA found the justifications provided by DOE to be adequately substantiated by analysis and modeling results. Based on the additional information submitted by DOE and included in PA, EPA concluded that DOE appropriately considered natural processes and events, deep drilling, shallow drilling, and mining in its PA-related evaluations. Refer to Section 194.33(a) in CARD 194.33 -- Consideration of Drilling Events in Performance Assessments for further discussion of drilling.

<u>Summary</u>

EPA's review of the CCA raised questions regarding screening of human-initiated activities, including fluid injection and brine extraction. In response to EPA requests for additional information and public comments, DOE submitted a significant body of additional information, including additional modeling to address the effects of these activities questioned by EPA. Stoelzel and O'Brien [1996], "The Effects of Saltwater Disposal and Waterflooding on WIPP," [Docket: A-93-02, II-G-1, CCA Ref. #611] was submitted in December 1996 and addressed fluid injection, but EPA's review of this document raised several questions [Docket: A-93-02, Item II-I-17] that were subsequently addressed in supplementary information from DOE. [Stoelzel and

Swift, 1997, "Supplementary Analyses of the Effects of Saltwater Disposal and Waterflooding on WIPP," and Docket: A-93-02, Item II-I-36] EPA and stakeholders also performed independent modeling. Although EPA received many public comments about the lack of a fluid injection analysis, DOE did consider fluid injection in the scope of performance and the additional fluid injection assessments adequately address the potential impact of fluid injection. EPA therefore concurred with DOE's screening decision to omit fluid injection from the performance assessment calculations; see EPA Technical Support Document for Section 194.32: Fluid Injection Analysis. [Docket: A-93-02, V-B-22] DOE provided supplementary information pertaining to brine extraction (solution mining) that was not included in the CCA submitted on October 29, 1996. Although the brine extraction FEP was not explicitly addressed in the CCA, EPA found that the supplementary information indicated that brine extraction will not have an impact on the PA.

DOE followed an acceptable process for identifying potential FEPs that could occur at WIPP using probability, consequence and regulatory criteria. DOE used the performance assessment process to refine the events to those that were relevant to WIPP. DOE put the features, events and processes into two groups: those FEPs that would occur if the repository were not disturbed by direct human intrusion, and those FEPs would occur if there were direct human intrusion into the repository. In the WIPP performance assessment calculations DOE modeled the case of no human intrusion occurring at WIPP and the case of direct human intrusion. EPA agreed that, after reviewing the initial DOE information in the CCA, supplemental information, and conducting independent analyses, DOE's process was adequate and DOE appropriately included scenarios that could affect releases from WIPP. EPA's basis for this decision is further discussed in multiple sections of CARD 32 and in specific responses to comments for this section and for section 23: Models and computer codes.

Many comments identified multiple scenarios in one comment. Comments most frequently identified the scenarios of fluid injection, drilling with mud, air drilling, and potash mining as the scenarios which were not adequately characterized or considered in DOE's performance assessment. The responses have been grouped so that these major issues have been addressed below.

<u>Fluid Injection</u>

(Comments 8.A.3, 8.A.4, 8.A.5, 8.A.8, 8.A.11, 8.A.14, 8.A.16, 8.A.17, 8.A.19, 8.A.20, and 8.A.21) DOE *did* address the fluid injection issue (waterflooding and brine disposal) in the Compliance Certification Application. EPA's initial assessment of DOE's screening results indicated that fluid injection FEPs, including enhanced oil recovery and brine disposal were not appropriately modeled. The screening assessment approach used by DOE appeared to be inadequate for injection-related activities, including liquid waste disposal. Subsequent to the submission of the CCA, both DOE [Docket: A-93-02, Item II-I-36] and EPA [Docket: A-93-02, V-B-22] performed additional modeling of the injection well scenario. EPA concluded that the combination of DOE's original modeling and additional modeling were adequate to show that fluid injection was appropriately screened out. EPA also concluded that, although scenarios can be constructed that move fluid to the repository via injection, the consequences from such an event are within that modeled in the CCA. Furthermore the probability of such a catastrophic failure occurring, given the necessary combination of natural and human-induced events, is low. For more discussion of fluid injection, see Response to Comments, Section 5.

In accordance with Section 194.32(c), DOE determined that water flooding (for secondary oil recovery) and brine disposal were the only fluid injection scenarios that were currently occurring at the time the application was submitted to EPA or could be initiated in the near future in the vicinity of the WIPP. DOE identified the Bell Canyon Formation below the Salado and Castile Formations as the primary target for fluid injection for brine disposal. DOE stated that this scenario had the potential to produce brine inflow to the WIPP. DOE modeled the fluid injection scenario using WIPP geology, and also using the geology identified in the Rhodes-Yates Field. [Docket: A-93-02, II-A-32, p. 26] The modeling results, which used conservative modeling assumptions, indicated that limited brine compared to natural inflow could potentially get into the WIPP from fluid injection activities in the WIPP case and more so in the Rhodes-Yates case. [CCA reference 611, section III]

Commenters raised questions about DOE's fluid injection modeling and EPA's review also raised questions regarding DOE's screening analysis of fluid injection. EPA required DOE to use modified values for some input parameters, including the period of simulation, and to model the behavior of the disturbed rock zone consistent with assumptions used in the PA. [Docket: A-93-02, Item II-I-17] EPA also required DOE to provide additional information on the frequency of fluid injection well failures. [Docket: A-93-02, II-I-17] EPA requested the information because the CCA did "not contain adequate justification for eliminating consideration of the occurrence of certain fluid injection scenarios at WIPP." [*ibid.,* p 3]

In supplemental work on fluid injection, DOE addressed all the issues identified by EPA. DOE modified the computer model grid configuration and added a new model to address concerns raised by both EPA and stakeholders. [Stoelzel and Swift, 1997, WPO # 44158; Docket: A-93-02, II-I-36b] DOE researched injection well operating practices in the Delaware Basin and identified significant differences between those in the vicinity of the WIPP and the Rhodes-Yates Field. DOE found that wells near the WIPP are typically less than ten years old and are constructed to much higher mechanical standards (e.g., multiple casing instead of single casing) than the older wells found in the Rhodes-Yates Field due to better technology and NMOCD requirements. DOE identified a range of well failure scenarios, ranging from undetectable brine flow to catastrophic well failure. DOE's data indicated that the probability of a catastrophic well failure in the vicinity of the WIPP is extremely low. [Docket: A-93-02, II-I-36b, pp. 29-33] DOE modeling confirmed that the presence of the Castile at the WIPP also substantially inhibits injected brine movement into the Salado anhydrite marker beds. This is due to "thief zones" into which brine can flow before reaching the marker beds at the waste horizon.

EPA performed its own independent studies of fluid injection. [EPA Technical Support Document for 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22] The results of this analysis show that the permeability in marker beds is generally lower than that used in the PA, and that other factors (such as injection rate, injection interval, etc.) also play a very important role in fluid injection.

In summary (Comments 8.A.3, 8.A.4, 8.A.5, 8.A.8, 8.A.11, 8.A.14, 8.A.16, 8.A.17, 8.A.19, 8.A.20, and 8.A.21) DOE *did* address the fluid injection issue in the Compliance Certification Application and in supplemental information. In addition, EPA conducted its own fluid injection analyses. On the basis of DOE's and EPA's analyses, EPA determined that fluid injection was appropriately screened out of performance assessment on the basis of low consequence. In addition, these separate analyses indicate that catastrophic failures of injection wells are also unlikely to occur.

DOE recognized that anhydrite interbed fracturing could occur as a result of high repository gas pressures, and included that scenario in its performance assessment calculations. DOE's fracturing model was based in part on the results of in situ fluid injection tests into anhydrite interbeds at WIPP, and in part on theoretical considerations. In response to public comments questioning the validity of the fracturing model used by DOE, EPA has reviewed in additional detail the basis for that model and has compared its modeling assumptions with those of an alternative model proposed in public comments. The alternative model is based on linear elastic fracture mechanics (LEFM) and assumes that the fracture occurs in a previously unfractured, elastic continuum. DOE's model assumes the fracture occurs in a previously fractured medium. While DOE's model predicts the simultaneous creation of multiple fractures, LEFM predicts the creation of a single fracture. For a given increase in permeability, DOE's model predicts a larger porosity increase than the LEFM model. In evaluating the applicability of these models to the anhydrite interbeds at WIPP, EPA notes that the interbeds contain pervasive natural fracturing, open pores and void spaces, as well as natural surfaces of weakness along bedding planes. Further, the *in situ* fluid injection tests at WIPP produced multiple parallel fractures rather than single fractures. [Beauheim et al.,WPO # 27246, Docket: A-93-02, V-B-14; and in Larson et al., WPO # 44704, Docket: A-93-02, II-I-24] Based on actual conditions at WIPP and the results of DOE's *in situ* injection tests, EPA concludes that DOE's fracturing model is adequate for use in performance assessment and more closely represents actual conditions at WIPP than the alternative LEFM model recommended in public comments. EPA's complete discussion of this issue is in the Response to Comments, Section 5, in the topic Anhydrite Fracturing.

Drilling scenario issues

Commenters 8.A.2, 8.A.4, 8.A.6, 8.A.9, 8.A.12, 8.A.13, 8.A.20, and 8.A.21 expressed concerns regarding drilling into the WIPP repository. Comment 8.A.2 concluded that drilling into the WIPP would not cause releases above the EPA limit, while Comments 8.A.4, 8.A.9, 8.A.20 and 8.A.21 contend that drilling has not been sufficiently address and will cause releases of radioactivity that violate the disposal regulations.

Section 194.32(e)(1),(2) required DOE to identify all potential processes, events or sequences and combinations of processes and events that may occur during the regulatory time frame and may affect the disposal system, including those used in performance assessment. EPA explicitly expected the performance assessment to include [CAG, p. 46] deep drilling and shallow drilling. DOE was also required to include an analysis of drilling under Section 194.33, which states:

> (a) Performance assessments shall examine deep drilling and shallow drilling that may potentially affect the disposal system during the regulatory time frame.
>
> (b) The following assumptions and process shall be used in assessing the likelihood and consequences of drilling events, and the results of such process shall be documented in any compliance application:
>
> (1) Inadvertent and intermittent intrusion by drilling for resources (other than those resources provided by the waste in the disposal system or engineered barriers designed to isolate such waste) is the most severe human intrusion scenario.

DOE identified the following drilling-related activities as being present in the Delaware Basin and potentially near the WIPP [Appendix DEL.5, Tables DEL-3 through DEL-7]:

- Oil/Gas exploration/exploitation and extraction, including enhanced oil recovery (shallow and deep drilling);
- Potash exploration/exploitation (shallow and deep drilling);
- Fluid injection related to oil/gas production (deep drilling);
- Sulfur boreholes (deep and shallow drilling);
- Hydrocarbon (gas) storage in geologic reservoirs, gas injection (deep drilling);
- Brine wells for solution mining (shallow drilling);
- Water supply wells (shallow drilling); and
- Geothermal resources (deep drilling).

In Chapter 6.2.5 of the CCA, DOE identified oil and gas exploration/exploitation and water and potash exploration as the principal human activities that must be considered within the PA. The remaining human initiated activities -- such as exploration for geothermal energy, water supplies, and sulfur and brine extraction (solution mining) were eliminated based upon low probability, low consequence, or for regulatory reasons. See Section 194.32(b) in CARD 32 -- Scope of Performance Assessments, for additional information pertaining to resource determination, evaluation, and screening.

Deep drilling is defined by EPA as events that terminate 2,150 feet or more below ground surface, while shallow drilling events terminate above 2,150 feet below ground surface. [Section 194.2] Oil and gas exploration, exploitation, and production comprise 99 percent of the deep boreholes in the Delaware Basin, with the remainder being sulfur, potash, and stratigraphic test boreholes. [Appendix DEL, Table DEL-4] DOE provided extensive information pertaining to the deep drilling process, from acquisition of leases to well completion and abandonment. [Appendix DEL.6.1, p. DEL- 47 and DEL.5.1] In the area near the WIPP site, deep drilling typically terminates between approximately 5,000 to 15,400 feet (2,134 to 4,695 meters) below ground surface. DOE indicated that mud rotary drilling is the typical drilling method used in the Delaware Basin.

Deep drilling can create several pathways by which radioactive contamination can reach the accessible environment if waste is intersected by a borehole. These pathways can augment releases categorized as either short-term and long-term. Short-term releases occur over a few days at most and are described by the cuttings/cavings, spallings, and direct brine release conceptual models. Cuttings are calculated as the waste transferred to the surface in the drilling mud with a volume equal to the product of the area of the drill bit times the height of the waste in the storage room. The cavings model determines the amount of waste material eroded by calculating the shear stresses acting on the borehole wall from the vertical and rotational flow components of the drilling fluid as it is pumped to the surface through the annulus between the drill collar and the borehole wall. The Spallings Conceptual Model addresses the calculation of direct solid waste release to the ground surface via the movement of high-pressure gas from the repository into the annulus of an intruding borehole. [Docket: A-93-02, II-G-1, Volume I, Chapter 6, p. 6-151] This release could occur when repository gas pressure is sufficient to expel drilling fluid from the borehole ("blowout") and open a conduit for pressure-driven release of repository gases containing particulate waste. The Direct Brine Release Conceptual Model describes short term releases of contaminated brine from exploratory boreholes that penetrate waste panels in the repository. [Docket: A-93-02, II-G-01, Volume X, Appendix MASS Attachment 16-2] It includes brine releases from both single and multiple intrusions. The other drilling-related conceptual models that address short-term releases of radionuclides (cuttings/cavings and spallings models) consider only solid materials. Longer-term releases from deep drilling scenarios involve flow and transport through transmissive units above the Salado where the borehole(s) provides the hydraulic connection between the repository and the overlying units. Deep boreholes which intersect waste can also hit brine reservoirs in the Castile Formation underlying the repository creating enhanced opportunities for radionuclide dissolution in brine. These possibilities are effectively captured by

DOE with the E1, E2, and E1E2 scenarios. EPA's review of these drilling release scenarios can be found in the CARD 33, Section 33.A.

To comply with the requirements of Section 194.33(b), DOE incorporated assumptions into the PA about the severity, frequency and randomness of drilling. DOE considered intermittent and inadvertent drilling, including exploratory and developmental drilling, as the most severe human intrusion scenarios and used them to calculate cumulative radionuclide releases. Results of these analyses are presented in the CCA, Chapter 6.5.

DOE considered three scenarios in PA for deep drilling: 1) one or more boreholes penetrate(s) the Castile brine reservoir and also intersect(s) a repository panel, (E1 computational scenario); 2) one or more boreholes intersect(s) a repository panel, (E2 computational scenario) and 3) multiple penetrations of waste panels, by boreholes of the first or second type, at many possible combinations of intrusion times, locations and combinations of borehole types (E1E2 computational scenario). EPA found that the PA identified all necessary drilling related scenarios and incorporated deep drilling events into PA, in accordance with Sections 194.32 and 194.33. [CARDs 32 and 33] The shallow drilling activities were screened from inclusion in the PA because DOE considered these activities to be of low consequence to PA calculations. [CARD 32, p. 6]

DOE modeled the occurrence of future drilling events through a random sampling methodology described in Appendix CCDFGF, Sections 2 and 3. The random drilling rate as it pertains to drilling events is discussed under Section 194.33(b)(2) of CARD 33. DOE incorporated drilling into the PA through repeated generation of independent sequences of drilling-related events that could occur at the WIPP over the next 10,000 years. The defining parameters for the occurrence of future drilling events include not only the interval of time between drilling events and the location of drilling intrusions but also the following four parameters:

- Activity of waste penetrated by each drilling intrusion (not related to deep or shallow drilling, but included for completeness);
- Plug configuration in the borehole;
- Penetration of the Castile brine reservoir; and
- Occurrence of mining (not related to deep or shallow drilling, but included for completeness).

DOE used random sampling from these distributions to calculate 10,000 different futures for the WIPP, expressed as CCDFs. [Chapter 6.4.13.9] For additional information regarding DOE's selection and implementation of these parameters, see Section 194.23(3) and (2) in CARD 23 --

Models and Computer Codes. For additional information regarding construction of CCDFs, see Section 194.34(a) in CARD 34 -- Results of Performance Assessments.

EPA's analysis of drilling

EPA reviewed the information presented by DOE in Chapter 6.2, Appendix DEL, and Chapter IX of NMBMMR 1995 to determine how extensively deep and shallow drilling was considered and whether the information provided was sufficiently comprehensive, accurate, and correctly calculated. EPA examined the list of references presented in the CCA relative to drilling [Docket: A-93-02 Items: II-G-1 References # 230, 357, 664, 667] and conducted a literature search for evaluation of the fluid injection study. [Docket: A-93-02, V-B-21] EPA determined that DOE's scrutiny of resources to assess deep and shallow drilling practices and frequencies was adequate and comprehensive. Refer to Section 194.32(a) and(c) in CARD 32 -- Scope of Performance Assessments for additional discussion of resource assessments. EPA also determined that DOE's conclusions regarding representative drilling methodologies in the Delaware Basin are consistent with available data. DOE's treatment of abandoned borehole properties and borehole plugging is discussed in CARD 33, Section 33.C.

Both DOE and EPA agree that human activities are likely and will release radioactivity from the WIPP, as stated in Comment 8.A.2. In fact, as indicated above, human activities are the most important mechanism for radioactivity to be released from the WIPP. [Section 194.33(b)(1)] During the 10,000-year period evaluated in the CCA, about six drilling penetrations through the waste are expected. The radioactive releases from these drilling penetrations have been estimated and have been included in the compliance calculations in the CCA. EPA has evaluated releases caused by numerous events, including direct brine release, spallings, cuttings/cavings, and release via lateral contaminant flow in the Culebra, as well as releases in the undisturbed scenario. In all cases, DOE has shown [Docket: A- 93-02, II-G-1, Chapter 6.5] that the cumulative effects of releases from these mechanisms are well below the EPA release limits. EPA questioned parameters used by DOE, and the PAVT [Docket: A- 93-02, II-G-28] was subsequently performed. Results of this analysis, too, showed releases to be well below the EPA limit, and EPA therefore concluded that results of the original PA performed by DOE were satisfactory. In conclusion, EPA agreed with Comment 8.A.2 in that the cumulative releases from mud drilling are well below the EPA standard, as shown in Chapter 6.5 of the CCA.

EPA disagrees with concerns in Comment 8.A.20 and points out that DOE has addressed the possibility of future human intrusion into the WIPP, as discussed in the preceding paragraphs. Human intrusions are described in the CCA in Section 6.3.2, "Disturbed Performance." Mining is not expected to directly disturb the waste because potash mining does not occur at sufficient depths to disturb the WIPP waste disposal rooms. Mining effects may, however, change the groundwater flow characteristics above the WIPP, as described in Section 6.3.2.1 of the CCA. With respect to drilling intrusions, during the 10,000-year regulatory time frame, about six drilling intrusions into the waste are expected to occur. These are described in the CCA in Section 6.3.2.2 (The Disturbed Performance Deep Drilling Scenario). In addition, the combined effects of mining and deep drilling are described in Section 6.3.2.3 (The Disturbed Performance Mining and Deep Drilling Scenario). Refer to CARDs 34, 32, and 23 for details on how drilling was considered in PA and results of PA.

The CCA analysis evaluated the direct drilling release scenarios referred to in Comment 8.A.21. These scenarios are described in Chapter 6, Section 6.4.6, and Appendix SCR. [Docket: A-93-02, II-G-1] EPA's evaluation of these scenarios can be found in EPA documents such as the Technical Support Document: Overview of Major Performance Issues [Docket: A-93-02, V-B-5], the Technical Support Document for Section 194.32: Fluid Injection Analysis [Docket: A-93-02, V-B-22], and EPA's Analysis of Air Drilling at WIPP. [Docket: A-93-02, V-B-29] The comment suggests that some of the direct brine releases (or perhaps drill cuttings) could be above the regulatory release limits. This assertion is not supported by any available information, including that in the CCA [Chapter 6.5] and PAVT.

EPA disagrees with Comment 8.A.12. DOE's performance assessment modeling of scenarios with human intrusion indicated that some combinations of parameters provided enough brine inflow to result in both high repository pressures and large volumes of brine in the repository, independent of any fluid injection scenarios. The consequences of drill holes penetrating the repository under such conditions were determined in the WIPP performance assessment and were included in computing the average cumulative releases for comparison with regulatory limits. [CCA Vol. I, Chapter 6.5: Docket: A-93-02, II-G-1] These consequences included transporting waste to the ground surface and transporting radionuclides into the Rustler Formation where it entered the Culebra Dolomite and was carried by moving groundwater toward the accessible environment. The transport scenarios raised in the comment have therefore already been included in both DOE's CCA and in EPA's PAVT.

(Comment 8.A.6) Both DOE and EPA agree that human activities are likely to release radioactivity from the WIPP. In fact, human activities are expected to be the most important mechanism for radioactivity to be released from the WIPP. During the 10,000-year period evaluated in the CCA, about six drilling penetrations through the waste are expected on the average. The radioactive releases from these drilling penetrations have been estimated and have been included in the compliance calculations in the CCA. Refer to CARDs 34 and 54, respectively, for results of performance and compliance assessments.

EPA has received many thoughtful comments from the public on release scenarios for the WIPP, such as Comment 8.A.13, and has carefully examined them all. The scenarios of principal public concern have included air drilling and associated spallings and direct brine releases, fluid injection, alternative transport mechanisms to the accessible environment, conventional and solution mining, alternative interbed fracturing model, and actinide solubility. These release scenarios are addressed in this section, section 23 (alternative interbed fracturing model), and section 24 (actinide solubility). Some of these scenarios, such as the different types of mining and fluid injection, have been considered by DOE in developing the performance assessment model used to evaluate WIPP. In these and other cases, EPA responded to public comments by performing a detailed reexamination of the basis for DOE's screening decisions. In cases such as for air drilling, EPA performed its own independent analysis of the applicability of the technology to WIPP conditions, use of the technology in the Delaware Basin, and impact of the technology should it be used at WIPP. In all cases, after comprehensive review, the Agency determined that the alternative release scenarios identified in public comments had either already been adequately addressed by DOE or the consequences of the release scenario had no significant impact on the performance assessment calculations.

EPA disagrees with the statements in the Comment 8.A.7 because the modeling in the CCA has not ignored events that will cause the radioactive release standards to be violated, nor has EPA ignored these events in its review of the CCA. EPA's review carefully scrutinized the likelihood that drillers would penetrate into pressurized brine reservoirs. EPA requested additional justification [Docket: A-93-02, II-1-01] for the probability of encountering brine pockets and the information was reviewed by EPA. The consequences of drilling both inside and outside the WIPP boundary were considered by DOE in the CCA and by EPA in its review of the CCA. EPA carefully evaluated the potential occurrence of brine pockets below the WIPP. EPA found that, on a geostatistical basis, DOE believed the probability of a borehole encountering brine below a waste panel to be 8 percent (Powers et al., 1996), partly because the brine is expected to be in fractures that are oriented vertically or slightly less than vertical. However, EPA noted that DOE's geologic and geophysical basis for the 8 percent probability value appeared questionable. [CCA Vol. I Section 2.1.6.1.3, p. 2-87, and CCA Vol. V, Appendix DEF.2, pp. DEF-1 to DEF-18; Docket: A-93-02, II-G-1] EPA also found that DOE's discussion of the size, orientation, and repressurization potential of the Castile brine reservoirs was not well supported by the CCA. [CCA Vol. I, Section 2.2.1.2.2, pp. 2-107 to 2-108, and CCA Vol. V, Appendices DEF.2, pp. DEF-1 to DEF-18, and DEL.7.5, pp. DEL-81 to DEL-87; Docket: A-93-02, II-G-1] The probability value for encountering a brine pocket was also poorly supported because other DOE data imply this probability could be as high as 55 percent. [CCA Vol I, Section 2.2.1.2.2, pp. 2-107 to 2-108; Docket: A-93-02, II-G-1]

EPA also considered the possibility that the WIPP-12 brine pocket may underlie the entire repository site and therefore the probability of encountering pressurized brine could approach 100%. This consideration is based on the assumption that the WIPP-12 reservoir is cylindrical in shape, which EPA considers unlikely due to brine residing in vertical or subvertical fractures. Although EPA agrees that part of the WIPP-12 reservoir may underlie part of the site, the time-domain electromagnetic (TDEM) survey data [CCA Vol. I, Section 2.2.1.2.2, Docket: A-93-02, II-G-1]; do not support speculation of a 100% probability of encounter. EPA reviewed the TDEM data and concluded that a 100% probability was supported by available data, and an upper bound value no higher than 0.60 was considered reasonable. [Technical Support Document for 194.23: Parameter Justification Report, Sections 4.1, 4.4, 4.5, Docket: A-93-02, V-B-14, Technical Support Document for 194.23: Review of TDEM Analysis of WIPP Brine Pockets, Docket: A-93-02, V-B-30] EPA therefore directed DOE, in the EPA Mandated Performance Assessment

Verification Test (PAVT) [Docket: A-93-02, II-G-26 and II-G-28], to change the probability of hitting a brine pocket to a range that incorporated low to moderate probabilities (0.01 to 0.6), and to sample this range.

As a result of the PAVT, EPA found that even when using a sampling probability that allowed for a greater number of possible brine pocket intrusions, the repository still meets the containment requirements. EPA concluded that the revised distribution sufficiently and accurately increased the probability of brine pocket occurrence consistent with that indicated by site data, and increasing the probability to 100% would not be consistent with examined data. Because the increased probability did not impact repository performance, EPA concluded that the original brine pocket characteristics were, in fact, acceptable. For more discussion on this topic, also see CARD 14, Section 14.B.5, EPA's Technical Support Document for Section 194.14: Content of Compliance Certification Application [Docket: A-93-02, V-B-3], and the Technical Support Document for Section 194.23: Parameter Justification Report. [Docket: A- 93-02, II-H-12]

Using a probability of one assumes absolute certainty that all exploratory boreholes that intersect the WIPP waste panels will also intersect a pressurized brine reservoir in the Castile Formation (Comment 8.A.7). EPA does not believe that assuming such certainty is reasonable. Adopting the other extreme, that the probability is zero, also implies a certainty that is not reasonable. In fact, the available information suggests that brine reservoirs are present beneath parts of the site and are not present beneath other parts. The most direct information on the presence of brine reservoirs beneath the repository is provided by TDEM data. As stated above, these data may be interpreted to indicate that brine reservoirs underlie as much as 55% of the repository, but using the same data brine reservoirs may also be interpreted to underlie as little as 10% of the repository. A geostatistical method used by DOE to estimate this percentage yielded a value of 8%. [WPO # 40199]

An upper limit of 60% and a lower limit of 1% were selected by EPA for this parameter in the PAVT. The upper limit is slightly larger than the largest estimated value for this parameter, but is less than one because available data do not support such high values and it is unreasonable to assume with absolute certainty that a reservoir is there. The lower limit is slightly smaller than the smallest estimated value for this parameter, but is greater than zero because it is also unreasonable to assume with absolute certainty that a reservoir is not there. Both the upper and lower limits used in the PAVT were also independently compared with the CCA value for brine pocket probability in EPA's sensitivity analysis. The results of that analysis showed that the CCDFs upon which regulatory compliance is based were not sensitive to changes in this parameter. [SA Report Table 3.5-1, Docket: A-93-02, II-I-13] Both the sensitivity analysis and the PAVT results therefore support EPA's conclusion that the original brine reservoir characteristics used in the CCA were, in fact, acceptable.

Air drilling scenario issues

Comments 8.A.8, 8.A.11, 8.A.16, 8.A.17, 8.A.3, 8.A.21, 8.A.4, 8.A.9, and 8.A.22 all express concern that the CCA did not include air drilling in the scenarios considered for PA. As a result, commenters believed that the consequences of air drilling were not evaluated in the CCA. Additional information is provided below as well as in responses to air drilling comments in this section, and in EPA's Analysis of Air Drilling. [Docket: A- 93-02, V-B-29]

Air drilling is a process in which air or another gas is used instead of water-based mud as a circulating fluid and is used for removing cuttings from a hole during drilling. Technical, economic, and safety considerations generally determine the choice of drilling method. Compared to mud drilling, air drilling can have the principal advantages of reduced formation damage in some production zones, potentially higher penetration rates, and easier penetration of hard rocks. [Docket: A- 93-02, V-B-29] The principal disadvantages of air drilling include a minimal capability to control high formation pressures, a minimal ability to prevent caving of borehole walls in weak formations, and a limited ability to cope with inflows from water-producing formations. Under favorable conditions, the advantages of air drilling may reduce costs and make it a preferred technology. Under less favorable conditions, the use of air drilling is precluded by both technical and economic considerations.

Drilling method analyses presented by DOE in the PA as Appendix DEL [DEL-26 to DEL-46] and Drilling Requirements and Practices in the Delaware Basin of New Mexico and Texas as Related to Inadvertent Human Intrusion into the Waste Isolation Pilot Plant, March 1996, provide the primary basis for DOE characterization of drilling activities. DOE examined drilling practices in the Delaware Basin and concluded that air drilling is not common practice in the Delaware Basin. Therefore, in accordance with Section 194.25(a) wherein DOE is required to assume that the characteristics of the future will remain what there are at the time the CCA was prepared, DOE concluded that it need not include air drilling in the CCA because it is not current practice in the Delaware Basin.

Review of oil field activities conducted by EPA as reported in the Technical Support Document for Section 194.32: Potential Impacts of Fluid Injection, EPA Office of Radiation and Indoor Air, Washington DC, October 1997 [Docket: A- 93-02, V-B-22, pp. 28-29], confirm DOE's general conclusion that mud rotary drilling represents typical practice in the Delaware Basin, particularly under conditions representative of the WIPP site. EPA examined the possibility of air drilling including well records, talked to industry contacts, and reviewed public comments and has determined that air drilling through the Salado and Castile Formations is not a current practice in the Delaware Basin. [Docket: A- 93-02, V-B-29] The Agency has determined that because of operational difficulties, air drilling is currently only rarely used in the Delaware Basin and little evidence has been found of any use in the vicinity of the WIPP Site. [Docket: A- 93-02, V-B-29] The Agency has therefore concluded that air drilling does not need to be included in the WIPP performance assessment.

Nevertheless, EPA conducted a technical analysis of the consequences of air drilling. EPA's technical assessment of spallings associated with a hypothetical air drilling event indicates that only limited volumes of waste material would fail and contribute to releases. The amount of spall from air drilling calculated for conditions of high pressure in the repository indicate that the volume of releases would be within the range estimated for drilling with mud (0.5 m^3 to 4.0 m^3).

(Comments 8.A.3, 8.A.4, 8.A.8, 8.A.9, 8.A.11, 8.A.16, 8.A.17, 8.A.21, and 8.A.22) EPA re-examined whether air drilling is practiced in the Delaware Basin. EPA acknowledges that air drilling has advantages over mud drilling under favorable conditions and that its use is technically possible at the WIPP site; however, as described in EPA's Air Drilling Report [Docket: A- 93-02, V-B-29], an extensive review showed that air drilling is only rarely used in the Delaware Basin and is essentially nonexistent in the vicinity of WIPP. This conclusion was developed from reviews of drilling records filed with State regulatory agencies and from discussions with knowledgeable industry contacts. EPA has identified, through a random search of 306 well records from the Delaware Basin in New Mexico and Texas, that air drilling is not a common practice. Only one of the 306 randomly selected well records had any direct reference to use of air technology (in 1958), but the records did not identify whether well was actually drilled with air. Limited evidence of air drilling was identified outside of the scope of the random survey, but data for these wells are sketchy. Of those wells suspected of being air drilled, some appeared to involve saving a well when adverse hydrologic conditions (unlike that near WIPP) were encountered, others were drilled with air only above the salt section, and some were drilled with air only in the production zone.

EPA concluded from multiple information sources that the rarity of air drilling in the Delaware Basin is real and not an artifact of a lack of awareness of the Agency's contacts. EPA believes that air drilling is only rarely practiced in the Delaware Basin because it is not practical under the existing geological and hydrological conditions. The Agency has therefore concluded that under the terms of its requirements in Section 194.33 for analyzing drilling events consistent with current practice at the time the CCA was prepared air drilling does not need to be included in the WIPP performance assessment. Also see EPA's Air Drilling Report [Docket: A-93-02 V-B-29] and this section of Response to Comments.

Furthermore, technical evaluations conducted by DOE and EPA to assess the impacts of air drilling (Comments 8.A.3, 8.A.4, 8.A.8, 8.A.9, 8.A.11, 8.A.16, 8.A.17, 8.A.21, and 8.A.22) indicate that the impact of including air drilling in calculations of release are insufficient to require inclusion in the PA. If EPA assumed that spallings releases would be as large as 64 m^3, as suggested by public comments, and that air drilling would occur about 1.65% of the time, as indicated as the upper bound from EPA's random survey of drilling practices in the New Mexico and Texas portions of the Delaware Basin, the expected volume of material released would still be low (3.3 m^3). EPA also explicitly modeled a potential air spallings release and identified that releases would be similar to those used by DOE in the CCA, which were determined assuming mud as the drilling fluid.

In summary, EPA concludes that because it is not a current drilling practice in the Delaware Basin, air drilling does not have to be included in the WIPP performance assessment. Furthermore, based upon analysis, EPA expects that the potential impact of air drilling, if it did occur, would be within the range of releases used in the compliance certification application.

Potash mining

Potash ore is found in the McNutt Potash Zone in the Salado Formation which lies above the repository horizon. Eleven ore zones have been identified in the McNutt but economic mineralization is not found in all ore zones. In the vicinity of the WIPP the ore lies at depths of 420 meters (m) (1,377.9 feet (ft)) to 530 m (1,738.8 ft) as compared to a repository depth of 655 m (2,148.9 ft). Two different types of minerals are currently mined -- sylvite (KCl) and langbeinite (K_2SO_4•$2MgSO_4$).

DOE, in the CCA, identified potash mining as an activity that occurs in the vicinity of the disposal system prior to or soon after disposal. [Docket: A-93-02, II-G-1, Chapter 6, Section 6.4.6.2.3] The assumed extent of this mining outside the disposal system was based on three elements:

- ♦ Existing potash leases [Docket: A-93-02, II-G-1, Chapter 2, Figure 2-37 or Volume X, Appendix MASS Attachment 15-5, Figure 1];
- ♦ Mined out areas in existing mines [Docket: A-93-02, II-G-1, Volume X, Appendix MASS Attachment 15-5, Figure 5]; and
- ♦ Offsets from existing hydrocarbon boreholes [Docket: A-93-02, II-G-1, Volume X, Appendix MASS Attachment 15-5, Figure 5].

DOE calculated the mineable reserves within the land withdrawal area using data from 40 cored holes. [NMBMMR, 1995, Docket: A-93-02, II-G-1, Ref. 460, Chapter VII] This data base of 40 holes provided sufficient information to calculate reserves within the WIPP site and within a one mile band around the site. Even though reserves were calculated outside the WIPP site, this information was not used in the CCA. Rather, existing leases outside the land withdrawal boundary were assumed to be fully mined prior to or soon after disposal.

Comments 8.A.3, 8.A.8, 8.A.11, and 8.A.17 state that EPA must further address the consequences of solution mining at the WIPP. DOE assumed that potash would be mined by room and pillar or other conventional methods and that solution mining of potash would not occur because of mineralogical and economic constraints. Because a permit was recently sought to conduct a pilot study north of the WIPP to assess whether solution mining of potash minerals is a feasible technology. EPA requested more information about the effects of solution mining for potash. DOE provided supplemental information [Docket: A-93-02, II-I-31] in which DOE concluded that the impacts of solution mining for potash would be the same as those for room and pillar mining, and that potential subsidence-induced hydraulic effects in the Culebra would be similar to those for typical mining practices.

The issue of solution mining for potash has also been addressed in the supplemental information provided by DOE, specifically addressing EEG's comment. [Letter from Robert H. Neill, February 7, 1996, on March 12, 1997, Docket: A-93-02. II-H-24] The essence of the response is as follows: "If solution mining for potash were undertaken in the vicinity of the WIPP it could result in subsidence. However, performance assessment calculations already assume that widespread subsidence will occur as a result of potash mining in the near future. The assumed extent of subsidence and its effects on the hydraulic conductivity of Culebra are independent of the mining methods used (underground excavation or solution mining)." This report also mentions "Poor management of the solution mining operations could conceivably result in water losses to hydraulically conductive units above the Salado. Large water losses would result in low potash yields and most likely remedial actions would be taken by the operators. Undetected leakages to the Culebra would be no more severe than leakages that might be speculated to occur during secondary oil production operations (water flooding) or brine disposal in the vicinity of the WIPP. The potential effects of such events have been analyzed by Stoelzel and O'Brien [1996, Docket: A-93-02, II-A-32] and have been shown to be of low consequence to the performance of the disposal system.

EPA has examined information presented by DOE and stakeholders [EEG-68, p. 135-137] and concludes that while solution mining is a possibility, it is not occurring in the Delaware Basin. Therefore, in accordance with Section 194.25(a), DOE need not consider solution mining because "performance assessments and compliance assessments conducted pursuant the provisions of this part to demonstrate compliance with Sections 191.13, 191.15, and Part 191, subpart C shall assume that characteristics of the future remain what they are at the time the compliance application is prepared, provided that such characteristics are not related to hydrogeologic, geologic or climatic conditions."

EPA also points out that the solution mining "examples" cited by stakeholders are well outside of the Delaware Basin, and were often initiated due to "large inflow" of water or due to the highly distorted nature of strata. [EEG-68, p. 136] Water inflow in Delaware Basin mines is not sufficiently high to mandate a change to solution mining, and Delaware Basin potash strata are not so highly distorted that solution mining is required. The two main minerals within WIPP area ores zones are langbeinite and sylvite. [CCA Table 2.7] Solution mining of langbeinite is not possible because the ore is not soluble to a significant degree. Solution mining of sylvite is technically feasible as shown in the studies reported by Davis and Shock, 1970. [Solution Mining of Thin Bedded Potash, Mining Engineering, July 1970 included as an attachment in Docket: A-92-03, IV-G-39] However, solution mining is not currently practiced probably because the ore beds in the McNutt are too thin for economical processing. [NMBMMR 1995, Chapter 4, *op. cit*.] Even if solution mining is practiced in the future, the subsidence effects would be similar to those from conventional mining. [TSD on Potential Effects of Mining on Ground-Water Flow and Radionuclide Transport at the WIPP Site, Section 5.1 for additional discussion, Docket: A-93-02, V-B-8] From a regulatory perspective, the Agency does not believe that the impact of solution mining on performance assessment need be analyzed for boreholes drilled in the future as specified in Section 194.33(d).

Issue B: The impacts/feasibility of air drilling at the WIPP must be evaluated.

1. Will EPA respond to comments on the potential impacts of air drilling? (32)

2. Why has air drilling not been evaluated in the CCA? (81)

3. Did EPA evaluate the December 5, 1995 DOE study that suggested air drilling would be the preferred method of drilling in potash zones after evacuation. (85)

4. Drilling with air instead of mud is an established technology used in the Delaware Basin and is entirely feasible at WIPP. (128)

5. What the proposed rule shows is that EPA did not evaluate at all the impacts of air drilling into the site. EPA did not realistically evaluate the impact of drilling with mud, which again results in releases that violate the disposal regulations. EPA did not evaluate releases from fluid injection even if it occurs outside the site boundary, which can lead to violations of the standard, let alone fluid injection within the site boundary, also leading to violation of the standard. EPA did not evaluate carbon dioxide injection for oil recovery even though that again is another realistic scenario that results in violation of the disposal regulations. (227)

6. In light of the DOE Office of Fossil Energy's optimistic assessment of the expansion of under balanced drilling for oil fields in the country and other factors discussed above, it would seem prudent for EPA to require or conduct an appropriate consequence assessment of the impact of drilling with air, aerated mud, foam and mist on the release of radionuclides from the repository. (265)

7. All the implications of the resource exploitation activities be taken into account in projecting the potential scenarios for future inadvertent breach of site and in computing the effects of those scenarios. In particular, the consequences of air drilling and fluid injection and mining, including solution mining, activities require additional attention from the EPA. (351) (716)

8. Our reports show that air drilling into WIPP would cause hundreds of cubic meters of waste to fracture and be brought to the surface. EPA's 10,000 year standard would be violated in less than a day. DOE has not analyzed air drilling at all. (404)

9. I request that you require the DOE to resubmit a compliance [application] that includes the issues of the [Hartman] scenario, modeling air drilling releases from [either] air and mud drilling, and the possibility of drilling into the WIPP site and hitting a brine reservoir. (428)

10. [R]esource exploitation activity should be taken into account in projecting the potential scenarios for future inadvertent breach of the site and, in computing the effects of these scenarios. In particular, the consequences of air drilling, fluid injection, mining, including solution mining, activities require additional attention from EPA. (484)

11. Major scientific concerns not included in the evaluation: one is the comprehensive modeling of gas, oil and potash. Drilling releases using current technological methods such as forced air and brine injection. The second would be a fully assessed possibility of fractures in the substrata caused by fuel injection and the level of commercial drilling around the WIPP site for the future given the next 10,000 years. (529)

12. [T]he Bredehoeft calculations were made incorrectly and the results were interpreted inappropriately, leading to an extreme over-estimate of the spall release. (655)

13. [T]he EEG recommended (EEG-6, May 1996) that at least the actual conditions at the site related to the presence of natural resources be fully and conservatively assumed in projecting compliance with the numerical containment requirements. This does not appear to have been done in the CCA, judging from the DOE resistance to consideration of fluid injection, air drilling, and mining scenarios. (709)

14. Statements made in Albuquerque by a member of EEG regarding air drilling were incomplete and -- because of this -- misleading in my opinion. This individual stated that under-balanced drilling (e.g. air/mist) is well suited for use in older fields. This statement while true unfortunately implies that air drilling is, or will be, used near WIPP. An important fact not discussed by this individual is that the presence of water bearing zones in an area make the use of air drilling not economically attractive to drillers seeking hydrocarbon resources. There is a well-characterized water bearing zone that lies over the repository-the Culebra. (834)

15. The reports on air drilling submitted by this office (II-D-120; IV-D-14) show, among other things, that air drilling is a proven and widely used technology which could be applied to drill at the WIPP site. Water present in the Culebra is not sufficient to inhibit use of air drilling equipment, except in a small part of the northwest comer (II-D-120 at 3-5). EEG has shown that under-balanced drilling is an emerging drilling technology well suited for drilling in aging oil fields or through sensitive reservoir zones; advantages include increased penetration rate, minimum formation damage, more complete cuttings removal, and more effective bit cooling. (EEG presentation to EPA, Jan. 7, 1998)(IV-F-2(a) at 104). (1029)

16. Drilling with air may be the method of choice in the WIPP area, since there will have been potash mining in overlying strata, and a driller will prefer to use a technology which avoids loss of circulation, such as air drilling (IV-G-I, Ref. 461 at 36). (1030)

17. Based on the survey and projections of the Duda and Medley study, EPA should require DOE to assign a 30% probability to the use of air drilling at WIPP. (1031)

18. EPA also surveyed various drillers concerning the use of air drilling in the Delaware Basin and decided, based on that, that "almost exclusively, air drilling in the Delaware Basin was found to have been done after the hole was drilled and the completion casing was set using a mud circulation system." (IV-A-I at 12). Surveys have already noted that drillers are surprisingly uninformed about the utility of air drilling (Graham report at 3-4). (1034)

19. EPA's after-the-proposed-rule drilling analysis is not adequate. It does not include current technical data on underbalanced drilling, including DOE information (see IV-F-2 and -3). The analysis includes unsupported assumptions and data and its modeling is inadequate. (1116)

20. EPA did not evaluate at all the impacts of air drilling at WIPP--though air drilling would result in releases that violate the disposal regulations. EPA did not realistically evaluate the impacts of drilling with mud. (1129)

21. Bredehoeft did not limit his consideration of scenarios to a choice of drilling fluid. He observes that air drilling is a proven technology and its frequency of use by the oil and gas industry is increasing. An examination of published materials shows that use of underbalanced drilling, including air drilling is expanding in the oil and gas industry with the explicit support of the DOE Office of Fossil Energy (Duda et al, 1996) and strongly suggests that the analyses may need to include other methods of underbalanced drilling, including foam, mist, dust, aerated mud and light weight solid additives. (1250)

22. While, the EPA Criteria requires consideration of practices in the entire Delaware Basin, neither agency reviewed the Texas records although a large portion of the Delaware Basin is located in Texas. EPA documents a conversation with Mark Henkhaus, District Manager of the Texas Railroad Commission in Midland, Texas who indicated that Burlington Resources has done air drilling in Reeves and Pecos Counties, Texas. Although not noted in the EPA document, Reeves County, Texas lies entirely within the Delaware Basin. Compliance with the EPA Criteria requires examination of the appropriate Texas records as well as the appropriate New Mexico records. (1251)

23. Neither DOE nor EPA could find documentation in the public record directly stating that this well [Lincoln Federal #1] was partially drilled with air. This raises a very important question about the reliability of the New Mexico records to document air drilling. If air drilling was indeed used in this well and that information is not stated in the public record, how many other wells have

been drilled with air (foam, mist, aerated mud, or other underbalanced methods) without documentation? (1252)

24. U.S. EPA (1998, pp. 15-16) presents an argument that water inflow will prevent air drilling in the vicinity of the WIPP. The argument must be viewed with caution. Although EPA alludes to cost limitations, there is no cost analyses for drilling a specified well in the vicinity of WIPP. Instead, referring to information from one industry contact (unnamed) and applying methodology presented by Lyons (1984, p. 109), EPA determined that the reasonable upper bound for water removal under current air drilling practice is in the range of 10 to 20 gallons per minute (gpm). EPA maintains that water inflow into a hole drilled at the WIPP Site would originate primarily from Culebra Dolomite and calculates that wells in the vicinity of WIPP with transmissivities greater than $1x10^{-5}$ m^2/s identify areas in which water inflow would prohibit air drilling. Furthermore, EPA states "other wells in the area have transmissivities in the 10^{-6} to 10^{-5} m^2/s range, causing much of the WIPP Site to be borderline for feasible air drilling" (U.S. EPA, 1998, p. 16).

The wells in the immediate vicinity of the WIPP shafts, H-1, H-16, and ERDA 9, each have transmissivities on the order of 10^{-6} m^2/s. That these would be "borderline for feasible drilling" is somewhat difficult to understand in view of the measured inflow data for that area, which ranged between 0.3 gpm to 0.9 gpm with an average of about 0.6 gpm (TSC-D'Appolinia, 1983, p. 5-2). And that was for the six foot diameter ventilation shaft. An oil and gas well would have a much smaller diameter, hence, an even lower inflow. (1253)

25. DOE interviews with drillers found that they would not consider using air drilling near the WIPP Site. However, written statements by others in the air drilling industry, including the DOE Office of Fossil Energy, identify an industry wide misunderstanding that has led some operators to incorrectly conclude that some wells are not suitable to air drilling. They note that the limited use of air drilling techniques, relative to fluid, is primarily a function of the limited knowledge of new developments and the industry's natural resistance to changing methods. (1254)

Response to Comments 8.B.1 through 8.B.25:

In the proposed WIPP certification decision, EPA accepted DOE's assertion in the CCA that "current drilling practice" in the Delaware Basin includes the use of mud as a drilling fluid. The definition of "current drilling practice" is important because of EPA's requirement in 40 CFR 194.33(c)(1) that DOE assume that "future drilling practices and technology will remain consistent with practices in the Delaware Basin at the time a compliance application is prepared. Such future drilling practices shall include, but shall not be limited to: the types and amounts of drilling fluids; borehole depths, diameters, and seals; and the fraction of such boreholes that are sealed by humans..." This requirement was made to avoid unnecessary and potentially unbounded speculation about the nature of future conditions, activities, and technologies associated with drilling in the basin. Because of this requirement, technologies that are not considered "current drilling practice" in the Delaware Basin do not need to be considered by DOE in performance assessment.

DOE did not identify air drilling as a current practice in the Delaware Basin, and therefore it was not included in the performance assessment. Public comments raised the issue that both air and mud drilling may occur in the Delaware Basin and that releases from air drilling could be greater than from mud drilling and potentially cause WIPP to fail the numerical containment requirements at 40 CFR 191.13. EPA examined the air drilling issue from several perspectives and documented its findings in the Technical Support Document, EPA's Analysis of Air Drilling at WIPP. [Docket: A-93-02, IV-A-1] This analysis was provided to major stakeholders known to be interested in this issue on January 27, 1998. [IV-C-15] In addition, a Notice of Availability for this report was published in the Federal Register on January 27, 1998. EPA afforded the public the opportunity to comment on this report for a 30-day period.

<u>Background information on air drilling</u>

This section presents an overview of current air drilling practices. The focus of this discussion is on the use of air drilling under the geological and hydrological conditions in the Delaware Basin. Much of the information in this overview was taken from documents prepared by the Gas Research Institute [GRI 1995] and from Air and Gas Drilling Manual. [Lyons 1984]

Air drilling refers to a drilling process in which air or another gas is used instead of water-based mud as a circulating fluid for removing drill cuttings from the hole. Air drilling technology was developed over 40 years ago and has been successfully used to drill a wide variety of wells in the United States. Although initially used predominantly for shallow and environmental applications, air drilling is now also used by the oil and gas industry for deeper wells in two primary ways: as a means to minimize formation damage in some production zones, and as a means to quickly drill through formations between the ground surface and target depth.

Air drilling uses a drilling rig and drill string that have many similarities to those used in conventional mud rotary operations. The primary differences are in the type of drill bit and circulating fluid, and in the use of air compressors, associated valving, and other specialized uphole and downhole equipment. Air or other gases or gas mixtures are pressurized at the surface with a compressor and booster system and injected into the drill string pipe. Typically, the pressurized air travels down the hole through the drill string, passes through the drill bit, and returns to the ground surface carrying the drill cuttings in the wellbore annulus. As the air passes through nozzles at the drill bit, its velocity increases, allowing it to clean the bottom of the hole and to also cool the bit. In some applications, the air also provides the energy needed to turn rotary bits or to activate percussion hammerdrills. At the ground surface, the cuttings are typically discharged through a blooey line (gas bleed-off line) to the flare pit where flammable formation gases are burned off.

Technical, economic, and safety considerations determine the choice of drilling method. Compared to mud drilling, air drilling can have the advantages of minimizing formation damage in production zones, reducing lost circulation problems, increasing penetration rates, facilitating penetration of hard rocks, forming straighter holes, minimizing drill mud costs, and allowing cleaner operating conditions. Air techniques are primarily used in drilling production wells where the geology is well known, the rock is stable, water inflows are not significant, and the formations being drilled are not highly pressurized. Under favorable conditions, the advantages of air drilling can reduce costs by reducing rig operating time and thus can make it a preferred technology. Air drilling to depths of more than 19,000 feet has been successfully accomplished in areas where geologic and hydrologic conditions were favorable.

The disadvantages of air drilling limit its use at locations where conditions are less favorable, often not because of technical limitations but due to economic considerations. Under less favorable conditions, the following disadvantages can raise the cost of air drilling to the point that it is no longer economical:

- Formation pressure control is minimal because there is little or no drilling fluid pressure to contain blowouts and, therefore, drilling is limited to geologic regions where reservoir pore pressures are low.

- Drilling is limited to geologic regions where the rock formations are stable because there is little or no drilling fluid pressure to support the borehole wall and prevent sloughing or "squeeze-in."

- There is a limited ability to cope with significant volumes of water entering the annulus from water-producing formations. The energy required to remove the water reduces the energy available to remove drill cuttings and reduces the efficiency of the drilling process.

- The drill pipe can experience high wear due to abrasion from cuttings moving up the annulus.

- The air provides little or no cushioning of the drill string during handling mishaps.

- There is great danger of downhole fire when drilling into formations containing flammable gases unless the air is replaced by a gas that is not combustible under downhole conditions.

- Fluid handling equipment must also be available on site to place and cement casing, which can require a duplication of equipment and a time-consuming switching back and forth from air- to mud- to air-filled boreholes.

Because of its disadvantages, air drilling is not typically used at locations where high formation pressures are likely to be encountered, where the rock is not self supporting and may cave or squeeze into the borehole, where high water inflows may be encountered, and where casing requirements necessitate frequent switching between air- and mud-filled boreholes. Air drilling technology is also not typically suited for exploratory drilling due to the risks associated with the minimal ability of air to control blowouts and to deal with weak formations and large water inflows when drilling into areas with poorly understood geologic and hydrologic conditions.

Air drilling is typically least expensive and most advantageous when performed in stable formations without the use of fluid additives. A water mist and foaming agents (surfactants or soap) can be added to the air stream to assist with removal of formation water and reduce the risk of downhole fire. Increasing the compressor and booster system capacity can also help to maintain drilling rates when encountering wet formations. Wells penetrating formations containing natural gas can be drilled using gases other than air to reduce the risk of downhole fire. Air drilling and air/foam technology is now commonly used to complete wells in a production zone or to re-work or re-stimulate an existing well. Although technologies are available to deal with a variety of adverse downhole conditions, such complications reduce the cost advantages that can be associated with air drilling. The cost savings potentially realized through use of air drilling are highly dependent on site specific conditions.

EPA's assessment of air drilling

In assessing the potential use of air drilling at WIPP, EPA first reviewed the regulatory requirements that have bearing on whether air drilling should be included in the WIPP performance assessment. These requirements are found at 40 CFR 194.32 (scope of performance assessments), 40 CFR 194.33 (consideration of drilling events in performance assessments), and the New Mexico Oil Conservation Division (NMOCD) Order R-111-P. Section 194.32(a) requires that performance assessments include, *inter alia,* deep and shallow drilling that may affect disposal system during the regulatory time frame. Section 194.33(c)(1) directs DOE to assume future drilling practices are consistent with practices in the Delaware Basin at the time the certification application was prepared. EPA used several sources of information to determine whether air drilling should be considered current practice, including an independent random well analysis, a "seven well analysis" of nonrandomly identified wells, contacts with drilling service suppliers, and the results of a comprehensive well survey performed by DOE.

Random well analysis

To help determine whether air drilling should be considered "current practice" in the Delaware Basin, EPA performed a random analysis of 306 deep wells within the Delaware Basin, examining the New Mexico Oil Conservation Division well files for Lea and Eddy Counties (203 wells) and Texas Railroad Commission well files for Culberson, Loving, and Reeves Counties (103 wells). Detailed documentation of this analysis is presented in the Technical Support Document, EPA's

Analysis of Air Drilling at WIPP. [Docket: A-93-02, V-B-29] Sections within each township and range in the Delaware Basin portion of these counties were selected randomly, and wells within each randomly selected section were also randomly chosen for examination. For wells in New Mexico, the filing system used by the New Mexico Oil and Gas Conservation Division facilitated a records search based on well location because the well files were organized by township and range. In contrast, the Texas Railroad Commission files are organized by lease number and field name, and can be cross referenced using American Petroleum Institute (API) numbers. Random well selection based on location was maintained in the Texas file search, although a more complicated process had to be used than in New Mexico. First, wells within the Texas portion of the Delaware Basin were selected randomly by township/range in the same manner as for the New Mexico well files. Approximately 400 wells were selected in Texas using this method. The files for these 400 wells were then examined but were found to have API numbers for only 103 of the 400 wells. Because the well locations in Texas were cross referenced by API number (they could not be located using township and range), EPA focused its search on the files for the 103 wells with API numbers. If a particular well file could not be located, file data for a well immediately adjacent to the missing well or a well within the same lease was randomly selected. The analysis excluded wells within the New Mexico Potash Exclusion Zone and wells drilled prior to 1950. These wells were excluded so that wells precluded from air drilling by regulation were not examined, and so that the analysis focused on those wells drilled within the Delaware Basin when the use of air drilling was greatest. Air drilling is a relatively new technology and was not widely used on a national basis prior to 1950.

Results of EPA's analysis indicated that the 306 drilling records examined showed only one potential incident of air drilling through the salt section. This well, the George H. Williams Federal Johnson No. 1, was drilled in T24S R34E, Section 13, and is approximately 18 miles southeast of the WIPP site. The well was drilled in 1958, and the only indication of air drilling is a note on a June 1958 record stating that the operator intended to drill out of the 8 5/8 inch surface casing to the Delaware Mountain Group using air (the surface casing was set from ground surface to the top of the salt section). There are no records that indicate whether this well was actually drilled with air as proposed.

EPA notes that there is evidence to indicate that wells were occasionally "dry drilled" through the Rustler Formation when mud circulation was lost (e.g., the Oscar State well in T24S R29E, Section 36). However, no wells examined in the 306-well EPA search were "dry drilled" through the salt section. Attachment 1 of EPA's analysis presents a table with an example of the information EPA gathered for each well that was examined using field records. Appendix B, of EPA's analysis presents summary data for wells examined by EPA and detailed well location data (township, range, quarter-quarter). Attachment 2 of EPA's analysis presents the approximate locations of the wells examined and is included in Appendix B.

EPA performed a statistical analysis of the random well record data to assess the probability of air drilling in the Delaware Basin. EPA used the standard Clopper-Pearson confidence bound to determine the probability of air drilling based on the number of wells in the sample that were found to have been air drilled. Using a 95% confidence level and assuming that the total number of wells is much larger than a sample size of 300 wells and that one of those 300 wells was air drilled, the number of air drilled wells in the Delaware Basin would be expected to be less than 1.65% of the total wells drilled. EPA concludes that these data indicate air drilling is a rare occurrence in both the New Mexico and Texas portions of the Delaware Basin.

Seven well analysis

EPA also examined wells not identified in the random search, but suspected of having been drilled using air. Detailed documentation of this examination is presented in the Technical Support Document, EPA's Analysis of Air Drilling at WIPP. [Docket: A-93-02, V-B-29] EPA identified these wells through public comments and through a DOE survey of well records. [Docket: A-93-02, Item IV-G-8; letter from Ross Kirkes] EPA is aware of seven wells in the New Mexico portion of the Delaware Basin that may have, at some point, been drilled using air or were "dry drilled." (Dry drilling is drilling without intentionally adding any drilling fluid.) Of these wells, three may have been "dry drilled" or air drilled into or through the salt section. These three wells are the Lincoln Federal No. 1 (T21S, R32E, Section 26), South Culebra Bluff Unit No. 4 (T23S, R28E, Section 23) and Amoco Federal No.1 (T23S, R28 E, Section 11). Operators of two of the four remaining wells (South Culebra Bluff Unit No. 3, T23S, R28E, Section 23, and Amoco Federal No. 3, T23S, R28E, Section 11) used air in the completion interval after mud was used to drill through the salt section. Air drilling was attempted in the remaining two wells, the Thorn and Grauten Russell Federal No. 1 (T26S, R32E, Section 20) and Federal Unit B.E. No. 1 (T24S R34E, Section 4), but the drilling fluid had to be switched to mud prior to drilling the salt section.

Drilling records for these seven wells did not contain extensive discussion of the air drilling process. EPA's determination of potential air drilling through the salt section for the first three wells listed above was based, for example, on single statements within the entire well files that imply air drilling was used, on mud plans which indicate that the driller planned to drill with air in the salt section, or on inferences that air was circulated in a hole while casing was set through the salt section.

EPA survey of drilling service suppliers

EPA contractor staff contacted suppliers of drilling services, who provide well data to the petroleum industry in New Mexico and Texas. EPA initiated this as a supplemental method to determine the extent to which air drilling is currently used in the Delaware Basin. Detailed documentation of this survey is presented in the Technical Support Document, EPA's Analysis of Air Drilling at WIPP. [Docket: A-93-02, V-B-29] None of the database suppliers could provide information on the type of drilling or drilling fluid used, and a database search for air drilling indicators was not found to be possible.

In view of the lack of a suitable electronic database, individuals from the drilling industry were contacted as another method to aid the Agency's understanding of the use of air drilling in the Delaware Basin. Some of these contacts were individuals already known to the Agency and others were selected by consulting major oilfield service companies with offices in New Mexico and west Texas. Additional contacts were identified by consulting the 1997 Hart's Permian Basin Yellow Pages for local contractors and suppliers. No preference was made in selecting the industry contacts, and volunteered information and names of other contacts were accepted from all individuals. EPA contractor staff contacted 25 individuals between November of 1997 and January of 1998. EPA contractors asked if they had knowledge of any wells drilled using air or gas within 20 miles of the WIPP site , wells drilled within the Delaware Basin, or wells drilled under conditions similar to those found at WIPP. Detailed documentation of these contacts is presented in the Technical Support Document, EPA's Analysis of Air Drilling at WIPP [Docket: A-93-02, V-B-29] In summary, the drilling contractors, tool rental companies, air drilling consultants, and state officials that were contacted regarding the use of air drilling near the WIPP site or within the Delaware Basin indicated that, almost exclusively, air drilling in the Delaware Basin was done after the hole was drilled and the completion casing was set using a mud circulation system. At that time, air or foam may have been used to stimulate the well's production, disposal, or recompletion zone, but not for the actual drilling. Air drilling was also used to drill production zones after having drilled the upper part of the well with mud. This use of air was reported in a well near Loving, New Mexico. Furthermore, air drilling was not done in the vicinity of the WIPP. Some wells were drilled with air north and southwest of Carlsbad until excess water was encountered; however, these wells were not in the Delaware Basin. Geologic and hydrogeologic conditions can change abruptly within and beyond the Capitan Reef, which defines the edge of most of the basin, and these areas were therefore explicitly excluded from the Delaware Basin in the rule. [40 CFR 194.2]

Industry contacts indicated that air drilling is more prevalent outside the Delaware Basin where conditions are more favorable. For example, in locations that are more favorable for air drilling, there is less water inflow and there is no stratum with brine pockets such as the Castile. Much of this drilling occurs either outside or on the edge of the Delaware Basin where geologic and hydrogeologic conditions are different and, hence, are more favorable than at the WIPP site . Air drilling is reported south of Monahans in Ward County, Texas, and south of Imperial in southern Pecos County, but neither of these areas are in the Delaware Basin. A single example of a well attempted to be drilled with air from the ground surface to total depth at or near the edge of the Delaware Basin in New Mexico was reported by Mr. Angel Salazar; however, this well could not be completed with air because of excessive water flows, and had to be completed with mud.

In addition, EPA contacted an industry representative to investigate the possibility that a well has recently been drilled using air near Fort Stockton, Texas. Mr. Michael Amos had indicated that he was currently drilling a well near Fort Stockton, using air. The area in question appears to be along the distant southeast margin of the Delaware Basin where the stratigraphic and structural characteristics of the Basin are different from that of the WIPP area. Mr. Amos indicated that while the well was installed using air, no salt section was encountered. Therefore, use of air to drill this well does not indicate that it is common practice to use air to drill through the salt section in the Delaware Basin.

Industry contacts indicated that the area between Carlsbad and the WIPP site was not considered suitable for air drilling because of problems with excessively wet formations, problems with borehole stability, and high pressure brine reservoirs in the Castile Formation. Some successful air drilling from the ground surface was found to have occurred in the Texas portion of the Delaware Basin, but these holes were located at the margin of the Basin where geological and hydrological conditions are not the same as at the WIPP site . None of the individuals contacted were aware of any oil industry related wells drilled within 20 miles of the WIPP site using air technology for any purpose. In addition, NMOCD regulatory personnel in Hobbs and Artesia indicated that no wells have been drilled from the ground surface with air in the New Mexico portion of the Delaware Basin because of the problems cited above.[33]

Examination of drilling records and discussions with industry contacts indicate that air drilling through the salt section in the Delaware Basin is not "common practice." Further, there is no indication that air drilling is *currently* used in the Delaware Basin, since all wells discovered to date that may have been initially designed to use air were drilled prior to the early 1980s. EPA does recognize that air drilling may be used as an alternative borehole installation method in very rare instances when site-specific or emergency conditions warrant its use, such as the 1991 Lincoln Federal No. 1 well. However, EPA concludes that air drilling is not "current practice" for drilling through the salt section in the Delaware Basin because of technical problems with wellbore stability and water inflows. In view of the scarcity of application of air drilling techniques under WIPP conditions and the scarcity of air drilling throughout the Delaware Basin in general, the Agency concludes, in accordance with 40 CFR 194.33(c)(1), that air drilling does not require consideration in WIPP performance assessment because it is not current practice.

<u>State regulations affecting air drilling</u>

NMOCD Order R-111-P describes requirements for potash mining and oil and gas operations within the "potash area" in Eddy and Lea Counties, New Mexico. [CCA Reference #462] Because the WIPP site is within the prescribed "potash area," the requirements of the Order apply to drilling in the vicinity of WIPP. Order R-111-P became effective in April 1988. It defines the boundaries of the potash area and applies to both private and Bureau of Land Management (BLM)

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[32] In addition, DOE performed an independent well file search within the Delaware Basin and has provided the preliminary results of that search. DOE has indicated that as of January 26, 1998, its analysis has shown that of the 3349 wells examined in the Delaware Basin in New Mexico, 7 wells (0.2 %) showed indications of air drilling (see Docket: A-93-02, IV-G-8; letter from Ross Kirkes). This information supports EPA's conclusion that air drilling is an extremely rare practice in the Delaware Basin.

lands in southeastern New Mexico. Subpart D of the Order requires that a surface casing string must be cemented into the basal Rustler Formation before drilling into the underlying Salado Formation and that a salt protection casing string must be cemented into the salt section before drilling into the underlying oil or gas production zone. Additionally, Subpart E of the Order requires that drilling in the area must be accomplished using salt saturated water as the drilling fluid using additives such as mud, if needed. These requirements protect the salt section from dissolution by drilling fluids, by water inflows from overlying formations (particularly from the Culebra Dolomite), and during oil or gas production. The requirements for multiple casing string installations and for cementing the casing strings to the ground surface reduce the economic advantage of air drilling because of the cost and delay of switching the borehole fluid several times from air to mud and back to air each time a casing string is set. If the hole were air drilled, the drilling fluid would probably have to be changed to mud to place and cement the casing, the mud would have to be displaced by water prior to and after cement drill-out for testing purposes, and the water would then have to be displaced by air to continue drilling. Therefore, NMOCD Order R-111-P effectively eliminates the use of air drilling in the potash area, including the WIPP site for the present and near-future.

As previously mentioned, to constrain speculation about future drilling practices in the compliance application, the Agency stipulated in 40 CFR 194.33(c)(1) that performance assessment consider only the present day drilling practices and technology occurring within the Delaware Basin. EPA intended this provision to refer to drilling procedures commonly used at the time DOE submitted its CCA or within several years before the submission of the CCA, rather than referring to every single practice used in the Delaware Basin. As discussed above, EPA has determined that the use of mud as the drilling fluid is the current practice for drilling through the salt section (the Salado and Castile Formations) and that air drilling through the salt section is not consistent with current drilling practices in the Delaware Basin. Thus, DOE properly excluded air drilling through the salt section from consideration in the WIPP performance assessment.

<u>Potential releases from air drilling</u>

An Agency concern associated with the air drilling scenario is that the lack of a mud-filled borehole may result in greater spallings releases if a waste panel is inadvertently penetrated. Spallings releases were found in WIPP performance assessment to constitute a significant fraction of total repository releases when inadvertent intrusion is presumed to occur, and significant increases in spallings releases could potentially cause the regulatory limits to be exceeded.

EPA examined the potential effects of spallings releases during air drilling from two perspectives. First, EPA assumed that air drilling did occur and estimated its effect on spallings releases. EPA found that even if an unrealistically high spallings release from air drilling did occur it still would not greatly affect the spallings releases estimated in the CCA. Second, EPA modeled the potential consequences of air drilling using a spreadsheet model that could be modified to use air as the fluid instead of mud. Results of this modeling indicate that only insignificant volumes of spalled material would be released during air drilling.

EPA statistically examined the possible mean release volume of spalled material that could occur if air drilling took place. Public comments have suggested that the spalled waste volume from air drilling would be larger than the 0.5 to 4.0 cubic meters determined by DOE for mud drilling. Even if the total possible release volume from a drilling event is assumed to be as high as asserted by some public commenters (such as about 64 cubic meters), the calculated mean release volume is still relatively low when coupled with the low probability that such an event might occur. To arrive at this conclusion, EPA assumed that: 1) the mean release volume based on the range of 0.5 to 4.0 cubic meters, uniformly distributed, is 2.25 cubic meters (releases of zero are ignored for this analysis even though there would be some modeling realizations where zero releases could occur); 2) less than 1.65% of the total wells in the Delaware Basin are air drilled; and 3) the total spalled volume is roughly equal to the maximum volume cited by testifiers in the January 5-9, 1998 WIPP hearings (64 cubic meters). The mean release volume, assuming air drilling, was then derived using the following:

$$MRV_{air} = MRV_{mud} (1\text{-}p) + Vp$$

where:

MRV = mean release volume
p = probability of air drilling
V= spalled volume

This calculation indicates that the mean release volume assuming air drilling at the determined probability yields an average release volume of approximately 3.3 cubic meters, which is more than the average release volume associated with mud drilling but still within the range of possible mean release volumes identified by DOE in the CCA.

To further address public comments, the Agency evaluated multiple modeling options for directly estimating spallings release volumes during air drilling. The Agency evaluated the modeling done previously by the Agency for the proposed rule. EPA decided that this modeling was inadequate to bound the impact of an air drilling event (that modeling is documented in Docket: A-93-02, V-B-10 and II-B-11). The Agency also reviewed the modeling work documented by Sandia National Laboratories (SNL) in SAND97-1369, Spallings Release Position Paper: Description and Evaluation of a Mechanistically Based Conceptual Model for Spall [Docket: A-93-02, II-G-23] to see if these models could be adapted to evaluate the air drilling scenario. Two models were considered, the Cavity Growth Model (i.e., the GASOUT computer code) discussed in Section 3.3 of the SNL report [Docket: A-93-02, II-G-23] and the Quasi-Static Model discussed in Section 3.4 of the SNL report. Because of extreme code design limitations the GASOUT computer code could not be used to evaluate the impact of an air drilling event. Spallings releases calculated using air as the fluid in the GASOUT code are not valid because the code is not designed to handle the full blowout process and the code contains several inherent limitations in implementing the basic equations describing the physical processes. These limitations limit its use to the narrow range of conditions considered in SAND97-1369. [*ibid.*] The GASOUT code limitations are discussed more fully in the EPA summary of the January 21, 1998 GASOUT Code Meeting. [Docket: A-93-02, IV-E-9]

The second model evaluated was the Quasi-Static model. The Quasi-Static Model is a bounding simplification of a mud drilling scenario in the form of a spreadsheet model and has the versatility to simulate an air drilling scenario (see Appendix A of the Technical Support Document, EPA's Analysis of Air Drilling at WIPP. [Docket: A-93-02, V-B-29] It predicts the expected failed waste volumes during a drilling event in a repository waste room. The Quasi-Static Model differs from the Cavity Growth Model in several ways. Unlike the Cavity Growth Model, which is limited to an examination of the first few seconds of the blowout process, the Quasi-Static Model can examine the entire process up to the time that the drilling fluid exhausts the borehole. In addition, the Quasi-Static Model does not have the instabilities that develop when GASOUT is used beyond its limited range of applicability. However, the Quasi-Static Model does not consider failed material removal from the bottom of the borehole which can affect the bottomhole pressure distribution. In spite of this limitation, it has been shown in SAND97-1369 [Docket: A-93-02, II-G-23] that the Quasi-Static Model generally predicts higher volumes of material to have failed in tension than the Cavity Growth Model. For example, Table 3-3 in SAND97-1369 [*ibid.*] compares the extent of waste failure using the Quasi-Static Model and the Cavity Growth Model (with the effects of material removal included) and shows the generally more conservative results obtained with the Quasi-Static Model. Porous medium gas flow in the Quasi-Static Model is based on a steady-state analytical solution rather than a fully transient numerical solution. This modeling approach was developed by Chan, et al., 1993 who showed reasonable similarity between numerical and steady-state solutions. This reasonable similarity was further supported by the comparisons between the Quasi-Static and Cavity Growth Models described in SAND97-1369. [Docket: A-93-02, II-G-23] For example, Figures 3-19 through 3-25 in that document show that both models generate similar mud column displacement curves, mud column velocities, bottomhole pressures and gas inflow rates for the first five seconds[34] of the blowout process. Based on this information EPA believes that the use of the Quasi-Static Model will provide reasonable estimates of failed waste volumes over a wide range of conditions.

The Agency reviewed the theoretical basis for the Quasi-Static Model, duplicated the calculations performed by SNL, and verified the modeling application and results documented by SNL in this report. Next the Agency adapted the input parameters of the borehole drilling fluid to those of an air drilling scenario. Then the Agency simulated the impact of an air drilling event and estimated failed waste volumes. For more detailed documentation on the Quasi-Static Model see Docket: A-93-02, II-G-23, p. 3-23.

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[33] Under conditions typical of those presented in Figure 3-19 through 3-25, the maximum failed volume in tension occurs in less than one second -- well within the five-second period included in the cited figures. This fact provides additional support for the assumption that the two models produce similar results during the critical period when the failure process is occurring. Deviations later in time are not relevant to the failure process.

The results of the Quasi-Static calculation are bounding and conservative. This is because the Quasi-Static Model predicts the waste volume that has failed (i.e., is available to be transported) because of the dynamics of the air drilling event. Waste material that has failed must also be transported to the surface through more than two-thousand feet of borehole. Therefore, the Quasi-Static Model over-predicts the volume of waste expected to be transported to the surface during an air drilling event.

As described in Appendix A of the Technical Support Document, EPA's Analysis of Air Drilling at WIPP [Docket: A-93-02, V-B-29], the Quasi-Static Model predicted waste failure volumes on the order of 1.4 m^3. These volumes are within the values predicted by the CCA and used by the PAVT evaluation. Since the DOE spreadsheets for the Quasi-Static Model were based on the movement of an incompressible fluid up the borehole, it was necessary to make some modifications to address the situation where a column of air rather than brine was being ejected from the borehole. This was done by assigning an average density to the air column based on the expected change over the borehole length. Subsequently, this simplifying assumption was verified by comparison with a modified spreadsheet approach which explicitly addressed compressible fluid flow. As shown in Appendix A [*ibid.*], good agreement was obtained between the two modeling approaches. Based on its conservative modeling analysis, the Agency concludes that if air drilling occurred, it would have spallings releases within the range of 0.5 to 4 m^3 identified in the CCA.

EPA concludes that because it is not a current drilling practice in the Delaware Basin, air drilling does not have to be included in the WIPP performance assessment. Furthermore, based upon its modeling analyses, EPA expects that the impacts of air drilling, were it to occur, would be minor and within the range of releases used by DOE in the CCA.

<u>Responses to specific issues raised in comments</u>

With regard to Comment 8.B.4, EPA believes that the surveys, interviews, and analyses described above adequately demonstrate that air drilling is used only rarely and is not an established technology in the Delaware Basin.

Comment 8.B.8 by the New Mexico Attorney General (NMAG) states "Our reports show that air drilling into WIPP would cause hundreds of cubic meters of waste to fracture and be brought to the surface." The cited report is presumed to be Air Drilling at WIPP [Docket# A-93-02, Item IV-D-1], prepared for NMAG by John Bredehoeft, in which failed waste volumes of hundreds and even thousands of cubic meters are reported. Those predictions were made by Dr. Bredehoeft using the code GASOUT. That code was developed by DOE to predict failed waste volumes for mud-filled rather than air-filled boreholes. Dr. Bredehoeft acknowledges the potential problems with such applications when stating on p. 6 of his report: "I recognize that by replacing the mud column in the borehole with a column of gas I depart significantly from what the code was designed to do...Needless to say, I recognize that GASOUT in its present form may not be fully applicable to the problem being addressed." Dr. Bredehoeft's concern about code applicability to air drilling was borne out in a January 21, 1998 EPA meeting at SNL with representatives of NMAG and DOE to discuss the GASOUT code. [Docket: A-93-02, IV-E-9] In that meeting the author of the code, Dr. John Schatz, stated that the code became unstable and produced erroneous results under conditions that caused a steep pressure gradient in the waste. Such conditions could include assigning a very low waste permeability or inducing an initial pressure gradient between the borehole and the waste panel that was larger than the gradient induced by mud drilling. The assumption of an air filled borehole would induce pressure gradients that were too steep for valid solution with the GASOUT code and the resulting model calculations would be in error. Based on the incorrect use of the GASOUT code and nonphysical modeling results by NMAG [Docket: A-93-02, IV-E-4], EPA concludes that the spallings volumes reported by NMAG to occur during air drilling are erroneous.

With regard to Comment 8.B.12, EPA agrees that Dr. Bredehoeft's calculations of spallings releases under air drilling were made incorrectly and significantly over estimate the volume of spallings releases. Additional discussion of this issue is provided above in the specific response to Comment 404 and in the discussion of EPA's modeling results.

With regard to Comment 8.B.22, EPA Analysis of Air Drilling [Docket: A-93-02, V-B-29] included a search for air drilling activity in the New Mexico portion of the Delaware Basin. Since that report, EPA augmented this search to include the Texas portion of the Delaware Basin. The results on the use of air drilling and the potential releases from air drilling presented here encompass the entire Delaware Basin. Nearly all of Reeves County, Texas, does lie within the regulatory definition of the Delaware Basin. [Section 194.2; see map in CCA Vol. I, Figure 2-39; Docket: A-93-02, II-G-1] The belief of Mr. Mark Henkhaus, District Manager of the Texas Railroad Commission in Midland, Texas, that Burlington Resources has done air drilling in Reeves County, Texas, was confirmed by Mr. Jim Ward, consultant to Burlington Resources in Midland, Texas. Mr. Ward indicated that Burlington Resources has made attempts to drill with air in the Delaware Basin but the wells watered out before a depth of 4,500 feet was attained. These wells were not drilled through any salt and were in an overthrust near the edge of the basin, see EPA's Air Drilling Report. [Docket: A-93-02, IV-A-01] The cited drilling operations were therefore not conducted under geologic and hydrologic conditions similar to those at WIPP. Burlington's drilling operations were considered along with others identified in EPA's drilling practices review; however, as previously stated, the use of air in drilling through the salt section was found to be so rare that air drilling cannot be considered a current practice in the Delaware Basin for purposes of performance assessment modeling.

The statement in Comment 8.B.23 that "Neither DOE nor EPA could find documentation in the public record directly stating that this well [Lincoln Federal #1] was partially drilled with air." is incorrect. EPA's findings regarding this well are stated on p. 6 of the Air Drilling Report [Docket: A-93-02, IV-A-01] as follows: "EPA is aware of seven wells in the New Mexico portion of the Delaware Basin that may have, at some point, been drilled using air or were "dry drilled." (Dry drilling is drilling without adding any drilling fluid, intentionally.) Of these wells, three may have been "dry drilled" or air drilled into or through the salt section. These three wells are the Lincoln Federal No. 1 (T21S, R32E, Section 26), South Culebra Bluff Unit No. 4 (T23S, R28E, Section 23) and Amoco Federal No.1 (T23S, R28 E, Section 11)." "Available file information indicates that drilling of the Lincoln Federal No. 1 well was initiated using a mud system, but mud circulation was lost in the upper Salado Formation, approximately 1,290 feet below ground surface. This hole was then dry drilled into the salt section to approximately 1,790 feet, after which the hole was apparently drilled using air to the top of the Delaware Mountain Group. (This is supported by statements in wells files that indicate air was circulated while casing was set to the top of the Delaware Mountain Group.) In this instance, air was not the intended drilling media, and was apparently used in an attempt to continue drilling when other methods (mud, dry drilling) failed. The Lincoln Federal No. 1 was drilled in 1991." To further address the possibility raised in Comment 1252 that the use of air drilling may not have been indicated on all drilling records, EPA also obtained information on the use of air drilling from knowledgeable industry contacts. As discussed beginning on p. 8 of EPA's Air Drilling Report [Docket: A-93-02, IV-A-01], these individuals independently confirmed that air drilling is rarely practiced in the Delaware Basin, that it is virtually nonexistent in the vicinity of WIPP, and that the well records were sufficiently accurate for the purposes of EPA's review.

To obtain additional information on drilling practices, drilling contractors, tool rental companies, air drilling consultants, and state officials were among the 25 individuals contacted by EPA regarding the use of air drilling near the WIPP site or within the Delaware Basin. These contacts indicated almost exclusively that, if air drilling was used in the Delaware Basin, it was performed after the hole was drilled and the completion casing was set using a mud circulation system. At that time, air or foam may have been used to stimulate the well's production, disposal, or recompletion zone, but not for actual drilling of the borehole through the salt section. These individuals indicated that technical and economic difficulties were probably the reason for the infrequent use of air drilling in the Delaware Basin. In rare instances, air drilling was used to drill production zones after the upper part of the well was drilled with mud. This use of air was reported in a well near Loving, New Mexico. Individuals pointed out that a few wells were drilled with air north and southwest of Carlsbad until excess water was encountered; however, these wells were not in the Delaware Basin. Geologic and hydrogeologic conditions can change abruptly within and beyond the edge of the basin, and EPA explicitly excluded these areas from consideration in WIPP performance assessment. The independent lines of evidence provided by these industry contacts regarding the infrequent use of air drilling, and especially air drilling through the salt section, indicates to the Agency that air drilling is not consistent with current practice in the Delaware Basin. This was confirmed by a separate analysis of 3,349 wells in the Delaware Basin performed by DOE. [Docket: A-93-02, IV-G-8]

Comments 8.B.15, 8.B.16, 8.B.17, 8.B.21, and 8.B.25 included speculation about an increased use of air drilling in the future, particularly in underbalanced drilling operations. While 40 CFR 194.32(a) requires that drilling be evaluated in the WIPP PA, 40 CFR 194.33(c)(1) identifies that future drilling practices are assumed to be consistent with drilling practices at the time the certification application was prepared. DOE is not required to speculate on the frequency of drilling practices beyond the time when the CCA was prepared. EPA believes that the distant future is essentially unknowable, that current practices, activities, and technologies provide a basis for projecting future practices, activities, and technologies, and that the use of current conditions as a surrogate for future conditions avoids unnecessary and potentially unbounded speculation about future conditions.

The Duda, Medley, and Deskins study [Strong Growth Projected for Underbalanced Drilling, Oil & Gas Journal, September 23, 1996] mentioned in Comments 8.B.3, 8.B.17 and 8.B.25 presents projections for underbalanced drilling throughout the United States. It is not specific to the Delaware Basin and conditions in the vicinity of WIPP, and EPA does not believe that the generalized and speculative projections it contains can be justified as a basis for WIPP performance assessment.

EPA assumes that the reference to underbalanced drilling in Comment 8.B.19, refers to air drilling. EPA disagrees with this comment in that EPA has presented, here and in Docket: A-93-02, Item V-B-29, its complete and current analysis of air drilling in the Delaware Basin and its potential impacts on the WIPP repository. EPA believes that its assumptions are well supported and that its modeling is adequate. The comment fails to identify the purported deficiencies in EPA's assumptions and modeling.

With regard to Comments 8.B.15 and 8.B.24, EPA found that the possibility of excessive water inflow was only one of the reasons given by industry contacts that air drilling was not used in the vicinity of WIPP (Comment 8.B.14). Other reasons, cited in EPA's Air Drilling Report [Docket: A-93-02, IV-A-01], included unstable ground above the salt section and the potential for hitting brine pockets in the Castile Formation. Again, these are merely reasons that EPA found for the lack of air drilling in the Delaware Basin, as demonstrated in the preceding discussion. The "unnamed" industry contact that cited a practical working limit of 7 gpm for water removal during air drilling was Conrad Lee of Davis Tool in Hobbs, New Mexico. His statement was presented on p. 11 of the Air Drilling Report. Although the commenter presents information suggesting that water inflows at the WIPP waste panels would not be sufficient to preclude air drilling, EPA did not consider that transmissivities lower than 1×10^{-5} m^2/s in parts of the land withdrawal area would provide sufficient reason to conclude that air drilling was currently practical in that area. First, if it is assumed that a driller would have no knowledge of the WIPP repository, it cannot be assumed that the driller would know the detailed transmissivity results of the WIPP siting studies and would therefore know that transmissivities were lower over the waste panels than to the northwest or southeast of the waste panels. Second, even if water inflows were not potentially problematic, unstable ground and the potential for hitting a brine pocket provide two additional reasons why drillers would not be likely to use air drilling at WIPP. Third, the three principal reasons for the lack of air drilling near the WIPP were not identified by EPA but by knowledgeable industry contacts. The virtual lack of air drilling near WIPP reported by the industry contacts was independently confirmed by EPA's records reviews, and the technical reasons for this lack of air drilling reported by the industry contacts were independently confirmed by EPA's investigations of water inflows, unstable ground, and Castile brine pockets. [EPA's Air Drilling Report, Docket: A-93-02, IV-A-01]

With regard to Comment 8.B.16, EPA found that despite the advantages of air drilling in dealing with lost circulation problems, other good reasons were given by industry contacts why air drilling is not used in the vicinity of WIPP. Those reasons, cited in EPA's Air Drilling Report [Docket: A-93-02, IV-A-01], included unstable ground above the salt section and the potential for hitting brine pockets in the Castile Formation. EPA believes that the distant future is essentially unknowable, that current practices, activities, and technologies provide a basis for projecting future practices, activities, and technologies, and that the use of current conditions as a surrogate for future conditions avoids unnecessary and potentially unbounded speculation about future conditions. This issue includes speculation about the technology that a future driller may choose to use to deal with potential loss of circulation when drilling through an area that may be mined for potash in the future.

Comments 8.B.5, 8.B.7, 8.B.9, 8.B.10, 8.B.11, 8.B.13, and 8.B.20 mentioned other issues in addition to air drilling that are addressed in other issues. Please see other responses to comments in this section on conventional (mud) drilling and brine reservoirs, fluid injection and the Hartman Scenario, CO_2 injection, conventional and solution mining, and drilling rates.

Comments 8.B.18 and 8.B.25 questioned the degree of knowledge that drillers have about air drilling and its capabilities, and suggested that this may have influenced the information provided by EPA's industry contacts in the aforementioned survey. EPA's industry contacts represented a wide spectrum of professionals, including state regulatory agency staff, air drilling contractors, and drillers who have used air methods. The Agency considers these individuals to be knowledgeable of drilling practices in the Delaware Basin and fully capable of providing accurate answers to the question of whether they had knowledge of any wells drilled using air or gas within 20 miles of the WIPP site , wells drilled within the Delaware Basin, or wells drilled under conditions similar to those found at WIPP. The consistency of the responses, that air drilling is a rare practice in the Delaware Basin, and the consistency of the reasons given for that rarity, indicates to EPA that these industry contacts had a knowledge of air drilling that was adequate for purposes of the survey. Detailed information on the Agency's industry contacts and their survey responses is given in EPA's Air Drilling Report. [Docket: A-93-02, IV-A-01]

Issue C: Air drilling is not a current practice in the Delaware Basin and appropriately omitted from the performance assessment.

1. The initial capital needed for air drilling far exceeds that of fluid drilling due to the additional expenses of air compressors and equipment, but because of the faster penetration rates offered by air drilling it results in less rig time and therefore lower drilling costs. However, if the driller anticipates in the interim any interruption in the air drilling process, you would have to convert back to fluid drilling, and, in doing so, you would diminish the economic advantages that air

drilling offers to begin with. So you would probably be better off to start with fluid drilling and stay with it. (176)

2. We looked at 1,400 well files, and we did find two holes that were drilled, at least in part, with air. These two holes I presume are the two Jim Amos mentioned in his memo that is attached to the Attorney General's analysis of air drilling. These were drilled in 1979. And in that 16-mile radius of the WIPP, there are 1,401 wells and only two drilled with air. Apparently they weren't very successful, or else the industry would continue that practice.

In conclusion, I would like to say air drilling is not conducted near the WIPP site. Two out of 1,400 certainly does not represent a current or a well-used practice. The drillers use air drilling where it's applicable, but only after they consider certain site-specific characteristics such as dry formations and areas in which they are certain there's no opportunity to encounter water-bearing formations. That is not the case near WIPP. (177)

3. The WIPP neighbors, the mining, oil and gas industry, have participated and cooperated with these efforts to secure certification. They have a clear and mutual interest in the safety and security of the region. They have shared their knowledge, and DOE is aware of drilling practices used in the region. I offer this to provide a perspective to what you might hear on the fluid injection and air drilling in the region. Neither is an issue. (202)

4. An appropriate quantitative assessment of future drilling intrusions is included in the CCA to ensure the safety of the site for future generations. The inclusion of speculative scenarios of the type proposed by the Attorney General's office regarding air drilling are justifiably excluded. Overwhelming evidence, discussed by Ross Kirkes last night, by the way, demonstrates that air drilling is not the current practice in the WIPP vicinity. (211)

5. With respect to air drilling, other commentators have stated that the DOE is determined that current drilling practice in the WIPP vicinity does not include the use of air drilling at appreciable frequencies. Therefore, air drilling can be excluded from the performance assessment. With respect to fluid injection, even with conservative assumptions, fluid injection events will not impact repository performance, so fluid injection can be excluded from the performance assessment. This screening is discussed further by DOE (Docket: A- 93-02, II-A-32, II-I-36) and by EPA (Docket: A- 93-02, V-B-22). (496)

6. [E]ven with the most conservative criteria for “labeling” air drilling operations, only 0.2% of the drill holes in the Delaware Basin have been drilled with air. It should be noted that DOE believes there may have been at most only one borehole drilled with air in the nine townships around the site since the inception of air drilling as a viable practice (although OCD records indicate none). Thus, even if air drilling is included as a current practice, the likelihood of a human intrusion using this technology into the repository over the regulatory period is extremely

low (remember that in any 10,000 year period, the intrusion rate from all forms of drilling results in an average of only 5-6 boreholes intersecting the waste footprint). (654)

7. The well record search has continued and now includes information from the entire New Mexico portion of the Delaware Basin. Within the nine-townships surrounding the WIPP, the records showed no evidence of air drilling. One possible exception to this may be the Lincoln Federal #1. This well is said to have been air drilled due to a loss of circulation at a depth of 1290 feet, but this has not been verified. The records associated with the Lincoln Federal #1 do not contain any evidence of air drilling. Rather, this information is based on verbal communications with the operating and drilling companies involved with the well. Nonetheless, the Lincoln Federal #1 may have been drilled with air, although it was not a systematic use of technology. Air drilling at this well was used from 2984' to 4725' merely as a mitigative attempt to continue drilling to the next casing transition depth. After this casing transition, mud drilling was used for the remainder of the hole. (662)

8. The area of the expanded search contains 3,756 boreholes. Of these, 407 well files were unavailable for viewing (in process), therefore, 3,349 well files constitute the database. Among these wells, 11 instances of air drilling were found in which any portion of the boreholes was drilled with air. Only 7 of these were drilled through the Salado formation at the depth of the repository. This results in a frequency of 7/3349' or 0.0021. This value is conservative in that it includes the Lincoln Federal #1, and four other wells which were proposed to be drilled with air, but no subsequent verification of actual drilling exists in the records. (663)

9. With respect to air drilling, other commentators have stated that the DOE is determined that current drilling practice in the WIPP vicinity does not include the use of air drilling at appreciable frequencies. Therefore, air drilling can be excluded from the performance assessment. With respect to fluid injection, even with conservative assumptions, fluid injection events will not impact repository performance, so fluid injection can be excluded from the performance assessment. (665)

10. As a once owner of an air drilling service in Lea County, New Mexico, I have found that it is not practical to air drill in this area because, in the intermediate hole, primarily the salt section, air has too high of a jet velocity. It erodes the salt and makes for a very costly cement job. If any type of flows are encountered, which is very probable in the base of the salt, the disposal of the waste water also expensive. Basically, what I am saying is that the end does not justify the means. Normally, this area is drilled with conveniently [sic] means. I feel that the way these wells are drilled now will not change in the future. (670)

11. The Attorney General's letter states that air drilling is "an established technology used in the Delaware Basin and is entirely feasible at WIPP." A survey of active drillers in the 314 square miles surrounding WIPP found that air drilling is not the current practice in this region. Review of several hundred well files within these sections showed no evidence that air drilling had been used

for any of these well sites. Drilling operators interviewed by DOE contractors stated unequivocally that this technology is not current practice in the vicinity of WIPP. Cited reasons included concerns regarding economics and operator safety. (723)

12. I conducted a survey of active drilling companies who have experience in the New Mexico portion of the Delaware Basin within the last 10 years. . .Of the fifteen companies responding, thirteen stated that they possessed the technology to drill with air. However, all fifteen stated they would not consider using drilling near the WIPP site. Reasons given include the following: 1. Shallow water in the Rustler formation would likely require drilling with fluid. 2. The threat of fluid in the Castile formation would also require drilling with fluid. 3. Deeper horizons may possess hydrogen sulfide (H_2S) gas. The hazards associated with H_2S can only be mitigated while drilling with fluid. (729)

13. [P]enetration rates near the WIPP are quite favorable using conventional drilling, thereby reducing the economic advantage of air drilling, the aforementioned risks notwithstanding. (730)

14. [A] records search was conducted to find evidence of past air drilling in the area. Well files at the New Mexico Oil Conservation Division (NMOCD) were searched for all wells drilled within the nine-township area surrounding the WIPP site (324 miles). This area contains 767 wells. No evidence of air drilling was found! . . .The nearest use of air drilling is approximately 16 miles from the WIPP site, near the town of Loving, where the two wells were drilled in 1979. These appear to be the wells mentioned by Mr. Jim Amos in his memo attached to the New Mexico Attorney General's analysis of air drilling. It is also important to state that this 16-mile radius contains over 1400 wells, and only 2 have been drilled with air. (731)

15. Air drilling has been excluded from use, by regulation, since 1982 in the portion of the Delaware Basin where the WIPP is located. In research by Westinghouse personnel, drilling companies operating in the 300 square miles surrounding the WIPP stated unequivocally that this technology is not a current practice. They further stated that use of this method in the region is impractical because of economic and operator safety concerns. Westinghouse personnel found only two wells out of 1,401 located within a 16-mile radius of the WIPP in which air drilling had been used. In both cases, the method was used only for drilling portions of the wells. (832)

16. The oil industry's definition of "feasibility" is based on economics, and not on technical ability. That is, from a purely technical perspective, one could drill certain intervals near WIPP with air, but there are other intervening intervals that must be drilled with fluid. Switching back and forth from fluid drilling to air drilling reduces the economic benefits to the point that the lowest cost method would be to simply drill with fluid, and forego the costs of air compressors and other hardware and procedures necessary for drilling with air... No one drilling under today's technology will make the decision to drill in the WIPP area with air drilling. It is uneconomic and absolutely reduces the chance of even successfully drilling a well. It is not feasible for an oil and gas driller to use air drilling technology in this area because it is not economic. (906)

Response Comments 8.C.1 through 8.C.16:

EPA has reached conclusions similar to those expressed in Comments 8.C.2, 8.C.3, 8.C.4, 8.C.5, 8.C.6, 8.C.7, 8.C.8, 8.C.9, 8.C.11, 8.C.12, 8.C.14, and 8.C.15 that air drilling is appropriately omitted from the WIPP performance assessment because it is not a current practice in the Delaware Basin.

EPA is also in agreement with the statements in Comments 8.C.2, 8.C.10, 8.C.11, 8.C.12, 8.C.13, 8.C.15, and 8.C.16 that technical, economic, and safety considerations determine the choice of drilling method in the Delaware Basin and in the vicinity of WIPP, and that adverse conditions in the vicinity of WIPP adequately explain the rarity of air drilling in that area. Although air drilling can have advantages over mud drilling under the right conditions, the circumstances wherein air drilling technology is applicable in the WIPP are limited. Air drilling techniques are primarily used in drilling production wells where the geology is well known, the rock is stable, water inflows are not significant, and the formations being drilled are not highly pressurized.

In addition to air drilling, Comments 8.C.3, 8.C.5, and 8.C.9 also mentioned fluid injection issues which are addressed by EPA in this section and in Section 5.

Issue D: EPA did not consider a DOE report on air drilling.

1. Did EPA evaluate the December 5, 1995 DOE study that suggested air drilling would be the preferred method of drilling in potash zones after evacuation? (8)

Response to Comment 8.D.1:

As a result of public comments, EPA has examined the DOE report mentioned by the commenter. The study referenced in this comment was funded by DOE to assess the viability of air drilling. The report indicates that air drilling can be a viable technology for drilling deep boreholes. EPA also conducted its own study of air drilling practices and impacts (see Issue 8.B discussion). EPA agrees with the DOE study that air drilling can be viable, as discussed in EPA's Air Drilling Report [Docket: A-93-02, V-B-29], but viability depends on both technical and economic conditions. Industry contacts do not indicate that air drilling is by any means a common practice in the vicinity of WIPP for both technical and economic reasons. In fact, an individual from United Drilling, experienced with potash drilling in the vicinity of WIPP, indicated that air drilling in potash test borings near the WIPP site had to be converted to mud due to a variety of technical problems, including water influx. EPA performed an extensive analysis of air drilling in the Delaware Basin, referenced above, and found little evidence that air drilling is currently common practice, including air drilling for potash exploration. EPA also points out that, in accordance with 40 CFR 194.33(c)(1), DOE must consider current drilling practices. Even if DOE's study results imply air drilling could take place, it is currently not sufficiently common in the Delaware Basin to be considered current practice. The Agency has therefore concluded that under the terms of its requirements in Sections 194.32(c) and 194.33(c) for analyzing drilling events consistent with current practice at the time the CCA was prepared, and for analyzing the effects of activities in the vicinity of the WIPP, air drilling does not need to be included in the WIPP performance assessment.

Issue E: Statements about drilling practices

1. Drilling is not something that is done casually. But at the same time, the process assumes that this same driller has no knowledge of the presence in the repository. That, I think, is a very conservative approach. (391)

2. Statements made by the Attorney General regarding the consequences of air drilling into the WIPP are, at best, misleading. Inherent in these statements are assumptions that a driller would take no action upon penetration of a waste region, and that spallings releases calculated in the technical report are credible. Neither of these assumptions is valid. Air drilling is an advanced technology requiring careful monitoring of the drilling process. Characterizing this as an uncontrolled process represents a serious disservice to operators currently using this technology. (724)

Response to Comments 8.E.1 and 8.E.2:

With regard to Comment 8.E.1, EPA agrees that drilling is not done "casually" and, in the vicinity of WIPP, is subject to a variety of regulations that dictate specific procedures, equipment and construction standards as specified in the DOE WIPP Compliance Certification Application, Appendix DEL [Docket: A-93-02, II-G-01], EPA's Technical Support Document for Section 194.32, Fluid Injection Evaluation [Docket: A-93-02, V-B-22], and EPA's report, Analysis of Air Drilling at WIPP. [Docket: A-93-02, IV-B-29] NMOCD Order R-111-P describes requirements for potash mining and oil and gas operations within the "potash area" in Eddy and Lea Counties, New Mexico, which became effective in April 1988. Because the WIPP site is within the prescribed "potash area," the requirements of the Order apply to drilling in the vicinity of WIPP. It defines the boundaries of the potash area and applies to both private and Bureau of Land Management (BLM) lands in southeastern New Mexico. Subpart D of the Order requires that a surface casing string must be cemented into the basal Rustler Formation before drilling into the underlying Salado Formation and that a salt protection casing string must be cemented into the salt section before drilling into the underlying oil or gas production zone. Additionally, Subpart E of the Order requires that drilling in the "potash area" must be accomplished using salt saturated water as the drilling fluid, using additives such as mud, if needed. These requirements protect the salt section from dissolution by drilling fluids, by water inflows from overlying formations (particularly from the Culebra Dolomite), and during oil or gas production. EPA has thoroughly examined drilling practices, and agrees with the commenter that drilling is not a haphazard affair. The assumption that drilling will occur is "the most severe human intrusion scenario." [40

CFR 194.33(b)(1)] By requiring DOE to consider human intrusion, EPA has required a very conservative analysis of the WIPP's containment capabilities.

With regard to Comment 8.E.2, EPA agrees that a driller using air drilling technology likely would take rapid action to seal off a well that had encountered highly pressurized gas or brine because of the danger presented by highly pressurized formation fluids. When drilling in the vicinity of the WIPP site , the use of air technology would be unlikely and if used a driller likely would be particularly cautious when drilling in the salt section because of the known presence of high pressure brine reservoirs in the Castile Formation. EPA did not specifically address the driller's reaction in its analysis of the air drilling scenario because the spallings release, if any, would occur within seconds, and because the time required for the driller to shut in the well would be difficult to quantify. The volume of spallings releases during an air drilling scenario was determined by the Agency's independent calculations to be within the range of spallings release volumes used by DOE in the CCA, and the assumption of an air drilling scenario would therefore have no consequence to the results of the WIPP performance assessment. [EPA Response to Comments, Section 8, Issue A; also see EPA's independent analysis of air drilling at WIPP in Docket: A-92-02, V-B-29] EPA agrees with the commenter that New Mexico Attorney General (NMAG) did not consider that the driller would act to seal the borehole long before any large volume of waste could be brought to the surface, see Comment 8.B.8. However, EPA found that the spallings releases calculated in the NMAG's report are not credible because the model was used outside its range of applicability.

Issue F: Release of air during air drilling was calculated instead of brine.

1. Air drilling may be an important issue in the release of contaminated brine to the surface and that EPA should evaluate the issue. (41)

2. EEG mistakenly calculated the "air" that would be released in an air drilling event (not the waste itself). (656)

Response to Comments 8.F.1 and 8.F.2:

With regard to Comment 8.F.1, EPA has determined that air drilling is currently not a common practice in the Delaware Basin and little evidence has been found of any use in the Delaware Basin (see Issue A discussion).

Even though air drilling is necessarily excluded from performance assessment on regulatory grounds because it cannot be considered a current practice, EPA believes that direct brine releases under air drilling would not be substantially different from brine releases under mud drilling. Because of the differences in drilling fluid densities and drilling techniques, the bottomhole pressure in brine-based mud drilling would be about 8 MPa, while the pressure in air drilling would be about 2 MPa. The bottomhole pressure for a borehole filled with repository brine would also be about 8 MPa because of the similar densities of repository brine and brine-based drilling mud (see SNL memorandum Response to Air Drilling Letter from R.H. Neill, EEG, to F. Marcinowski, EPA, 12/31/97 by P. Vaughn and D. O'Brien dated January 15, 1998. [Docket: A-93-02, IV-G-7] The surge of brine into the borehole as the drilling fluid is ejected would be more rapid under air drilling because of the lower initial bottomhole pressure. However, once the drilling fluid is ejected and the brine begins to flow from the hole at the ground surface, the borehole would be full of brine, the bottomhole pressure would be increased to about 8 MPa due to the weight of the column of brine, the resistance to flow up the borehole would be the same as in mud-based drilling, and the release to the ground surface would be essentially the same under either drilling scenario. Therefore, even if air drilling were considered in performance assessment, the direct brine releases would be expected to be essentially the same as the values calculated by DOE in the CCA. EPA therefore believes that the direct brine releases calculated in the CCA adequately represent either a mud drilling or an air drilling scenario.

EPA concurs with Comment 8.F.2, which refers to an issue raised by the EEG regarding direct brine releases during an air drilling scenario. The issue involved EEG's independent use of DOE's BRAGLFO-DBR model to calculate direct brine releases for a wellbore column filled with air rather than a brine-based drilling fluid (commonly called "mud" drilling), and EEG's erroneous prediction of significantly greater direct brine releases than were calculated in the CCA. The error came to light during a meeting called by EPA to discuss the applicability of the GASOUT code for calculating spallings releases during air drilling (see Response to Comments, Section 8, Issue B), where representatives of EEG were present. Although the issues discussed at that meeting related to the GASOUT code have been summarized by the Agency [Docket: A-93-02, IV-E-9], issues related to EEG's use of BRAGFLO-DBR were peripheral to the focus of the meeting and were not included in that documentation. The problem was acknowledged by EEG to have occurred because the EEG was not aware of the details of how properties were assigned to the various materials in the model. Because the model was developed assuming brine as the drilling fluid, the properties of the brine in the repository were automatically made the same as the properties of the drilling fluid. Thus, in changing the properties of the drilling fluid from those of brine to those of air, the EEG inadvertently also changed the properties of the brine in the repository to those of air. The EEG's conclusion that the resulting release calculation applied to repository brine was therefore erroneous.

Issue G: Air drilling and spallings release

1. Spallings releases with air drilling will occur at much lower repository pressures than with mud drilling and will occur in nearly every intrusion. (129)

2. At higher repository pressures spallings releases will be orders of magnitude larger with air drilling than with mud drilling, because of the larger pressure differential between the borehole and the repository. (130)

Response to Comments 8.G.1 and 8.G.2:

With regard to Comment 8.G.1, EPA agrees that spallings releases with air drilling will occur at lower repository pressures than with mud drilling. Because of the weight of the column of mud, a minimum repository gas pressure of about 8 MPa will be required before spallings releases can occur with mud drilling. The weight of a column of air is negligible, but a high bottom hole air pressure is needed to remove cuttings during air drilling and a minimum repository gas pressure of about 2 MPa will be needed before spallings releases can occur. Because the threshold pressure for a spallings release is lower for air drilling, the potential is also present for spallings releases to occur more often. The cumulative spallings releases used by DOE in the CCA ranged from 0.5 m^3 to 4 m^3, assuming a mud drilling scenario. When the low frequency of air drilling is considered, even if the cumulative spallings releases associated with air drilling were as large as 64 m^3, as suggested by public comments, the expected volume of material released by a combination of mud and air drilling would still be low (3.3 m^3) and within the original range of values used by DOE in the CCA. EPA therefore concludes that even if air drilling scenarios were included in performance assessment, they would not result in a significant change in calculated releases.

With regard to Comment 8.G.2, EPA does not believe that spallings releases under air drilling will be orders of magnitude larger than under mud drilling. The author is believed to be referring to the report "Air Drilling at WIPP" prepared for the NMAG by John Bredehoeft [Docket: A-93-02, IV-D-1], in which failed waste volumes of hundreds and even thousands of cubic meters are reported. By comparison, the spallings release volumes used by DOE in the CCA ranged from 0.5 m^3 to 4 m^3. The large volume predictions were made by Dr. Bredehoeft using the code GASOUT. That code was developed by DOE to predict failed waste volumes for mud-filled rather than air-filled boreholes. Dr. Bredehoeft acknowledges the potential problems with using the code to model air drilling applications by stating on p. 6 of his report: "I recognize that by replacing the mud column in the borehole with a column of gas I depart significantly from what the code was designed to do... Needless to say, I recognize that GASOUT in its present form may not be fully applicable to the problem being addressed." Dr. Bredehoeft's concern about code applicability to air drilling was borne out in a January 21, 1998 EPA meeting at SNL with representatives of NMAG and DOE to discuss the GASOUT code. [Docket: A-93-02, IV-E-9] In that meeting the author of the code, John Schatz, stated that the code became unstable and produced erroneous results under conditions that caused a steep pressure gradient in the waste. Dr. Schatz stated that such conditions could include assigning a very low waste permeability or inducing an initial pressure gradient between the borehole and the waste panel that was larger than the gradient induced by mud drilling. The assumption of an air filled borehole would induce pressure gradients that were too steep and the model calculations would be in error. Based on the results of that meeting, EPA concludes that the spallings volumes reported by NMAG to occur during air drilling are erroneous.

To better address the issue of spallings volumes under an air drilling scenario, EPA performed its own calculations using a spreadsheet version of the GASOUT equations that provided acceptably accurate estimates and did not have the stability problems of the numerical code. The results of those calculations are documented in the report, EPA's Analysis of Air Drilling at WIPP. [Docket: A-93-02, V-B-29] For the relatively high repository gas pressure of 14.5 MPa and an average waste tensile strength of 10 psi, EPA calculated failed waste volumes of 0.19 m^3 for mud drilling and 1.4 m^3 for air drilling. [EPA's Analysis of Air Drilling at WIPP, 1998, Appendix A, Docket: A-93-02, V-B-29] In this example the failed waste volume increased by a factor of about 7 when air drilling was assumed. This factor is much less than the increases predicted in the aforementioned NMAG report, and is believed by the Agency to be reasonable. As described in the response to Comment 8.G.1, air drilling is rarely used in the vicinity of WIPP and the increases in failed waste volumes under air drilling scenarios do not significantly affect the cumulative spallings volumes used by DOE in the CCA.

References

Hansen, F.D., M.K. Knowles, T.W. Thompson, M. Gross, J.D. McLennan, and J.F. Schatz, 1997. Spalling Release Position Paper: Description and Evaluation of a Mechanistically Based Conceptual Model for Spall. SAND97-1369, Sandia National Laboratories, Albuquerque, New Mexico. Docket: A-93-02, II-G-23.

Issue H: Waste interactions in the repository can cause explosions.

1. Salt is a hydrophilic medium. That means when any thermal activity occurs in the salt, moisture is drawn to whatever is creating that thermal activity, unlike, say, stone where water is repelled if heat is generated. Okay. That means that all the thermal heat that you get from the remote-handled waste and the contact-handled waste which is hot, in addition to the mixture of chemical mixed hazardous and chemical waste, and decomposing organic materials, and gas formation, draws more and more moisture to the site, so what we're going to end up with is a toxic, nasty cocktail that is highly pressurized under there, and no way we can get down and clean it up. (465)

2. I insist that EPA and DOE prove by sound scientific fact how the various buried materials will interact with each other and the environment. DOE knows that the waste is a chemical mixture, often of unknowns. The different types of waste, low and high levels of all descriptions, each with a different chemical makeup, all from different categories, may react differently to each other causing explosions of all kinds. (524)

3. From an absolute layperson's point of view the whole question of containing highly volatile materials in a sealed repository seems totally absurd. Basic knowledge of radioactivity tells me one of the primary qualities of radioactivity is that it is hot, hot. When is something is hot it expands. And when it is in a sealed container it will explode the container. Basic understanding

of the nature of mixing components in an unlike slurry, unlike -- of an unlike nature, mixing them together in a slurry is that it will give of gases, and gases building up in a sealed container will explode. (531)

4. It is known that the drums that would carry the nuclear waste would erode in 3-5 up to 15 years. The radioactive waste would then begin to travel throughout the caverns at the WIPP site. (1103)

<u>Response to Comments 8.H.1 through 8.H.4:</u>

In addressing the requirements of Section 194.32 (e)(1) EPA expected the compliance application to identify and assess all natural and human-initiated processes and events, as well as sequences and combinations of features, events and process (FEPs), that may effect the disposal system, including waste related processes. DOE addressed the FEP compilation and screening process in Appendix SCR and Stenhouse et al. (1993). DOE identified waste/repository FEPs as one of the categories to be evaluated in its FEP compilation process. Of the 108 Waste and Repository Induced FEPs considered [Appendix SCR Sections 2.1 through 2.8], DOE concluded that 50 should be retained for the PA. Some of the FEPS that may have an effect on the chemical interactions of the repository are: disposal geometry, waste inventory, seal physical properties, radionuclide decay and ingrowth, salt creep, backfill chemical composition, changes in the stress field (creep), pressurization (gas), brine inflow, wicking, actinide sorption and solubility, effect of metal corrosion, and colloid transport. EPA's analysis of the FEPs development and screening can be found in CARD 32.

Comment 8.H.1 misstates the meaning of "hydrophilic," which means that the salt has the property of attracting and holding moisture within its crystal structure. These so called waters of hydration are held within the crystalline salt and do not easily migrate. A more important aspect of the comment is the potential for thermally enhanced fluid migration.

Comment 8.H.1 refers to the effects of heat generation and the possibility that heat may enhance the migration of water within the repository and the surrounding salt formations. The phenomenon is called the Soret effect and is addressed in CCA Vol. XVI, Appendix SCR, Section 2.7.3. [Docket: A-93-02, II-G-1] The Soret effect is a thermally enhanced diffusion process and occurs only in the presence of a thermal gradient, not just an elevated temperature. In other words, the temperature must vary with location in order for Soret diffusion to occur.

Appendix SCR, Section 2.5.7 examines several heat-generating processes that could occur in the repository. Section 2.7.3 concludes that the thermal gradients from these processes could not be large enough for Soret diffusion to be significant. The heat sources considered include radioactive decay, nuclear criticality, metal corrosion (iron and aluminum), microbial degradation of cellulose, concrete seal hydration, and magnesium oxide backfill hydration. The rate of heat generation would decrease with time as radioactive decay reduces the inventory. EPA agrees with DOE's conclusion because, according to the CCA [Chapter 4.3.1, p. 34], the waste will be placed randomly in the repository so that slightly elevated temperatures would be expected to occur [Appendix SCR 2.2] throughout the repository, thus minimizing temperature gradients. In addition, a conservative analysis of the heat generated by the waste in the WIPP showed that the maximum temperature increase from radioactive decay would be 1.6 degrees Celsius and would occur 80 years after emplacement of the waste. [Appendix SCR, Section 2.2.2, Docket: A-93-02, II-G-1]

Comment 8.H.2 also notes that there would be no way to clean up the materials in the repository. WIPP is designed as a permanent disposal facility, so that after closure the waste is to remain entombed. DOE's performance calculations indicate that even with the processes expected to occur in the waste after closure, the repository will meet EPA's radioactive waste disposal standards. [CCA Chapter 6.5] DOE has no regulatory mandate to clean up the disposal rooms after final emplacement of the waste. However, EPA required DOE to demonstrate removal of the waste is feasible for a reasonable period of time after disposal [Section 194.46], and DOE included this information in the CCA 7.6 Waste Removal. See CARD 46 for EPA's analysis of DOE's compliance with the removal of waste requirement.

(Comments 8.H.2 and 8.H.3) There are two concerns related to explosions. In the pre-closure operational phase explosions could create hazards to the workers at WIPP. DOE plans to monitor gas buildup and take steps (e.g., installing brattice cloths at room openings) to minimize impacts of explosions during the operational phase, however, the pre-closure phase is not considered in long-term performance assessment. The potential for explosions in the repository after closure was considered in the CCA and is discussed in CCA Vol. XVI, Appendix SCR, Section 2.3.6. [Docket: A-93-02, II-G-1] Sources of heat in the repository are radioactive decay, concrete seal hydration, metal corrosion (iron and aluminum), microbial degradation of cellulose, and hydration of the magnesium oxide backfill. As explained in Appendix SCR, Section 2.5.7, these processes can not produce high enough temperatures for explosions to occur. In Appendix SCR Section 2.3.6 DOE states that: "The potential effects of gas explosions are accounted for in performance assessment calculations. Nuclear explosions have been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years." DOE discusses [*ibid.*] the possibility and consequences of gas explosions after closure of the WIPP facility and concludes that the consequences would be no worse than a roof fall in the repository rooms, and that the most explosive gas mixture potentially generated will be a mixture of hydrogen, methane, and oxygen which will convert to carbon dioxide and water on ignition. As such, it is included in the post-closure performance assessment. The repository after closure will be anoxic (without oxygen) and therefore reduce the potential of igniting an explosion of any significance. Explosion of any kind, prior to this anoxic condition has been considered in the panel design. [SCR-49] Various researchers, such as, Sanchez and Trellue [1996], Arguello and Torres [1988], Thorne and Rudeen [1981], and Loken and Chen [1995] studied the thermally induced stress and expansion in the material properties in the repository. Based on their findings [SCR-52] DOE decided to exclude the thermal effects from PA calculation. EPA determined that DOE's identification and screening of FEPs meets the requirements of Section 194.32. See CARD 32 for EPA's analysis of the scenario screening process and results.

(Comment 8.H.4) The commenter is correct in identifying that the drums holding the waste have a short-life expectancy. In the CCA analysis, no reliance is placed on the nuclear waste containers after closure of the facility. The waste drums are expected to corrode and generate gas and affect the repository environment (e.g., interaction with brine will create reducing conditions). These have been evaluated in the screening process and included in the performance assessment. [Appendix SCR 2.5.1.2; CCA Chapter 6.4.3.3] If the "caverns" referred to by the commenter are the underground WIPP disposal rooms, the potential migration of radioactivity throughout the WIPP underground facility has been included in the CCA analysis discussed throughout Chapter 6 of the CCA. [6.4.3.2 Repository Fluid Flow] Many migration processes were evaluated in the analysis, including liquid transport in brine, gas transport, and transport by microbes. [Appendix SCR, Table SCR.2] Transport was assessed through the repository rooms, the interbeds beneath the waste, the disturbed rock zone around the repository excavations, the panel seals, the shaft seals, and the Culebra Formation above the repository. Information on the potential transport processes is summarized in Appendix SCR, Table SCR.2. This table also gives section references where more detailed information can be found on each transport process. See CARD 32 for EPA's analysis of the scenario screening process and results.

If the "caverns" referred to by the comment are karst features, EPA has examined the hydrogeologic data and has found no indication of karst caverns at the WIPP site. For more information on karst, see Section 3, Karst at WIPP.

Issue I: Effects of existing boreholes on performance assessment

1. The miners have already bored thousands of holes while searching for natural resources such as oil, gas and potash -- these drilled holes would eventually cause large releases of stored radioactive waste. (1104)

Response to Comment 8.I.1:

EPA agrees that a significant number of boreholes have been drilled in the vicinity of WIPP while searching for and exploiting natural resources such as oil, gas and potash. EPA found that DOE appropriately quantified the presence of such boreholes and addressed the potential for such boreholes to cause large releases of stored radioactive wastes through evaluation of human intrusion in the CCA and FEP screening with respect to activities related to boreholes along the boundary of the WIPP Land Withdrawal Act (LWA) boundary. As discussed in the following response, such boreholes do not have the potential to cause large releases of stored radioactive wastes.

Section 194.32 requires that the PA include the effects of excavation mining, drilling, fluid injection and future development of leases. The PA also must include the effects of current activities such as secondary oil recovery methods (water flooding), disposal of natural brine, solution mining to extract brine, etc., in the vicinity of the repository. Section 194.32 requires identification of all processes, events, or sequences, and combinations of processes and events that may occur during the regulatory time frame that may affect the repository. Also, DOE must document why any events or processes, or sequences so identified are not included in the PA.

DOE included an assessment of the potential effects of existing boreholes as part of its FEP screening analysis. DOE's results of this assessment are presented in Appendix SCR, Section 3.3.1.4. DOE concluded that available information indicated natural borehole fluid flow through abandoned boreholes would be of very little consequence during operational phase activities, based, for example, upon known hydrologic head conditions. EPA concluded that DOE's screening arguments for low consequence was reasonable; see EPA Technical Support Document for Section 194.32: Scope of Performance Assessments [Docket: A-93-02, V-B-21] for a detailed discussion. DOE identified this flow to be of importance to the PA if such a borehole penetrated a Castile brine reservoir under the repository. In such a scenario the flow would only have long-term (i.e. post operational period) importance. DOE did not consider abandoned borehole flow induced by waste-related conditions in the PA because Section 194.25 instructs DOE to assume that characteristics of the future remain what they are at the time the compliance application was prepared. Because no waste has been emplaced in the repository yet, waste-related conditions could not exist at the time the CCA was prepared. In addition, DOE screened out the occurrence of flow through undetected boreholes based on low probability, claiming that the occurrence of such boreholes in the controlled area is highly unlikely given the intense scrutiny given the site over the past 25 and more years. The CCA includes Appendix DEL, which describes the oil and gas exploration and exploitation activities in the Delaware Basin and immediate WIPP area. This document presents the location of oil and gas wells in the Basin and WIPP area and includes maps presenting the location of existing leases. Based on the review of the data provided on existing boreholes, EPA concluded that DOE's screening arguments for low consequences for the impacts of existing boreholes is reasonable, see EPA Technical Support Document for Section 194.32, Scope of Performance Assessments. [Docket: A-93-02, Item V-B-21]

Issue J: Sufficient conservatism exists in the analysis of WIPP.

1. You have heard comments to the DOE performance assessment is conservative. Many conservative assumptions were used without uncertainties. The estimates and releases in generating the CCDF are therefore larger than should be expected under realistic assumptions, because of these conservative choices. (495)

2. Please take into account the current conservatism when being asked to examine new scenarios, because there is a great deal of conservatism in this regulation. (527)

3. Specific examples of worst-case assumption overkill include requirements for chemical backfill, massive panel closure systems, and even more massive permanent passive markers. Their rationale is at best dubious and, at worst, amounts to appeasement before blackmail. (549)

Response to Comments 8.J.1 through 8.J.3:

These comments on the issue of conservatism express concerns that an overlying conservative approach in the regulatory requirements, analysis, or design of WIPP could be problematic. EPA believes that a project such as WIPP, which must adequately meet its performance requirements for thousands of years, must be conservatively analyzed and designed because of the large uncertainties involved. In regulatory requirements, conservatism means providing adequate protection to human health and the environment. In performance assessment, conservatism means over estimating repository releases. In design, conservatism means providing a robust isolation system that can successfully perform under unanticipated conditions. However, in each case, a conscious effort has been made by both EPA in developing the regulations and by DOE in meeting the regulations to avoid low probability, "worst case" scenarios that in practice are likely to be unnecessary and costly to address. In Section 194.32(d) of the Rule, EPA did not require DOE to consider processes and events that have less than one chance in 10,000 of occurring over the 10,000-year regulatory time frame. In implementing its scenario screening process, DOE appropriately eliminated many features, events, and processes from further consideration in performance assessment based on low probability. [CCA Vol. XVI, Appendix SCR]

Many of the modeling parameters needed for performance assessment are not known with accuracy and to compensate for this, assumptions had to be made about parameter values. For parameters that were found to be both uncertain and significant to performance assessment results (that is, the results of performance assessment were found to be sensitive to changes in the parameter values; [EPA's Sensitivity Analysis Report, Docket: A-93-02, V-B-13], those parameters were treated as sampled variables in performance assessment. In treating a parameter as a sampled variable, conservatism was reflected in assuring that the sampled range was large enough to include all reasonable values of the parameter. For parameters that were uncertain but less significant to performance assessment, estimated constant values were used and an attempt was made to select realistic values if the influence of the parameter on repository releases was not well understood (the interactions among future events and processes in the repository were so complex that many parameters had the potential under different conditions to either increase or decrease releases). If the influence of a parameter on releases was understood and the parameter was uncertain, parameter values were assigned that would tend to increase releases.

In its review of DOE's CCA, EPA found that DOE's representation of a number of parameters was not consistent with available information. These parameters included, as examples, the probability of encountering a brine reservoir in the Castile Formation, the assumptions regarding the effectiveness of passive institutional controls, and the permeabilities of intact and degraded borehole plugs. EPA directed DOE in letters dated March 19, 1997 [Docket: A-93-02, II-I-01, enclosure 3] and April 25, 1997 [Docket: A-93-02, II-I-27, Enclosure 2] to conduct new performance assessment modeling that included modified values of these and other parameters. These changes were included in the mandated Performance Assessment Verification Test (PAVT). [DOE 1997b and 1997c] As a result of the PAVT, EPA found that the original parameter values used by DOE were, in fact, acceptable because the PAVT results were well below the regulatory limits. For more discussion on this topic, also see CARD 14, Section 14.B.5, EPA's Technical Support Document for Section 194.14: Content of Compliance Certification Application (Docket: A-93-02, V-B-3), and the Technical Support Document for Section 194.23: Parameter Justification Report. (Docket: A-93-02, V-B-14) Specific examples of conservative assumptions that have been incorporated into the analyses that are presented in EPA Docket: A-93-02, V-B-29, air drilling report and the responses to comments, Section 8, carbon dioxide injection.

While EPA believes that no parameter values were incorporated into the performance assessment that represented unreasonably extreme, "worst case" assumptions, EPA does agree with the author of Comment 495 that the release estimates are likely to have been over estimated due to conservatism. An example of conservatism in the PA would be the fact that the PA does not consider features, events and processes that would enhance the ability of the WIPP to contain waste. [CCA 6.2.2] EPA has also reviewed release scenarios suggested in public comments and has rejected those that were found to have a low probability of occurrence or were based on assumptions that were not reasonable in the context of the geologic and hydrologic conditions at WIPP. Examples are provided in EPA's response to several comments received regarding the use of air drilling at WIPP and the volumes of spallings releases that would result (see responses to comments on Section 8, Issue G).

EPA does not agree with the author of Comment 8.J.3 that the engineered barriers, seal systems, and other design elements of WIPP are overkill. Chemical backfill is important for modifying WIPP system chemistry to reduce actinide mobility, and panel closures are important to isolate filled waste panels and prevent dispersion of hazardous constituents and radioactive particles during the WIPP operational period. The panel closures are also included in performance assessment modeling.

Issue K: Drilling rates used by DOE are not consistent with those in the WIPP area.

1. DOE's analysis of drilling practices involved an unrealistic assessment of probabilities and ignored tremendous amounts of historical data. (76)

2. Clearly, the repository is located in a mineral-rich resource-rich area. The intensity for drilling for oil and gas around the 4 mile by 4 mile WIPP site is very high, and almost certainly the only reason that there's no drilling within the site is it has been withdrawn for exclusive use by WIPP. (189)

3. EPA did not require drilling rates that are consistent with the extensive drilling throughout the area. (231)

4. The future drilling rate used in the CCA, as specified by the EPA, estimated that the number of boreholes for the next 10,000 years was an average from the last 100 years. . . [T]he present study looks at several different drilling rates, and concludes that the relationship is approximately linear

between releases and drilling rates. It shows that a factor of approximately 23 is needed to reach the EPA release limit at a probability of 10^{-1} from values used in the CCA. The overall mean for the highest release at 4.68 x 10^{-1} boreholes/km^2/yr exceeds the EPA limit of 10 EPA units at a probability of 10^{-3}. Yet this does not seem to be likely, as the number of boreholes would have to exceed one million, or 4,680 boreholes per km^2. (1078)

5. [In its proposed rule EPA did not use:]

> * drilling rates with extensive drilling throughout the site, as occurs in areas immediately surrounding the site; (1141)

6. EPA has accepted DOE's drilling rate of 46.8 boreholes per square kilometer per 10,000 years (at 58822) even though that rate is only about half of the current drilling rate over the past 50 years. . . SRIC believes that the correct drilling rate should be 90 boreholes per square kilometer per 10,000 years. (1162)

7. In 1996, according to EEG-62, Figure 2.2-2, there were 139 oil and gas wells within two miles of the WIPP site boundary. According to maps obtained from Midland Map Company, Midland Texas, there are now 177, and 47 more have been planned and located. . . The current drilling rate, therefore, is 36 per m^2 per 100 years. This is 30 times greater than the estimate of 120 per m^2 per 10,000 years used by DOE in performance assessment (CCA, pp. 6-182, DEL-81). (1174)

<u>Response to Comments 8.K.1 through 8.K.7:</u>

The Compliance criteria require DOE to examine the effects of deep and shallow drilling events that may potentially affect the WIPP during the regulatory time period. 40 CFR 194.33(a). Shallow drilling is defined in Section 194.2 as drilling events that do not reach the WIPP depth of 2,150 feet below the surface. Deep drilling is defined in Section 194.2 as drilling events that reach or exceed the WIPP depth of 2,150 feet. Both types of drilling events include exploratory and developmental wells. DOE concluded that future shallow drilling events were of low consequence to the performance assessment calculations (Ref. CCA,6.0 and Appendix DEL p.81). For further discussion on EPA's evaluation of the screening process and scope of the performance assessment, refer to Section 194.32(e) in CARD 32 -- Scope of Performance Assessments.

Section 194.33(b)(3) requires that the frequency of deep drilling shall be calculated in the following manner: "(1) Identify deep drilling that has occurred for each resource in the Delaware Basin over the past 100 years prior to the time at which a compliance application is prepared. (ii) The total rate of deep drilling shall be the sum of the rates of deep drilling for each resource." CCA Vol. V, Appendix DEL, Section 7.4 [p. DEL-81] presents DOE's calculated drilling rate in the Delaware Basin. The drilling rate was calculated using deep boreholes drilled for hydrocarbons, sulfur, and potash as well as for stratigraphic test holes based on information derived from industry standard data described above (but did not include test holes drilled during the WIPP investigation) (CCA Vol. V, Appendix DEL, Table DEL-4). DOE calculated a rate of 46.765 deep holes per square kilometer (0.39 square mile) over 10,000 years. In this calculation DOE used 10,804 [Appendix DEL Table 7] deep boreholes to determine the rate. The calculated rate is 46.765 deep boreholes per square kilometer or 0.39 per square mile over 10,000 years.

EPA acknowledges that no one resource will last for the entire 10,000 year regulatory time frame and reasoned that while the resources targeted by drilling today may not be the same as those drilled for in the future, the present rate at which boreholes are drilled can provide a reasonable and likely conservative estimate of future drilling rates. EPA has required that evaluations be premised on the hypothesis that drilling will never completely cease. While some resources may become depleted over time, and while the rate of extraction of those resources may decrease, the increased rate of drilling for newly discovered resources has been assumed to compensate for this decline. In effect, present day drilling rates are used by EPA as surrogates for the rates of drilling for unknown resources in the future. Although the current drilling rate may be higher than that used in performance assessment as stated in Comment 8.K.6, the use of a 100 year drilling rate more adequately reflects the actual drilling that will take place over the long term. In addition, an examination of drilling records in Texas and New Mexico has shown that accurate data on drilling activity dates back approximately 100 years. Although the actual future rates of drilling are inherently unknowable, EPA believes that the approach it has required for estimating future drilling rates is reasonable and appropriate for use in performance assessment at WIPP and is consistent with current drilling rates in the Delaware Basin.

Regarding Comment 8.K.2, in response to a request by DOE, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) provided information on mineral resources within the WIPP site . In addition to oil and gas, NMBMMR [1995] identified potash, caliche, salt, and gypsum as potential resources. Of these, oil, gas, and potash within the McNutt Potash horizon of the Salado Formation were considered when evaluating the effects of resource exploration and recovery in performance assessment because DOE concluded that the other resources are not economically attractive given the low sales price of the reserves and more cheaply mined alternatives. [Ref. 460 Final Report Evaluation of Mineral Resources at the WIPP site Docket: A- 93-02,II-G-I] EPA agrees that a large amount of drilling has occurred in the Delaware Basin, and believes that the drilling rates are adequately reflected in the drilling rate assumptions it has required in performance assessment. EPA also agrees that drilling in the immediate vicinity of WIPP has been affected by the withdrawal of that land from public use by Congress. [Appendix DEL, and CCA 7.5] However, EPA required that drilling be considered to occur in the future at the WIPP site after active institutional controls cease. With regard to Comments 8.K.3, 8.K.5, 8.K.6, and 8.K.7, EPA believes that although the average drilling rates used in the CCA are lower than the present rates in the Delaware Basin, the present rates are exceptionally high because of the demand for oil and gas. EPA believes that a lower average rate is more appropriate for the purpose of assessing the long term (10,000-year) performance of the WIPP repository because future drilling rates are expected to fluctuate as described above.

EPA agrees with Comment 8.K.4. The radionuclide releases are dominated by drilling intrusions and the releases are approximately linear with the number of drilling intrusions. This is because as the number of drilling intrusions increases, the total radionuclide releases also increase. EPA agrees that it is unlikely that the drilling rate could be as high as 4,680 boreholes per square kilometer because this would mean that there would be one borehole approximately every 15 meters.

Issue L: The drilling potential is overestimated.

1. As a former reservoir engineer, it appears to me the petroleum potential of the WIPP area has been very significantly overestimated, as has the potential for human intrusion. The use of fluid injection has been also overestimated. If the site is rejected on the basis of the petroleum issues, I think we will have rejected a sound site for reasons that are fundamentally unsupportable. (443)

Response to Comment 8.L.1:

Based on a review of information supplied by DOE in the CCA, including the Evaluation of Mineral Resources at the Waste Isolation Pilot Plant Final Report Volume I-IV [NMBMMR 1996] and the CCA Vol. V, Appendix DEL, and on EPA's independent evaluation of petroleum related activity Technical Support Document for Section 194.32: Potential Impacts of Fluid Injection [Docket: A-93-02, V-B-22], EPA has determined that there is petroleum production potential on and in the vicinity of the WIPP site. EPA believes that the parameters used to represent the repository system in performance assessment and to screen issues such as petroleum industry related fluid injection for inclusion in performance assessment have been appropriately justified by DOE on consequence and regulatory grounds. [CARD 33, CCA 6.0, Docket: A- 93-02, II-A-32 and II-I-36] Potential fluid injection impacts were assessed by DOE in Stoelzel and O'Brien, 1997 [Docket: A-93-02, II-A-32] and Stoelzel and Swift, 1997. [Docket: A-93-02, II-I-17] EPA evaluated these documents [Docket: A- 93-02, IV-B-22] and found that bounding values were appropriately used for certain parameters including the fluid injection rate and the frequency and potential for leakage to occur. Although EPA agrees with Comment 8.L.1 that petroleum potential, fluid injection and related issues may have been overestimated in these evaluations as required to ensure sufficient and conservative analysis, petroleum-related issues have not been found to be sufficient reason for rejection of the WIPP site. For a discussion of fluid injection issues, please see the responses to comments Section 8, Issue Y and Section 5.

Issue M: Borehole plug effectiveness

1. The PA assumptions that plugs will be ineffective is unrealistic and results in the understatement of releases of radioactivity. (138)

2. The treatment of borehole plugging is notably deficient. . . Despite noting that the decisive factors in plug design are site-specific, the CCA assigns plug configurations according to a ratio that disregards site conditions and depends entirely on conditions and requirements existing everywhere but at the site of the borehole. Thus, plug configurations are based on the ratio of the occurrence of such configurations throughout the entire area surveyed (MASS Att. 16-3, at 2-3). To project that regulatory authorities would call for anything less that the most effective plugs is wholly unrealistic. (1039)

3. The CCA erroneously applies ratios based on a survey of boreholes subject to plugging and abandonment since 1988 in New Mexico -- and fails to survey Texas practices on the reasoning that the Texas regulations do not apply at WIPP (MASS Att. 16-1, at 1). Of course, the New Mexico regulations generally applicable to the New Mexico portion of the Delaware Basin also do not apply to WIPP, because WIPP is subject to specific regulations for the potash area. Thus, on DOE's own reasoning, the rules and practices in non-potash areas of New Mexico should be disregarded as well. (1040)

4. DOE claims that borehole plugs will remain effective for 10,000 years. Unless a continuous concrete plug is shown to withstand the pressure encountered in the WIPP-12 brine reservoir, this claim is entirely unsubstantiated. (1173)

<u>Response to Comments 8.M.1 through 8.M.4</u>:

EPA recognized that intrusion boreholes would play a key role in assessing the ability of the WIPP repository to successfully isolate waste over the 10,000-year regulatory time frame and provided specific direction to DOE on how future drilling practices should be incorporated into performance assessment. With regard to borehole plugging practices, 40 CFR 194.33(c) states that "Performance assessments shall document that in analyzing the consequences of drilling events, the Department assumed that: (1) Future drilling practices and technology will remain consistent with practices in the Delaware Basin at the time a compliance application is prepared. Such future drilling practices shall include, but shall not be limited to: The types and amounts of drilling fluids; borehole depths, diameters, and seals; and the fraction of such boreholes that are sealed by humans; and (2) Natural processes will degrade or otherwise affect the capability of boreholes to transmit fluids over the regulatory time frame."

EPA reviewed the data presented in CCA Chapter 6 and Appendices DEL and MASS to determine if DOE assumed that future drilling practices and technology will remain consistent with current practices in the Delaware Basin. In addition, EPA reviewed the CCA to determine if DOE performed appropriate assessments of future drilling practices and technologies, including the types/amounts of drilling fluids, borehole dimensions, and the fraction of such boreholes that are sealed, and whether the assessments were consistent with data presented in these appendices. EPA's evaluation of state files, private database records, and independent industry practice information confirmed DOE's assumptions regarding future drilling practices and technologies, including the types/amounts of drilling fluids, and borehole dimensions. [Docket: A- 93-02, II-G-26]

To meet the requirements of Section 194.33(c)(2), DOE indicated in CCA Chapter 6 and Appendix MASS that oil and gas well plugging configurations in the Delaware Basin can be generalized into three categories: a two-plug configuration, a three-plug configuration, and a continuous plug. In all cases, the plugs were made of concrete. DOE assumed that borehole plugs would exhibit variable permeability through time and concluded that the fully degraded permeability for each of the three types of plug systems never exceeds that of silty sand (10^{-11} to 10^{-14} m^2).

EPA evaluated DOE's assumptions, calculations, and data values for borehole degradation and associated permeability changes, including borehole degradation processes, location in the borehole, and models that implement degradation. EPA also evaluated whether DOE had assumed the fluid transmission capabilities of boreholes would degrade over time due to natural processes, and the validity of DOE's assumptions, calculations, and data values for borehole degradation over time. [CARD 33 (c) (2), and PAVT Docket: A- 93-02, II-G-26]

CCA Appendix DEL, Attachment 7 (Inadvertent Intrusion Borehole Permeability), addressed borehole permeability variation based largely on a study by the Westinghouse Waste Isolation Division (WID). The WID report used published literature, plugging field tests, and oil and gas companies' experience to assess borehole permeability. The report addressed wells that were plugged since 1988, when the State of New Mexico adopted new drilling and plugging regulations. Boreholes existing prior to 1988 are limited in number within the WIPP Land Withdrawal Area. DOE accounted for the risk and uncertainties associated with boreholes drilled prior to 1988 in performance assessment by using various behaviors of plugs in the Delaware Basin, as discussed in Section 194.33(c)(1) of EPA's CARD 33. The functional life of the long, continuous plug configuration was assumed to exceed 10,000 years. The functional life of the short (>150 ft.) borehole plugs in the two- and three-plug configurations was considered to be 200 years above the depth of the repository and over 10,000 years below the depth of the repository. Beyond 200 years the permeability of the degraded borehole filling material was assumed to increase to a value equivalent to that of a marine silty sand above the depth of the repository and decrease by one order of magnitude below the depth of the repository. The permeability of the filling material below the depth of the repository was decreased to account for compaction by partial creep closure of the lower portion of the borehole. [CCA Vol. I. Chapter 6, Section 6.4.7.2.2] The degraded permeability values were held constant during the remainder of the regulatory period. This topic is discussed further in relation to plugging configurations below.

DOE assumed that processes that affect long-term borehole permeability include steel casing corrosion and concrete plug alteration. Refer to CCA Appendix DEL, Attachment 7, for DOE's detailed evaluation of these degradation mechanisms. DOE described different portions of the borehole over which degradation would act by first assigning plugging configurations for deep drilling in the Delaware Basin to one of the three aforementioned categories: a two-plug configuration, a three-plug configuration, and a continuous plug. DOE evaluated the frequency of plug configurations based on those of 188 Delaware Basin wells installed since 1988. EPA considered this to provide an adequate database for analysis. Based on this study, DOE assigned the following frequencies for each configuration. [CCA Vol. I, Chapter 6, Section 6.4.12.7, p. 6-198]

- ♦ One continuous plug through the evaporite sequence: probability of 0.02;
- ♦ Two plugs -- one in the Bell Canyon Formation below the potential Castile brine reservoirs and one in the Rustler Formation between the Culebra Dolomite and the repository: probability of 0.68; and
- ♦ Three plugs -- two as described for the two-plug configuration and a third plug in the Salado Formation below the depth of the repository: probability of 0.30.

DOE estimated that a concrete plug would have an initial permeability of 5×10^{-17} m^2. DOE assumed that the steel casing would corrode due to the saline groundwater environment [CCA Vol. V, Appendix DEL, Attachment 7, Appendix B] and the concrete plugs would degrade when sufficient water entered the plug to cause chemical degradation of the matrix. [CCA Vol. V, Appendix DEL, Attachment 7, Appendix C] DOE assumed that the "corroded casing and degraded plug will fill the hole with material with a permeability approximating that of silty sand (10^{-11} to 10^{-14} m^2), and over time any of this material below the repository will compress through creep closure of the borehole to a permeability about one order of magnitude lower." [Appendix DEL, Attachment 7, p. 19] Plug configurations do not apply explicitly to shallow drilling, except that abandoned shallow boreholes typically are continuously cemented and "are expected to not have an effect on the performance of the WIPP." [Appendix DEL5.2, p. DEL-41]

DOE concluded [Appendix DEL7.4] that permeability for each of the three types of plug systems never exceeded that of silty sand (10^{-11} to 10^{-14} m^2) over the 10,000 year regulatory time frame[35]. DOE offered the following borehole permeability changes over time:

- ♦ Continuous plug:
  - 5×10^{-17} m^2 for over 10,000 years
- ♦ Two plugs:
  - -- Between the repository and the surface:
    - 5×10^{-17} m^2 for 200 years;

[34] Long-term borehole permeability was incorporated into PA modeling via the BH_SAND parameter (parameter ID 3184), used in BRAGFLO. CARD 23 -- Models and Computer Codes.

- 10^{-11} to 10^{-14} m^2 after 200 years.
- -- Between the Castile and the repository:
  - "very high" permeability to 200 years; (10^{-9} m^2)
  - 10^{-11} to 10^{-14} m^2 from 200 to 1,200 years;
  - 10^{-12} to 10^{-15} m^2 after 1,200 years.
- -- Below the Castile:
  - 5 x 10^{-17} m^2 for over 10,000 years;

♦ Three plugs:
- -- Between the repository and the surface;
  - 5 x 10^{-17} m^2 for 200 years;
  - 10^{-11} to 10^{-14} m^2 after 200 years;
- -- Below the repository:
  - 5 x 10^{-17} m^2 for over 10,000 years;

The lengths of the concrete plugs used in the scenarios above were assumed by DOE to be:

♦ Continuous plug: 3,000 feet (900 meters)

♦ Other plugs: 150 feet (45.73 meters)

EPA reviewed CCA Appendices DEL and MASS and determined that DOE sufficiently identified natural degradation mechanisms that will affect boreholes over time. EPA also examined the plug configurations presented by DOE and compared these generalized configurations with those for oil/gas and potash resource boreholes in the WIPP vicinity, as evidenced by the resources targeted and necessary plugging techniques. As a result, EPA determined that DOE's plug configurations (which directly impact the portions of the borehole over which degradation processes are expected to act) and plug probabilities were adequate representations of the plugs in the WIPP area. [EPA Technical Support Document for Section 194.23: Parameter Justification Report; Docket: A-93-02, V-B-14]

If degraded boreholes are assumed to be filled with materials analogous to unconsolidated silt to silty sand, the permeabilities of 1 x 10^{-11} to 1 x 10^{-14} m^2 (1 to 10,000 md) used by DOE are not unreasonable estimates of values by industry standards. [Freeze and Cherry 1979, Ref. 257,Docket: A- 93-02, II-G-I] However, for purposes of comparison, the permeability range reported for shale and unweathered marine clay varies from 1 x 10^{-21} to 1 x 10^{-17} m^2 (1 x 10^{-5} to 0.1 md). [CCA Vol. X, Appendix MASS Attachment 16] As discussed below, EPA investigated this assumption and believes that permeability values could be lower than DOE assumed. Lower values are more conservative because they allow for greater gas pressurization of the WIPP and a potential increase in releases due to mechanisms such as spallings. [Technical Support Document for Section 194.23 Parameter Justification Report, Section 5.17; Docket: A-93-02, V-B-14]

EPA began by investigating the permeability of borehole materials and drilling fluids used in the petroleum industry. Literature values for the permeability of the concrete used in borehole plugging applications can range from 9×10^{-21} to 1×10^{-16} m^2 (1×10^{-5} to 0.1 md); these values are also cited in some of the publications referenced in the CCA. EPA also investigated the permeabilities of drilling muds. Filter cake and compacted clay-based drilling muds can have permeabilities of less than 9.9×10^{-22} m^2 (1×10^{-6} md) based on field data for 11 ppg mud. [Technical Support Document for Section 194.23: Parameter Justification Report, Section 5.17; Docket: A-93-02, V-B-14]

EPA concluded that drilling mud circulated in Delaware Basin boreholes may not have the degree of clay-based solids loading typically experienced elsewhere (as discussed in CCA Vol. X, Appendix MASS 16-3, Appendix C); however, natural cuttings could contribute to lower borehole permeability than that postulated by DOE. Lower initial permeabilities, more effective plug segments, mixed layers between plug components that would take time to degrade, and lower fluid velocities than DOE assumed in its calculations could significantly retard plug degradation and could maintain the effective seal of the plug sequences for hundreds or thousands of years beyond that assumed by DOE in CCA Appendix MASS, Attachment 16.

DOE provided a variety of plausible mechanisms to increase plug permeability, and EPA believes that this high range of permeability may be attained. [CARD 33 Section 33 (c) (2)] However, EPA also believes that there is a probability that the low end of the range of borehole permeabilities (effective over several hundred vertical feet of borehole) would be lower than the low end of the range estimated by DOE. Since the effective permeability for fluid movement through any given borehole will actually be controlled by the permeabilities of all zones through which the fluids must pass, the effective average permeability could be dominated by small sections of remaining competent plug or other low permeability material. If complete degradation does not occur throughout a well, or if natural materials and mud provide additional layers with sealing properties, it is possible that the effective average permeability over several hundred feet of abandoned borehole could remain in the range of 9×10^{-21} to 1×10^{-16} m^2 (1×10^{-5} to 0.1 md) over a period of hundreds, if not thousands, of years.

EPA concluded that the borehole permeabilities assigned in the CCA [Vol. X, Appendix MASS, Appendix 16] were consistent with the broad range of available permeability data, but did not adequately incorporate the total range of permeability conditions that could exist in boreholes. Permeabilities assigned by DOE may therefore overestimate the degree to which plugs would lose effectiveness. EPA concluded that an alternative case could be made in which many of the plugs would retain a larger degree of effectiveness. As such, a lower maximum permeability value of *approximately* 1×10^{-17} m^2 (1×10^{-2} md) is quite possible (particularly for long-term conditions) and may have an impact on performance assessment results. As a result, EPA included both long- and short-term plug permeability changes in the performance assessment verification test (PAVT).

[Docket: A- 93-02, II- G-26 and 28] EPA required that performance assessment simulations be conducted with lower minimum permeabilities (an undegraded concrete plug minimum of 1 x 10^{-19} m^2 instead of the constant value of 5 x 10^{-17} m^2 used in the CCA, and a degraded borehole filling minimum of 5 x 10^{-17} m^2 instead of the minimum value of 1 x 10^{-14} m^2 used in the CCA) to account for possible cases in which complete degradation does not occur throughout a well, or where natural materials and mud provide additional layers with sealing properties. See Section 194.23(a) in CARD 23 -- Models and Computer Codes for more information regarding the permeability values assigned by EPA in the PAVT. Results of the PAVT indicate that a lower borehole permeability does allow greater pressure build-up in the repository and, hence, greater release potential from mechanisms such as spallings. However, releases predicted by the PAVT were still well below the EPA release limits. [Docket: A-93-02, V-B-21 and V-B-22] For information on EPA's evaluation of the PAVT, Docket: A-93-02, V-B-05.

In summary, EPA agreed that the high permeabilities assumed by DOE were generally appropriate; however, EPA believed that it is also possible for abandoned boreholes to have a lower permeability, similar to that of a recently plugged borehole. [Technical Support Document for Section 194.23: Parameter Justification Report; Docket: A-93-02, V-B-14] Therefore, in the PAVT, EPA required [Docket: A-93-02, II-I-27] DOE to include larger ranges of undegraded concrete plug and long-term borehole filling permeability values. The range of 1 x 10^{-17} to 1 x 10^{-19} m^2 was used in the PAVT for an undegraded concrete plug, and the range of 1 x 10^{-11} to 5 x 10^{-17} m^2 was used in the PAVT for a degraded borehole filling. EPA believes that these ranges adequately cover the behavior of plugs in the Delaware Basin. The PAVT results indicated that even with these changes in the range of permeabilities for degraded borehole plugs, the repository releases did not violate EPA's containment requirements.

EPA believes that its detailed review of DOE's borehole plugging assumptions provided an adequate basis for the Agency's conclusion that DOE's assumptions were acceptable. Although EPA originally questioned many of those assumptions, further investigations substantiated many of DOE's assumptions, and the use of modified permeability ranges in the PAVT did not cause releases to exceed regulatory limits.

With regard to Comment 8.M.1, EPA reviewed natural borehole degradation processes and the subsequent effect of these processes on borehole permeability. Based on available information [for example, Sandia National Laboratory WPO # 41131 and CCA Vol. XI, Appendix PAR, p. 192; Docket: A-93-02, II-G-1], EPA found that the permeability range used in the CCA for degraded borehole filling was not conservative because lower permeabilities were possible and would increase pressure buildup in the repository. The Agency believes that, primarily due to the solidification of drilling muds within the borehole in time, variations in the long term permeability of borehole plugs will occur and that a lower value for the low end of the permeability range would be appropriate.

As discussed in Section 194.33(c)(2) in CARD 33 -- Consideration of Drilling Events in Performance Assessment and response to ANPR comments (issues B and C), borehole plugs are assumed to degrade according to specific probabilities for borehole plug configurations. With regard to Comments 8.M.2 and 8.M.3, DOE did not assign plug configurations in a fashion that disregards site conditions but attempted to assign plug configurations based on probable field results for typical practice. This is consistent with the requirement in Section 194.32(c) (that "Performance assessments shall include an analysis of the effects on the disposal system of any activities that occur in the vicinity of the disposal system prior to disposal and are expected to occur in the vicinity of the disposal system soon after disposal." If only activities, regulations, or practices that currently apply to the WIPP site had been considered in performance assessment, no borehole penetrations of the waste panels would have been included because such activities are not allowed within the land withdrawal boundary). DOE assumed "that for the purposes of predicting long-term performance, review of the records indicates that current practice on Federal lands may be adequately represented using three scenarios: one with two deep plugs, one with at least three deep plugs, and one in which multiple plugs may approximate the OCD requirement for continuous plug that extends all the way through the host." [CCA Vol. V, Appendix DEL, Attachment 7, p. 3] DOE made these assumptions because drilling for oil and gas (not just potash) must be considered, and therefore plug configurations for the oil and gas industry must be considered. If "continuous plugs" were assumed in all instances, then it must also be assumed no oil and gas drilling would occur at WIPP because the potash exclusion zone drilling restriction would be in place. EPA concluded that oil/gas drilling must be considered [CARD 33, pp. 33-1, 33-3], and also determined it reasonable and appropriate to include plugging practices for the oil and gas industry in performance assessment. The area surveyed by DOE for determining alternative plugging practices was reviewed by EPA and found to be appropriate for use in assessing the long-term performance of the WIPP.

The statement in Comment 8.M.4 that DOE claims that borehole plugs will remain effective for 10,000 years applies only to plugs set below the depth of the repository. Under the 3-plug scenario described above, such plugs would affect fluid flow between the repository and a Castile brine pocket, but would not affect fluid flow between the repository and the ground surface. DOE attributes the long life of the lower plugs to a less aggressive chemical environment. [CCA Vol. I Chapter 6 Section 6.4.7.2.2 and Vol. X Appendix MASS Attachment 16-3] The justification for this assumption was questioned by DOE's independent Conceptual Models Peer Review Panel, but the assumption was accepted by the Panel when it was determined that the additional flow through the borehole would have little effect on repository performance. This finding was based on the permeability of the underlying Bell Canyon Formation which was too low to allow significant flow in the borehole, and on information presented by DOE indicating that additional flow from Castile brine reservoirs into the repository would not significantly change repository conditions. [Docket: A-93-02, II-G-12, Section 3.12] EPA has reviewed and concurs with the peer review panel's findings. [CARD 27(a)(1)] Additionally, EPA does not question the ability of the borehole plugs assumed in performance assessment to withstand the potentially high pressures that could be generated in the WIPP repository. Borehole plugging is a standard practice in the oil and gas industry, where plugs are required to withstand downhole pressures greater than those that could occur in the WIPP waste panels.

Issue N: Borehole plug lifetime

1. EEG suggested the borehole plug lifetime should be a sampled parameter based on two observations. 1) It is likely that the performance assessment calculations are sensitive to the assumed borehole plug lifetime. 2) Borehole plug lifetime is an uncertain parameter. The use of a constant value for borehole plug lifetime in all the calculations is inconsistent with DOE's guidelines for sampled parameters. Contrary to the assertion in the DOE response (II-H-46), the EEG did not argue that the estimate of 200 years is unreasonable.

The DOE (II-H-45) claims that borehole plug lifetime uncertainty is accounted for by assuming that two percent of the plugs are continuous (long-lived) and hence do not degrade (II-H-46). This claim is wrong.

The EEG recognizes that sampling borehole plug lifetimes would be impractical using the present performance assessment design. The DOE should investigate the influence of borehole plug lifetimes on repository conditions and assess the potential impact on CCDF calculations.

The EPA mandated verification test used a range of permeabilities of degraded boreholes that extended lower than the range used in the CCA calculations. The lowest permeability effectively limits flow through the borehole. The effect may have similar consequences to the effect on the repository conditions of long lived borehole plugs. Thus, the EPA mandated verification test may, in conjunction with the CCA calculations, provide a bound on the influence of variable borehole lifetimes. This, however, is speculation and needs to be confirmed. (1316)

Response to Comment 8.N.1:

In response to Comment 8.N.1, EPA considers that lowering the low end of the range of sampled permeabilities for degraded concrete borehole plugs from 1 x 10^{-14} m^2 used in the CCA to 5 x 10^{-17} m^2 used in the PAVT has the same effect as sampling an extended lifetime for the plug as recommended in this comment. The effect is the same because the permeability of an intact, undegraded plug used in the CCA was the same as the low end of the range for degraded borehole filling in the PAVT. Lowering the low end of the range resulted in low permeability values being randomly selected more often. Sampling an extended lifetime for the plug would also result in low permeability values being selected more often. EPA believes that the results of these two approaches are the same, and considers that the effects of an extended plug lifetime have already been included in the PAVT. [Docket: A- 93-02, II-G-26 and 28]

Issue O: ERDA-9 borehole plug

1. The questions to be asked and the issues to be considered before the effect of ERDA-9 can be written off, are:

- How far is ERDA-9 from the drift E-300 *at the repository level?* Boreholes are seldom vertical; they deviate. For example, the borehole H-19-B-4, drilled under strict specifications for hydrologic and tracer testing of the Culebra aquifer in 1995-96, deviated 9.5 meters (31 ft) in 229 meters (752 ft) depth. At that rate, a borehole drilled to 655 meters (2150 ft) depth of the repository may deviate 27 meters (89 ft). Could ERDA-9 be very close to E-300 at the repository level?

- How far does the DRZ of E-300 extend?

- Whether or not there is pressurized brine reservoir underlying ERDA-9 is not definitely known, although there is good reason to suspect it. . .

- How will ERDA-9 be sealed?. . .

Why is EPA not requiring at least a special plugging procedure for ERDA-9 and other boreholes that penetrate the repository horizon within the WIPP site? (1296)

<u>Response to Comment 8.O.1:</u>

Comment 8.O.1 contains several references to the relationship between ERDA-9 and DRIFT-E. ERDA-9 will be continuously plugged with concrete through the entire salt-bearing section and any water-bearing horizon. [CCA Vol. I, Chapter 3, Section 3.3.4, Table 3.2] Because of the long-term effectiveness and low permeability of continuous borehole plugs (discussed above in Issue L), DOE has found that boreholes with continuous plugs do not impact repository performance and specific modeling of boreholes with such plugs is not necessary. ERDA-9 is therefore not specifically modeled in performance assessment. The need for DOE's commitment to effectively seal ERDA-9 and other site characterization boreholes with continuous concrete plugs was raised as a specific issue by DOE's independent Conceptual Models Peer Review Panel, and was satisfactorily resolved when DOE indicated that deep, unplugged boreholes within the Land Withdrawal Area, including WIPP 13, WIPP 12, ERDA-9 and DOE1, will be sealed with a continuous concrete plug through the salt section and any water bearing horizon. The relationship of ERDA-9 to the DRZ does not impact facility performance since the borehole will be plugged in the pre-closure time frame and the DRZ will have healed within 25 years. [Chan 1995] The precise distance to the borehole from a waste panel is not known but it is believed to penetrate the repository horizon within several meters of a drift wall in the operations area. This borehole does not penetrate the repository excavation. The Peer Panel conceded that ERDA-9 is in the DRZ, but it would be sufficiently plugged *and* the DRZ would disappear before the plug degrades. The Peer Panel noted that site characterization boreholes were not included in BRAGFLO, but found that the low permeability and permanence of a continuous concrete plug made it unnecessary. [CCA Vol. XII, Appendix PEER, Attachment PEER-1, p. 3-21 and Docket: A-93-02, II-G-12 p. 12] The existence or absence of a Castile brine reservoir is not an issue with respect to ERDA-9 because no further activity such as deepening is planned for that boring.

References

Chan, K.S., D.E. Munson, A.F. Fossum and S.F. Bodner, 1995; Inelastic Flow Behavior and Argillaceous Salt. SAND 94-3017, Albuquerque, New Mexico, SNL.

Issue P: Error in referencing

1. The discussion in the preamble relating to borehole plugs (62 FR 58823) is not supported by the original document (II-E-34). In particular, the portion of the preamble discussion relating to perfect plugs was appropriately referenced in II-E-34, but the discussion of plugs that fail was not. (1)

Response to Comment 8.P.1:

Comment 8.P.1 refers to a statement in 62 FR 58823 in the preamble to EPA's proposed rule regarding the Certification Decision on the WIPP. The statement in the preamble reads "EPA and public commenters also disagreed with DOE's use of a small range of values for the long-term borehole plug permeability. [Docket: A-93-02, II-I-17] For example, one commenter asserted that DOE should evaluate both "perfect plugs" (i.e., low permeability) and plugs that "fail" (i.e., very high permeability)." [Docket: A-93-02, II-E-34, Comment 113] Comment 113 was received from the Environmental Evaluation Group during a stakeholder meeting with EPA. That comment consisted of a request for consideration of perfect borehole plugs in the CCA and did not address plugs that fail. The author of Comment 8.P1 is therefore correct in stating that the discussion of plugs that fail was not appropriately referenced.

Issue Q Earthquakes could effect WIPP's containment of waste.

1. Do you think it impossible that major earthquakes could happen around WIPP and cause large pressurized releases of radioactive brine once or many times in the next 10,000 years? (259)

2. And a few days ago we heard that there were several earthquakes in the southern part of the state. They were over three on the Richter scale. It's not very high but I don't need to be a seismologist to know that that's the beginning often of bigger earthquakes. (400)

3. Earthquakes are big and unpredictable and very strong. For years we've known that there's a major fault in New Mexico, and now we are hearing that for years it has been rumbling deep down in the earth down there, and lo and behold this winter it came up where people could feel it. (567)

4. I think that WIPP isn't what the DOE thought it was 20 years ago, and EPA needs to reevaluate and say, we've got the geologic problems, we've got earthquakes down there, we've got brine. (573)

5. Carlsbad is only 238 miles from the recent January 4,1998 earthquake in Mountainair/Willard and 241 miles from the more quake prone area around Socorro, where, in the next 50 years there is a one in ten chance of a quake large enough to crumble an adobe structure. That's just in the next 50 years and the recent Estancia Valley quake did not happen in a predictable area. How about predicting seismology the next 10,000 years? (828)

6. Section 2.6 of the CCA documents the development of the design basis earthquake (DBE) for the WIPP. The DBE is determined from the seismic record to be the largest expected earthquake induced ground motion at the WIPP and is used in the design of structures, systems, and components that are needed for the confinement of radionuclides at the WIPP (such as the Waste Handling Building). . . Based on the information gathered at and around the WIPP site and the methodology in the [Appendix] GCR, the DBE for the WIPP is 0.1 g (98.8 cm/s^2). Accelerations this large are only expected to occur once in 1,000 years. The small magnitude earthquakes that were part of the Willard Swarm have no impact on the WIPP due to their small size and their distance. (1098)

7. The largest earthquake of the Willard Swarm was 3.8. [S]ince the magnitude scale is exponential, this earthquake is 1/50 of the maximum that can occur under the WIPP before any damage would occur to the buildings used to provide confinement of radionuclides. (1099)

<u>Response to Comments 8.Q.1 through 8.Q7:</u>

(Comments 8.Q.1, 8.Q.2, 8.Q.3, 8.Q.4, 8.Q.5, 8.Q.6 and 8.Q.7) The intensity of ground shaking is the primary cause of destruction from an earthquake, and it is vastly different in the underground and on the surface. Moreover, the effects of earthquake in pre- and post- mining operation (sealing) periods and pre- and post- creep closure periods at WIPP will be substantially different. In addition, the ductile nature of a salt deposit makes it deform differently than typical hard rocks and the magnitude of displacement due to rupture (if any) will be less. The natural characteristics (barriers) of the underground repository in the bedded salt will help to withstand seismic activities. EPA reviewed DOE's earthquake (seismic) scenario in Technical Support Document for 194.14: Content of Compliance Application, Section IV.B.4.f.

(Comment 8.Q.1) Approximately 200 years after shaft seal emplacement, the rooms, passages and waste panels of WIPP will close due to creep strain in the salt. Once the open spaces are closed and the waste is compacted, the WIPP will respond to any earthquake which might occur as would any other body of bedrock in the region. Other rocks in the region have high interstitial pore pressures which are comparable to those that could eventually exist in the waste after degradation. No release of fluid or gas from deep bedrock has been observed in the WIPP region as the result of an earthquake and EPA concludes that there are no data to suggest that major brine release due to earthquake activity would occur.

(Comments 8.Q.2, 8.Q.4) Many years of seismological monitoring, microseismal studies and geologic study demonstrate that there are no probable sources of large earthquakes at or near the WIPP site. [Docket: A- 93-02, II-G-1, Chapter 2.6] The only sources of significant earthquakes in the region lie far to the west of the site along the Rio Grand rift or to the south along major plate tectonic features in Mexico, although measurable earthquakes have occurred closer to the WIPP. [CCA Chapter 2.6, p.2-180, Docket: A- 93-02, II-G-1] Micro-earthquakes (rm 3.0 or smaller) most of which are too small to be felt, or small, shallow teleseismal ground motion related to distant earthquakes are the only seismicity expected at the WIPP site during the very short period that the repository will persist as an underground opening. EPA notes that the Willard Swarm [Sandford, 1977] is located in the Rio Grande Rift; over 100 miles east of WIPP, and seismic activity of similar magnitude in this area is too weak to have an impact at WIPP.

(Comment 8.Q.3) DOE has used three seismic source zones to calculate the risk of seismic activity in the WIPP area. On the basis of these calculations, they predict [Appendix SCR-11] "Using conservative assumptions about the maximum magnitude event in each zone, the study indicates a return period of about 10,000 years (annual probability of occurrence of 10^{-4}) for events producing ground acceleration of 0.1 gravities. Ground acceleration of 0.2 gravities would have an annual probability of occurrence of about $5x10^{-6}$. " The maximum frequency of magnitude of the known earthquakes is less than four for the Central Basin Platform area. [Rogers and Malkiel, 1979. "A study of earthquakes in the Permian Basin of Texas - New Mexico," Bulletin of the Seismological Society of America, vol. 69, p. 843-865] However, a safe design for WIPP was based on the highest magnitude established for the area. The Design Basis Earthquake, which indicates the maximum probable ground motion for which the WIPP facility is designed, has been calculated to be magnitude six. The Rattlesnake Canyon earthquake of January 2, 1992 did not affect the surface and underground facilities at WIPP. This earthquake was of magnitude 6 and occurred approximately 60 km from WIPP. [P. Sanchez, 1992, NMED, "The January 2,1992, M_D = 5.0 Rattlesnake Canyon Earthquake of Southeastern New Mexico"] The WIPP does not occur within 15 km of a known major earthquake focal point, and EPA concludes that the depth of the WIPP facility protects it from the short-period energetic teleseismal ground motions that would be experienced from more distant earthquakes.

DOE examined seismicity as part of its features, events, and process analyses, and concluded earthquakes could be excluded based on low consequences. EPA concurs with this analysis, as the risk that a release of radionuclides from the repository due to opening of fracture pathways caused by an earthquake is too small to be credible.

As EPA stated in the Technical Support Document for 194.14: Content of Compliance Application, Section IV.B.4.f, "Chapter 2.6 [pp. 2-180 to 2-205] of the CCA presented generalized information regarding earthquake occurrence in the WIPP area, and Appendix GCR includes additional information pertaining to specific earthquake lactations prior to 1978. Based on the information provided in the CCA, EPA concluded that the information provided regarding the seismology of the WIPP site and surrounding area is acceptable."

EPA finds Comments 8.Q.6 and 8.Q.7 are compatible with its position related to the seismic activities in the area. As mentioned in the comment the DBE for WIPP is 0.1g (100 gals). Building codes are normally formulated to resist this amount of acceleration. The lesser magnitude earthquakes such as Willard Swarm, are primarily originated from non-tectonic source. These are expected to have lower frequencies and duration. Destructive effects of earthquakes are also dependent upon the frequency and duration of a seismic activity.

References

Sanford, A.R., K. H. Olsen and L. H. Jaksha, 1981, Earthquakes in New Mexico, 1849-1977, New Mexico Bureau of Mines and Mineral Resources, Circular 171.

Richter, 1958; Elementary Seismology.

Issue R: Gas pressure will cause fracturing and impact radionuclide release scenarios.

1. The question was raised what about the high [pressure] gas? You compress all of this waste and the steel and salt started coming together and starts generating its own gas, plus the walls crunch in, ore comes up and you're compressing the volume of this air and gas is being generated to 146th of it's original volume and creating immense, immense pressures. Well, the Department of Energy in their response says all that gas is going to be absorbed by the anhydrite. Later that Dr. Phillips mentioned, and there is no mention made of well, is that high pressure gas going to make its way up through the [disturbed] rock zone. They never make the comparison that the high pressure gas goes in the anhydrite but it doesn't go into the disturbed rock zone. . . The assertion then is that the high pressure gas is going to open up fissures in the shaft seals and then the brine is going to follow and is going to be whisked off, off into the Pecos River ultimately. (314)

Response to Comment 8.R.1:

Bio-degradation and corrosion are the main processes by which the repository gas will be generated. [Appendix SCR 2.5, Docket: A- 93-02] Microbial degradation of cellulosic, plastic and rubber materials requires brine and is not expected to continue (approximately) beyond 2,000 years. [Refer to CCA 6.4, Appendix MASS 8-2, Appendix SCR and Appendix BRAGFLO 4.1 Docket: A- 93-02, II-G-I and PAVT, Docket: A- 93-02, II- G-28 and 26.] Gas generation from corrosion will also depend upon the brine entering the repository. Corrosion of metals takes place in oxic (just after closure - when oxygen is still available) and later in anoxic conditions. The rate of gas generation from this process is given in CCA Table 6-10, p.104. Gas generation is an important process that may affect creep closure, fracturing and failure in the surrounding rocks and release of radionuclides due to drilling. Therefore it is necessary for DOE to evaluate the gas generated in the repository and to estimate the pressure (volume) associated with it. DOE has calculated the gas pressure in the repository using SANTOS (a two dimensional finite element program for the quasistatic, large deformation, inelastic response of solids). [Appendix PORSURF, Docket: A- 93-02, II-G-I, Appendix SCR 2.5, p.58, and Appendix MASS Attachment 8] The amount of gas that can be generated is calculated using BRAGFLO (a two phase flow code used to simulate gas and brine flow in the repository. The various effects of creep closure, gas generation and fracturing are also incorporated in this code. [Appendix BRAGFLO, Docket: A- 93-02, II-G-I]

DOE assumed that the pressure in the repository due to gas generation can eventually approach the lithostatic pressure (14.8 Mpa). [Appendix MASS-13 and CARD 23] This pressure can initiate deformation in the naturally ruptured anhydrite beds, partings and the zones with low tensile strength. This fracturing typically is expected to follow the previously existing fracture orientations. These openings are treated as pressure equalizing receptacles. Butcher, in SAND-97-0794, Waste Isolation Pilot Plant Disposal Room Model describes, "Fracture openings are expected to act as gas pressure-limiting devices: once the gas pressure within the repository becomes approximately equal to lithostatic pressure, pressurization ceases and any gas causes flow out through the interbeds." [CCA, EXEC-4, 6-102, Docket: A- 93-02, II-G-I]

Gas generation and repository pressurization were considered in the CCA analysis. The comment incorrectly refers to ore, which is not present in the WIPP repository horizon. DOE has used average stoichiometry model to estimate the gas generation. This is based on the experimental data. [Appendix MASS - 8] The rate of gas generation for corrosion and microbial degradation was experimentally determined and from this ranges of gas generations were obtained by linear interpolation in BRAGFLO as described in CCA 6-103, Table 6-10. This is assumed to be dependent upon the availability of brine. DOE concluded that it is reasonable to believe that pressure more than 14.8 Mpa (above lithostatic) can not be maintained for any length of time without creating dilation and fracture. [Docket: A- 93-02, II-I-03] It is also experimentally established that fractures are created when fluid pressure exceeds in situ stress normal to the fracture and tensile strength of the rock. [Beauheim, R.L, W.R.Wawersik and R.M. Robarts, Coupled Permeability and Hydrofracture Test to Assess the Waste-Containment Properties of Fractured Anhydrite, Int. J. Rock Mechanics v.30, no.7, 1159-1163, (1993)] These findings are in concurrence with the criteria of failure discussed in the "Fundamental of Rock Mechanics", a widely used text book by J. C. Jaeger and N.G.W.Cook, p.87 and 226, Chapman and Hall Publisher. Based on the above cited experimental evidence and fundamental criteria of failure in rocks (as explained in the above mentioned text book), EPA concluded that the brittle lithologic units with preexisting fractures at WIPP, could not withstand the pressure for a prolonged period of time. This pressure is defined (in the above references) as at least equal to or more of the combination of in situ stress and the tensile strength of the brittle lithologic unit. Therefore, EPA does not believe that it is physically possible to generate "immense, immense pressure " as envisioned in the comment.

The possibility of gas and brine flow through the disturbed rock zone (DRZ) around the shafts was also included in the CCA analysis. The seal system in the PA has been represented by 11 discretized zones. These zones, with different sealing materials, are used in BRAGFLO (a computer code which represents three dimensional geometry of the disposal system in two dimension) to simulate the fluid flow, gas generation and creep closure in the repository for the regulatory period. It is assumed that compact clay, concrete, asphalt and the concrete monolith will seal the shafts for the short term and ultimately creep closure will seal the system permanently (DOE conducted experiments to test the sealing system, Appendix SEAL). DRZ represents a zone where the mechanical and hydrological properties of rocks have been changed due to excavation. [Borns and Stormont, 1989, The Delineation of the Disturbed Rock Zone Surrounding excavations in Salt, Proc. 30th U.S. Symp. On Rock Mechanics, p.353-360] These changes depend upon the depth of occurrence, surrounding materials and the nature of excavation. [CCA 6-112, Appendix MASS, Docket: A- 93-02, II-G-I and Butcher 1997, Waste Isolation Pilot Plant Disposal Room Model SAND 97-0794] Creep closure in the halite due to deviatoric stress (created by excavation) will start (soon after the stress disequilibrium is created) and will progress towards the excavation. But due to the presence of seal materials, a back pressure is developed and this creates resistance which will increase the mean stress (one of the components of the deviatoric stress). This process will help the closure of DRZ and thus in time in situ properties of the halite will be restored . The rate of closure is relatively higher than the normal healing of DRZ (as expected in DRZ surrounding the rooms). This is due to the back pressure, nature of the seal materials and the depth of occurrence. [CCA, p. 6-112] Therefore, the shaft at any time after operational closure of the repository cannot act as an avenue for release in an undisturbed condition. The pressure is insufficient to force radioactivity upward or horizontally to the accessible environment, much less the Pecos River, during the 10,000-year analysis. [CCA EXEC- 4, Chapters 3 and 6, Docket: A-93-02, II-G-I] The possible transport of radionuclides associated with "Spallings" (pressurized condition in the repository) during an Inadvertent drilling intrusion has been considered in performance assessment. [Docket: A- 93-02, II -G-I, CCA, p.6-103]

Issue S: Gas generation may keep rooms from closing around the waste.

1. The decay at the waste and the barrels in which it is packed creates flammable gases. The waste is also wrapped in plastic bags which can create a static electrical spark. During the operations, this combustion of flammable gases in electrostatic plastic bags could create a spontaneous fire or explosion at the facility or when the waste is moved. Also the amount of gas generated may be enough to keep the rooms from closing around the waste as planned. (492)

Response to Comment 8.S.1:

The CCA analysis deals with the long term performance of the WIPP facility and not with waste handling procedures during the operational period. However, past experience with transuranic waste at DOE facilities has indicated that the exploding drum scenario is not a concern. [Section 4 in CCA, Docket: A- 93-02, II-G-I] Also, air circulation in rooms will be significantly reduced when brattice cloths are placed, reducing the available oxygen for combustion. CCA Vol. XVI,

Appendix SCR [Docket: A-93-02, II-G-1] discusses the possibility and consequences of gas explosions after closure of the WIPP facility and concludes that the consequences would be no worse than a roof fall in the repository rooms. As such, it is included in the post-closure performance assessment.

The CCA shows that gas generation is not significant enough to interfere with the expected creep closure of the rooms. DOE acknowledges that gas generation will increase fluid pressure and this will lower the deviatoric stress and hydraulic gradient in the repository which will slow the closure process. However, the consumption of brine will cease the generation of gas. [CCA, p.6-4] The analysis is accomplished by coupling the gas generation (repository pressurization) and creep closure models. Information on the linking of the conceptual models can be found in CCA Vol. X, Appendix MASS. [Docket: A-93-02, II-G-1] EPA agrees with DOE's analysis of gas generation on the creep closure process. [CARD 23 and CARD Section 14 (4)]

Issue T: Carbon dioxide injection was not properly considered in the performance assessment.

1. EPA's contention that CO_2 fluid injection will have limited applicability to oil recovery in the vicinity of WIPP is contradicted by existing evidence of the practice in the Delaware Basin. (49)

2. First let me say it is very appropriate that CO_2 flooding be examined. CO_2 flooding is becoming a major factor in the production panorama of west Texas and southeast New Mexico. (262)

3. What we've got on this second and final slide is a balance sheet of the factors that I believe will affect whether or not the areas of the floods be developed. Positive factors you can read, we are in the middle of a future growth area of floods, but the negative factors are long and in essence we've got several issues that I don't believe the industry will be able to overcome. The biggest of those is the smaller reservoirs and the unproven reservoir sweep. So it is a very expensive proposition to put in a CO_2 flood, and the risks of an unsuccessful flood still haunt the industry. Since the WIPP area reservoirs are small, channelized and target oil reserves in less than a million barrels, what we are left with is a conclusion that CO_2 flooding of the WIPP area reservoirs is unlikely. (263)

4. The EPA does not anticipate that CO_2 injection for oil recovery will be a widespread practice in the future near WIPP (EPA CARD-23, p 131). However, EPA's reasons do not have supporting references and appear to be at odds with the published literature. . .But an examination of the current and relevant literature strongly suggests that the Delaware Mountain Group sands are excellent prospects for future CO_2 flooding. (700)

5. EPA did not evaluate carbon dioxide injection for oil recovery. (1131)

6. DOE's position is at odds with the following observations. First, CO_2 flooding has been demonstrated to be quite successful in mature fields in the Delaware Basin such as the Twofreds (Silva, 1996, pp. 142-145). Second, the DOE continues to sponsor university research on Delaware Basin oilfields, such as the Geraldine Ford and the West Ford, aimed at optimizing infill drilling and CO_2 flooding throughout the Delaware Basin (U.S. DOE 1997). Third, oil and gas companies continue to purchase mature fields, such as the El Mar in the Delaware Basin, specifically for carbon dioxide flooding (Moritis 1993, Silva 1996). Fourth, the recently drilled reservoirs surrounding the WIPP such as Cabin Lake, Livingston Ridge, Los Medanos, and Lost Tank have oil and reservoir characteristics (Brown 1995; May 1995a; White 1995; May 1995b) that easily qualify them as potential candidates for future CO_2 flooding using the enhanced oil recovery (EOR) screening criteria described by Taber, Martin, and Searight (1997a, 1997b). (1259)

Response to Comments 8.T.1 through 8.T.6:

In the CCA [Appendix SCR], DOE determined that carbon dioxide injection was not a current practice in the Delaware Basin and therefore omitted it from consideration in the performance assessment. Because public comments indicated that CO_2 injection is performed in the Delaware Basin. EPA reviewed the issue and identified that it is occurring in the Texas portion of the Delaware Basin. However, EPA has not been able to identify CO_2 injection in the New Mexico portion of the Delaware Basin. Because CO_2 injection does occur in the Delaware Basin, EPA conducted an analysis of the consequences it could have on performance assessment calculations. EPA found that CO_2 flooding need not be evaluated as part of the PA due to low consequence in the unlikely event that the technology is utilized. Below is a detailed account of EPA's CO_2 review of the topic and an analysis of the potential effects of CO_2 injection in the vicinity of WIPP outside of the controlled area.

Technology description

The use of CO_2 miscible flooding for enhanced oil recovery in west Texas and southern New Mexico began in 1972. [Schumacher, 1978] In this area, most CO_2 injection activity is located on the Central Basin Platform and on the Northwest Shelf. [Lambert, 1996] A limited number of CO_2 flooding projects have also occurred within the Delaware Basin. [Lambert, 1996; Xue, 1994] Economy of scale, oil prices, proximity to CO_2 supply and reservoir heterogeneity are several controlling factors that strongly influence project decisions. [Klins, 1984; Lambert, 1996] In addition, CO_2 flood research projects have been conducted. [Dutton et al, 1997; Hallenbeck, 1994; Wehner, 1996; Schechter, 1996]

Carbon dioxide miscible flooding is the injection of CO_2 into an oil reservoir resulting in high displacement efficiency of the contacted oil and improved recovery. [Donaldson, 1989] CO_2 injection is typically used in tertiary recovery processes after the economic limits for waterflooding have been reached. When CO_2 is injected and mixing occurs, the viscosity of the crude oil is reduced. The CO_2 increases the bulk and relative permeability of the oil, and increases reservoir pressure so that the resulting mixture flows more readily toward the production wells. When CO_2 begins to appear at the producing well, it is typically recovered, cleaned of impurities, pressurized and re-injected.

Three types of CO_2 miscible flooding are presently employed by the petroleum industry for tertiary oil recovery: (1) injection of carbon dioxide in a slug, followed by water or carbonated water; (2) injection of carbonated water directly and (3) injection of carbon dioxide at high pressure to achieve mixing directly with the reservoir oil and the formation of an oil-miscible slug in the formation. [Donaldson, 1989]

The major factors contributing to oil recovery in carbon dioxide flooding are formation of a miscible slug, in situ modification of viscosity, changes in oil density, and compressibility of oil fractions. By maintaining the CO_2 slug in a single dense phase, its solubility with crude oil is increased considerably. Crude oil viscosities ranging from 5 to 90 centipoise can be reduced by a factor between 10 and 100 times under high injection pressures of carbon dioxide.

A number of factors must be considered when evaluating reservoirs as candidates for CO_2 flooding. The most important factors to consider are reservoir geometry and heterogeneity, residual oil saturation, oil gravity, reservoir depth, and availability of CO_2. [Klins, 1984] Early breakthrough and poor sweep efficiency are common problems that must be avoided for a successful CO_2 flood project. [Yaghoobi, 1996] Minimum miscibility pressure is most dependent on oil gravity. Suitable oils are usually in the 25-45^0 API range and are present in reservoirs 4,300 to 9,000 feet deep so that displacement can take place above the minimum miscibility pressure. For 40^0 API oils, the minimum miscibility pressure ranges from 1200 psi at 100^{0}F to 3000 psi at 250^{0}F. Reservoir depth is important because the minimum miscibility pressure must not exceed the formation fracture pressure. If the fracture pressure is exceeded, then the CO_2 flooding efficiency will be decreased; therefore, the operator the of the CO_2 injection will try to stay below fracture pressure. Reserve volumes that might be recovered using the technology become increasingly important with any incremental increase in distance from existing CO_2 pipelines. [Lambert, 1996]

Table 1 shows parameters typical of CO_2 flood projects in the Permian basin of Texas, the Delaware Basin portion of Texas, and Lea County New Mexico. All CO_2 flood projects found in New Mexico occurred outside of the Delaware Basin. [Data in this table are derived from van Poolen, 1980; Tanner, 1990; Kane, 1990; Magruder,1990; Thrash, 1979; Flanders, 1994; Bellavance, 1996; and Lambert, 1996.]

As evidenced by the data in Table 1, most of the ongoing CO_2 floods referenced in this area are located outside of the Delaware Basin. Although CO_2 floods occur in the Texas portion of the Delaware Basin [Thrash, 1979], a literature review did not indicate that CO_2 flooding is currently used in the Delaware Basin within New Mexico. The New Mexico projects referenced in Table 1, including Maljamar and East Vacuum Fields [Pittaway,1985; Stevens, 1992], are located outside of the Delaware Basin on the Northwest Shelf and Central Basin Platform of the Permian Basin. No CO_2 pipelines are known to exist near WIPP. The Twofreds and Ford Geraldine projects are in the south Texas portion of the Delaware Basin.

Major CO_2 Projects in West Texas and New Mexico

State	Field	Formation	Depth (ft)	BHT(°F)	Oil Gravity	Operating Pressure (psi)
Lea Co., New Mexico	East Vacuum	Grayburg-SanAndres	4398	101	38	2100
Lea Co., New Mexico	Maljamar	Grayburg-SanAndres	4000	90	36	1900
Andrews Co., Texas	Means	San Andres	4400	N/A	29	2000
Ward & Loving Co., Texas	Twofreds	Delaware	4820	104	36	2330
Scurry Co., Texas	Kelly-Snyder (SACROC)	Canyon Reef	6700	130	41	2200-2300
Yoakum Co., Texas	Wasson	San Andres	4890	107	32	2000
Andrews Co., Texas	Dollarhide	Devoian Chalk	7800	120	40	-
Culberson Co., Texas	Ford Geraldine	Delaware	2680	83	40	-
Hockley Co., Texas	Slaughter Estate	San Andres	4985	105	32	-

Potential effect of CO_2 injection

In order to investigate the potential effect of CO_2 injection should it occur in the future, EPA conducted some bounding calculations. Using numerous conservative assumptions, we estimated the rate of CO_2 flow through a hypothetical wellbore annulus into an anhydrite interbed at the depth of the WIPP repository. These assumptions included constant pressures at the point of injection and at the intersection of the interbed with the borehole, continuous degradation of the grout in the wellbore annulus between those two points, and an infinite permeability in the interbed. In spite of these worst-case assumptions, which increase the potential effect of the gas injection, no CO_2 is expected to reach the repository from the Land Withdrawal Boundary.

For these calculations, the bottomhole CO_2 pressure used is based on the maximum injection pressures that would be allowed by the New Mexico Oil Conservation Division (NMOCD) for oil reservoirs in the Delaware Mountain Group near the WIPP site . The interbed pressure is set equal to the fracture initiation pressure in Marker Bed 139 used by DOE in the CCA. Use of a constant bottomhole pressure and a steady-state solution conservatively ignores the lower transient flow rates at the marker bed that would occur at the start of injection. The calculation also conservatively assumes that CO_2 injection occurs continuously without shutdown, and that no losses to other interbeds occur as CO_2 is assumed to be displaced through approximately 3500 feet (1,067 m) of degraded annulus cement. Another conservative estimate is that there are no additional thief zones (high permeability rock unit that facilitates increases in gas flow) between the injection point and the marker bed. Additional thief zones would cause additional pressure bleed-off and reduce the amount of gas that could get to the marker bed. Without considering these factors, the net effect of a deeper CO_2 injection horizon would be an additional pressure to drive flow through the annulus.

A simple, but conservative, analytical calculation method was selected to estimate vertical flow through the wellbore annulus for a situation where CO_2 from a hypothetical tertiary recovery project in the Delaware Mountain Group near WIPP is assumed to communicate though degraded annulus cement to the anhydrite interbeds present at the repository level. The rate (q) of flow of gas in cubic feet per day for a given gradient can be calculated using Darcy's law as [Craft and Hawkins, 1959, pp. 262]:

$$q = 6.328\ kA(\Delta P)/u(\Delta l)$$

where

k = permeability (darcys)
A = area (square feet)
ΔP = pressure differential (psi)
Δl = distance (feet)
u = viscosity (cp)

For simplicity, all parameters in this steady-state equation are expressed at pressure and temperature averaged between the two end points. Note that this calculation is independent of total volume injected into the hypothetical well because the rate is dependent on input pressure to the annulus at the bottom.

Interbed depth was assigned as 2168 feet (660.8 m) based on values reported for Marker Bed 139 at the base of the shaft on p. 6-89 of the CCA. Reservoir depth was assigned as the shallowest productive oilfield in the immediate vicinity of the WIPP site at a depth of 5625 feet (1,715 m) as reported in Table C of the EPA Fluid Injection Technical Support Document. [1997] Distance, Δl, was assigned as the difference between these two depths, (5625-2168) = 3,457 feet.

Cement grout in the wellbore annulus was assumed to have uniformly degraded over the 3,457 feet between the injection point and the marker bed to the median value for the permeability of degraded boreholes used in the EPA-mandated Performance Assessment Verification Test (PAVT). The Agency considers this median value to be appropriate because it is based on a range that emphasizes lower permeability values. [EPA Parameter Justification Report 1997 Section 4.3] Note that the average permeability of materials in a series is calculated as the harmonic average [Craft and Hawkins 1959]:

$$k_e = \frac{l_T}{\frac{l_1}{k_1} + \frac{l_2}{k_2}}$$

where k is permeability, l is distance and l_T is total distance. For example, a 3457 foot (1,054 m) long annulus with 100 feet (30 m) of cement with a permeability of $1x10^{-5}$ md ($9.9x10^{-21}$ m^2) and the remaining 3,357 feet (1,024 m) of annulus with a permeability of 520,410 md ($5.1x10^{-10}$ m^2), would have an effective permeability for the entire annulus system of 22.3 md ($2.2x10^{-14}$ m^2). Assumption of an infinitely large interbed permeability allows the interbed to accept all CO_2 flow from the wellbore annulus without creating a back-pressure that would reduce that flow. This simplifying assumption ignores any resistance to flow in the interbed and conservatively assumes that the only resistance to flow is offered by the wellbore annulus. The remaining parameters of annulus cross-section area and CO_2 viscosity are considered reasonable and appropriate and are discussed in the following paragraphs.

Pressure at the interbed was assigned as 1,842 psi (12.7 MPa) based on the fracture initiation pressure reported for Marker Bed 139 on p. 6-118 of the CCA. Pressure at the hydrocarbon reservoir was assigned as 3,561 psi (24.6 MPa) based on personal communications regarding injection pressure limitations with Mr. David Catanach of the NMOCD Santa Fe office. [Catanach, 1997] This maximum bottomhole injection pressure is based on standard NMOCD requirements of 0.2 psi per foot of depth at the wellhead, corrected to a bottomhole pressure gradient of 0.633 psi/ft at the top perforations in the completion. This is consistent with pressures reported for other CO_2 floods in west Texas and Southeastern New Mexico listed in the table above.

Permeability (k) was assigned as the median value of a uniform distribution of log permeabilities for degraded cement used by DOE in the PAVT. This value was used as a reasonable estimate of maximum effective permeability that could be expected to exist over a relatively long annulus distance of 3,457 feet. In the PAVT the value of the permeability parameter ranged from $5x10^{-17}$ to $1 x10^{-11}$ m^2 and had a median of $2.2x10^{-14}$ m^2 or 0.0223 darcys.

Area (A) was assigned based on typical well construction practices as reported in Appendix DEL of the CCA and in Figure BI of the EPA Technical Support Document for Section 194.32: Fluid Injection Analysis. [Docket: A-93-02, Item V-B-22] The annulus area between a typical 7 7/8" hole and a 5 1/2" casing is 0.1773 ft^2 based on correlations presented on p. 76 of the Halliburton Cementing Tables. [1995]

Viscosity, u, of CO_2 is estimated as 0.079 cp at 100º F and 2701 psi. [van Poolen, 1980] The viscosity of CO_2 decreases as temperature increases. Pressure was assigned as discussed below and a reservoir temperature of 100º F has been assigned as a typical temperature recorded for neighboring Delaware Mountain Group oil reservoirs as reported in Table C of the EPA Technical Support Document for Section 194.32: Fluid Injection Analysis. [Docket # A-93-02, Item V-B-22]

Using the above parameter values and unrealistically assuming that no CO_2 will enter any of the units between the injection zone and the anhydrite target bed, the steady-state CO_2 flow rate [q = 6.328 kA(ΔP)/u(Δl)] to the anhydrite interbed is calculated using this method as follows:

> CO_2 flow rate = (6.328 * 0.0223 * 0.1773 *(3561 - 1842)) / (0.079 * 3457)
> = 0.157 cu ft / Day

This rate, at an average pressure[36] (2701.5 psi) and temperature (100ºF), can be corrected to rate at a pressure and temperature representative of interbed conditions (1842 psi and 80ºF) by applying ideal gas law regarding compressibility as follows:

> Interbed CO_2 flow rate = 0.157 * (2701.5 / 1842) * (540 / 560)
> = 0.222 cu ft / Day

The significance of a CO_2 flow rate of 0.222 cu ft/day was evaluated by determining the relative volume of Marker Bed 139 that would be occupied by CO_2 within the minimum radial distance from a hypothetical leaking CO_2 injection wellbore assumed to exist at the Land Withdrawal Act (LWA) Boundary and the repository footprint shown as 7,661 feet (2,335 m; see CCA Vol. I, Figure 3-9). The effective pore volume (PV) of the marker bed is estimated as follows, assuming an average effective porosity of 1.1% [CCA Vol. I Table 6-15] and an average bed thickness of 2.8 ft (0.85 m); [see CCA Vol. I Figure 6-13 Row 6]:

> Effective pore volume =PV
> PV = 3.14*r^2*phi*h = 3.14*7661^2 *0.011*2.8 = 5.68 x 10^6 cu ft
>
> where:
>
> r = radius, assumed as 7661 feet

---

35 Average pressure is calculated using the reservoir pressure and Marker Bed 139 pressure to produce (3561 + 1842) / 2 = 2701 psi. Average temperature is estimated as 100 of as recorded for the WIPP site (80ºF) and neighboring Delaware Mountain Group oil reservoirs (approximately 120ºF) as reported in Table C of the EPA Fluid Injection TSD (1997).

phi = porosity, assumed as 1.1%
h = thickness, assumed as 2.8 feet

EPA has identified no CO_2 flood operations that have existed for more than 26 years [Schumacher 1978], the CO_2 injection phase of floods can be designed for 10 years [Ring, 1996], and typical CO_2 flooding operations appear to reach economic limits after approximately 10 to 16 years. [Flanders and DePauw, 1994; Flanders and McGinnis, 1994] Thus a maximum life of 20 years has been assigned as a reasonable value for the assumed flood duration. Based on the worst-case assumptions outlined for these calculations, a twenty year project could displace about 1,622 cu ft of CO_2 into Marker Bed 139 from a failed injection well (0.222 cu ft/day * 365 days/year * 20 years = 1622 cu ft). This is about 0.029% of the pore volume in the interbed within 7661 feet of the injection well (minimum distance from the LWA boundary to the repository) with a piston-like displacement radius of less than 130 feet. This displacement radius is the area that would be filled by CO_2 calculated as [$(1622/3.14*0.011*2.8)^{1/2}$]. These values are negligible, indicating that under the assumed conditions, most of the CO_2 in the interbed would remain within a few hundred feet of the injection well and the impact on interbed fluid pressures and fluid displacement would be negligible beyond a few hundred feet from the injection well.

If the hypothetical CO_2 flooding operation continued for 50 years, based on the assumptions outlined for these calculations, about 4,054 cu ft of CO_2 could enter Marker Bed 139. This is approximately 0.07% of the pore volume within 7,661 feet of the injection well in the single interbed assumed to be open to flow, with a piston-like displacement radius of less than 205 feet. In other words, even after 50 years and using extremely conservative assumptions, most of the CO_2 that could hypothetically enter the interbed would remain within a few hundred feet of the injection well and would not migrate to the WIPP repository.

Summary

EPA initially determined that DOE's decision to screen CO_2 injection from performance assessment calculations was appropriate. However, public comments submitted to EPA have suggested that CO_2 is or could be used in the vicinity of WIPP and should be evaluated. EPA reviewed available data regarding the technology and industry practice and determined that the use of CO_2 miscible flooding for enhanced oil recovery is currently practiced in the west Texas portion of the Delaware Basin. Most CO_2 injection activity, however, is in the area located outside of the Delaware Basin. CO_2 flooding projects have not occurred within the New Mexico portion of the Delaware Basin. Sufficient site specific concerns related to reservoir size, proximity to existing pipelines and reservoir heterogeneity indicate that limited potential for implementation of the practice exists in the vicinity of WIPP under current conditions.

Moreover, although it appears that CO_2 injection has only limited potential for use around WIPP, simple calculations for a hypothetical flood indicate that, even if it were to occur, CO_2 injection does not pose a threat to WIPP. EPA's calculations assumed that CO_2 would be injected into the

Delaware Mountain Group below WIPP and readily migrate to Marker Bed 139, through which CO_2 is assumed to flow toward the repository. For the very conservative assumptions specified in this study, even for long periods of time, there is little potential for injected CO_2 to ever reach the repository and interact with WIPP waste. Therefore, EPA has shown that CO_2 injection should be omitted from the performance assessment calculations because of the minimal consequences that would occur as a result of CO_2 injection.

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Units and Conversion Factors

Area	square mile (mi^2) x 2.589988 = square kilometer (km^2)
Area	acre x 4046.873 = meters (m^2)
Permeability	millidarcy (md) x 9.869x10-16 = meter squared (m^2)
Pressure	pound per square inch (psi) x $6.895x10^{-3}$ = mega pascal (MPa)
Volume	cubic foot (cf) x 0.02832 = cubic meter (m^3)
Volume	barrel x 0.1589874 = cubic meter (m^3)
Temperature	degree Fahrenheit (°F) –32.0/1.8 = degree Celsius (°C)
Temperature	degree Celsius (C) +273.15 = degree Kelvin (°K)
Mass	pound (lb) x 0.3732 = kilogram (kg)
Density	pound/cubic foot (lb/ft3) x 0.01602 = gram/cubic centimeter (g/cm^3)
Density	pound/gallon (ppg) x 0.09977= gram/cubic centimeter (g/cm^3)
Density	°API x 141.5/131/5+°API = gram/cubic centimeter (g/cm^3)
Dip	foot/mile (ft/mi) x 0.1894 = meter/kilometer (m/km)
Length	foot (ft) x 0.3048 = meter (m)
Length	inch (in) x 2.54 = centimeter (cm)
Viscosity	centipoise (cp) x $1x10^{-3}$ = pascal-second (Pas)

Conversion references include (Bradley, 1989), (Eshbach, 1975) and (Perry, 1973).

Issue U: CO_2 is a cost effective recovery method.

1. *EPA maintains that CO_2 injection costs far more than brine injection due to the easily available sources of brine and the injection quantities required.*

This statement fails to recognize the availability of carbon dioxide in southeast New Mexico, the practice of conserving water whenever possible, the history of CO_2 flooding in the Permian Basin including parts of the Delaware Basin, the efficiency of a miscible type displacement to increase oil production and extend oil field life, and the willingness of local governments to work with companies to encourage the use of CO_2 flooding. If the EPA statement had any merit there would be no CO_2 flooding used in the Permian Basin or any other oil field for that matter. But as shown here, there is extensive CO_2 flooding in the Permian Basin as a result of a large investment in pipelines across New Mexico to bring carbon dioxide from southeast and southwest Colorado and northeast New Mexico to West Texas. (1260)

Response to Comment 8.U.1:

EPA has acknowledged the use of CO_2 flooding for enhanced oil recovery in the Permian Basin, primarily to the northeast and east of the WIPP site outside the edge of the Delaware Basin. EPA's statement that CO_2 injection typically costs more than brine injection is valid. Because the cost of carbon dioxide, additional labor time and slower recovery make this process relatively more costly. It is also known that CO_2 flooding is used in the Permian Basin, that a pipeline network to bring CO_2 to certain limited areas of the Permian Basin is in place, that in certain circumstances the technology can increase oil recovery, and that under certain research and tax incentives have been granted to investigate and/or encourage the use of the technology. Regardless of all these considerations, the balance of evidence indicates that CO_2 injection is only sparingly used in the West Texas portion of the Delaware Basin, and is not used at all in the New Mexico portion of the Delaware Basin. The commenter is incorrect in asserting that CO_2 technology would not be used anywhere in the Permian basin or in any other oil field if it were more expensive than brine injection. CO_2 flooding is normally attempted only after waterflooding has been completed, and may be used at that time despite the relative cost if economic recovery was achievable. It is commonly understood in the oil industry that secondary oil recovery operations such as CO_2 injections are typically more expensive and complicated than primary operations, and enhanced oil recovery using CO_2 is the final step undertaken in the exploitation of hydrocarbon reserves due to increased expense risk and complications. [van Poolen, 1980, p. 132]

The commenter is correct in asserting that a large investment has been made to construct any CO_2 pipelines currently in place. Significant operating expenses are also associated with ongoing maintenance and operation of these facilities. To bring CO_2 flooding into any additional areas of the Permian Basin, into the Delaware Basin or to the vicinity of WIPP will entail significant additional capital expenditure which will have to be justified by sufficient additional production potential from applying CO_2 EOR technology to fields in the area. At this time, EPA is not aware of permits or plans for such pipelines or projects.

Issue V: CO_2 injection is more difficult to control than fluid injection.

1. *The EPA maintains CO_2 injection is more difficult to control, since the rocks are more permeable to gas than to brine, higher injection pressures are required to maintain desired pressure configurations.*

It is not clear why EPA believes that the relative permeability of gas and brine in rock has a role in making CO_2 injection more difficult to control. Please provide a more detailed explanation and references for the statement. (1261)

Response to Comment 8.V.1:

A number of parameters must be considered when evaluating reservoirs as candidates for CO_2 flooding. The most important factors to consider are reservoir geometry and heterogeneity, residual oil saturation, oil gravity, reservoir depth, and availability of CO_2. [Klins, 1984, pp. 41-43] Early breakthrough and poor sweep efficiency are common problems in CO_2 flood projects. [Yaghoobi, 1996, pp. 245-256] Reservoir heterogeneity inhibits uniform contacting of CO_2 with oil and causes pockets of oil-CO_2 mixtures or free CO_2 gas. The low viscosity of oil mixed with CO_2 or free CO_2 gas result in a much higher phase mobility as compared to oil which has not been contacted by CO_2. This promotes rapid movement of the higher mobility phases through the reservoir and early breakthrough to the producing wells, thereby reducing sweep efficiency. [van Poolen 1980, pp. 136-137; Klins, 1984, pp. 41-42] Therefore, EPA concluded that there are a number of complicating factors relative to permeability with respect to gas associated with CO_2 injection.

Tertiary recovery process is relatively more difficult than the secondary (water flooding) and it requires higher displacement efficiency of the contacted oil (discussed in Technology Description Section, see Donaldson 1989). In addition, when carbon dioxide mixes with oil it reduces the viscosity of oil. In this process the bulk of the oil is increased. This creates additional pressure in the reservoir. This process is not directly controllable. Difficulty in controlling pressure has also been mentioned in Twofred Waterflood and Co2, EEG-62.

Issue W: EPA did not provide a reference.

1. *The EPA maintains the presence of gas could inhibit production in that any gas present will be in the nonwetting phase and will occupy the portions of the oil reservoir that have relatively large apertures.*

EPA did not provide any references for this statement. (1262)

Response to Comment 8.W.1:

The statement cited is from CARD 23, Response to Comments, Issue O: Oil Production/Brine Injection Effects. EPA did not provide a reference for the speculation made in this comment. DOE draws the same conclusion as EPA in Docket: A-93-02, IV-G-34, Attachment 6, Section 2.15, p. 10.

Issue X: EPA incorrectly stated that there are no natural gas storage horizons in the Salado Formation.

1. EPA's assessment that there are no natural gas storage horizons in the Salado Formation (CARD 32, p.71) is contradicted by existing storage facilities in the Salado. (50)

2. EPA maintains that "there are no natural gas storage horizons in the Salado Formation" (EPA CARD-32, p. 71). As shown on a map presented to EPA by EEG on October 10, 1996, there are eight gas storage underground facilities in southeast New Mexico, three of which are in the Salado Formation in which the salt was "washed out to create a cavern", according to entry in a State document. (701)

3. Discussions and analyses of human activities with regard to resource extraction are implicitly limited to the Delaware Basin. The EPA states in CARD 32, p. 16, "Hydrocarbon storage takes place in the Delaware Basin but involves reinjection of gas into pre-existing boreholes into depleted reservoirs." This is a correct statement, and it is clear that the EPA considers the Delaware Basin as the appropriate region of interest, and that gas storage activities outside the basin are excluded from consideration. This is reasonable and appropriate due to geologic variations and differences elsewhere in New Mexico and Texas. In addition, the EEG's statement and map which display three natural gas storage facilities in the Salado are incorrect. The facilities identified by the EEG are not natural gas storage facilities, but liquefied petroleum gas (LPG) storage facilities. Also, as identified in the following map, there are five such LPG storage facilities, not three. Nonetheless, these facilities in the Salado are located outside of the Delaware Basin. (921)

4. EPA maintains that "there are no natural gas storage horizons in the Salado Formation" (EPA Card 32-71). As shown on a map presented to EPA by EEG (1996) on October 10, 1996, there are eight gas storage underground facilities in southeast New Mexico, three of which are in the Salado Formation in which the salt was "washed out to create a cavern." Furthermore, the natural gas storage wells cannot be dismissed with a statement that they are not in the Delaware Basin. (1267)

Response to Comments 8.X.1 through 8.X.4:

Underground natural gas storage is primarily used to help offset increased loads placed on gas pipelines which must handle increased fuel requirements to major residential or industrial customers during cold weather. For this reason gas storage reservoirs are usually located near major metropolitan areas or near large industrial users of natural gas such as a major petrochemical complex. [Katz, D.L. and Lee, R.L., 1990, Natural Gas Engineering - Production and Storage, p. 494, McGraw-Hill Publishing Co, New York, NY; Ikoku, C.U., 1984, Natural Gas Reservoir Engineering, pp. 322-323, John Wiley & Sons, New York, NY]

In addition to depleted oil or gas reservoirs, hydrocarbons may be stored in underground, man-made cavities in relatively impermeable rock such as salt, shale, or granite. These storage cavities may be created by conventional or solution mining operations for mineral production or specifically for storage purposes. Use of hydrocarbon storage cavities created in salt formations by solution mining was first conceived in Germany during World War I. [Ikoku, C.U., 1984, Natural Gas Reservoir Engineering, pp 343-344, John Wiley & Sons, New York, NY]

EPA has determined that DOE must consider only activities that take place in the Delaware Basin. Storage facilities located in the Salado, but outside of the Delaware Basin, are not relevant to the screening criteria or to the PA. In Card 32, p. 71, EPA stated that there are no natural gas storage horizons in the Salado Formation. EPA should have stated that there are no known gas storage horizons in the Salado Formation in the Delaware Basin "in the vicinity of the WIPP." This issue was addressed by DOE in a March 12, 1997, letter to Ms. Ramona Trovato [Docket: A- 93-02, II-H-24] in response to EEG's letter of February 7, 1997. [Docket: A- 93-02, II-H-12] According to DOE's letter, "there are no natural gas storage facilities in the Salado in the vicinity of the WIPP, and there are no existing leases which would indicate plans for such activities in the near term."

Section 194.32(c) of EPA's regulations require DOE to include in performance assessment "... an analysis of the effects on the disposal system of any activities that occur in the vicinity of the disposal system prior to disposal and are expected to occur in the vicinity of the disposal system soon after disposal." To avoid unnecessary and potentially unbounded speculation about the nature of future conditions, EPA required DOE to only include in performance assessment activities that meet the foregoing criteria. Because there are no known natural gas storage facilities in the Delaware Basin in the vicinity of WIPP and there are no existing leases that would indicate plans for such activities in the near future, natural gas storage was appropriately screened from use in performance assessment based on regulatory requirements.

In addition, DOE has specifically responded to this issue in Docket: A- 93-02, IV-G-34 p.47, February 24, 1998 (Also responded in the Comment 921 and 1267). DOE's current research in this area supports EPA's position. DOE states, "In addition, the EEG's statement and map which display three natural gas storage facilities in the Salado are incorrect. The facilities identified by the EEG are not natural gas storage facilities, but liquified petroleum gas (LPG) storage facilities. Also, as identified in the following map, there are five such LPG storage facilities, not three. Nonetheless, these facilities in the Salado are located outside of the Delaware Basin."

Furthermore, as DOE correctly points out in Appendix SCR p.105 the mechanism of temporary gas storage, does not support, for economic reasons, drilling of new or additional boreholes. Typically, in oil or gas fields, depleted reservoirs and existing boreholes are used for gas storage. The injected gas is retrieved through the same boreholes when required. Therefore, new human intrusion will not effect the repository.

However, even if natural gas or LPG was currently being stored or was planned to be stored underground in the near future in the vicinity of WIPP, an analysis by EPA indicates that the activity would not affect the ability of the WIPP repository to successfully isolate waste because the migration potential of that gas would be minimal (see analysis below). The major factor to be considered when selecting a reservoir for gas storage is containment of the gas. This requires a very low permeability medium and a detailed understanding of the target reservoir geology. In addition, containment of a gas in a rock unit would require maintaining the gas pressure below the fracture initiation pressure of the rock storage unit. If the gas was stored at a pressure high enough to fracture the rock storage unit, the rock permeability could be increased to the point that it would no longer contain the gas. [Ikoku, C.U., 1984, Natural Gas Reservoir Engineering*,* p 348, John Wiley & Sons, New York, NY]

In order to investigate the potential effect of gas storage in the Salado Formation near WIPP, should it occur in the future, EPA conducted some bounding calculations. A simple but conservative analytical calculation method was selected to estimate horizontal flow from the gas storage chamber through the Salado anhydrite interbeds present at the repository level. An estimate of the distance over which stored gas would migrate after a period of time may be determined from Darcy's law for linear flow through porous media. The assumption of porous medium flow rather than fracture flow is appropriate because, as observed above, considerable care is taken to assure that gas pressures remain below a level that would fracture the rock. The following flow equation was used: [Calhoun, J.C.,1982, Fundamentals of Reservoir Engineering, pp 188-189, University of Oklahoma Press, Norman, OK]

$$q = kA(\Delta P)/u(\Delta l) \qquad [1]$$

where

q = flow (cm^3/sec)
k = permeability (darcy's)
A = area (square cm)
ΔP = pressure differential (atm)
Δl = distance (cm)
u = viscosity (cp)

The amount of fluid that has moved at any given time after the fluid front has moved to a distance l is given by:

$$V = Al\Phi \qquad [2]$$

where

V = volume (cm^3)
Φ = porosity

By taking the derivative of V with respect to time of the second equation, combining these two equations and integrating from time zero to time t yields:

$$\Phi l^2/2 = k(\Delta P)t/u. \qquad [3]$$

Solving for distance yields:

$$l = (2k(\Delta P)t/u\Phi)^{0.5} \qquad [4]$$

Reservoir parameters were obtained from Salado lower anhydrite composite properties which were used as input data for the BRAGFLO model. [Stoelzel, D.M. and Swift, P.N.,1997, Supplementary Analyses of the Effect of Salt Water Disposal and Waterflooding on the WIPP, pp 78-79, Sandia National Laboratories]

$k = 1.288E\text{-}19\ m^2$
= 1.305E-07 darcy

ΔP = difference between fracture initiation pressure and ambient pressure
= (1.430E+07 – 1.408E+07) Pa
= 2.177 atm

Φ = 1.1E-02 fraction
t = 50 years
= 1.5768E+09 sec

u = 0.017 cp for methane gas [Amyx, J.W., Bass, D.M. & Whiting, R.L., 1960, *Petroleum Reservoir Engineering – Physical Properties, p 280,* McGraw-Hill Book Co, New York, NY]

Substituting these values into equation [4] above yields:

$$l = [\ (2 * 1.305E\text{-}07 * 2.177 * 1.5768E{+}09) / (0.017 * 1.1E\text{-}02)\ ]0.5$$
$$= 2188 \text{ cm}$$

In other words, even after 50 years, the gas front would have advanced only 21.88 meters through the Salado anhydride interbeds. Given that in the near future, a natural gas storage reservoir could be developed no closer than about 2,000 m from the repository (the approximate distance to the WIPP Land Withdrawal Area boundary), a gas migration distance of about 22 m is negligible.

A similar calculation may be made to estimate horizontal flow from an LPG storage chamber through the Salado anhydrite interbeds present at the repository level by conservatively using the viscosity of liquid propane, 0.1152 cp [Amyx, J.W., Bass, D.M. & Whiting, R.L., 1960, Petroleum Reservoir Engineering – Physical Properties, pp. 310-312*,* McGraw-Hill Book Co, New York, NY], in equation [4].

Equation [4] for liquid propane becomes

$$l = [\ (2 * 1.305E\text{-}07 * 2.177 * 1.5768E{+}09) / (0.1152 * 1.1E\text{-}02)\ ]^{0.5}$$
$$= 323 \text{ cm}$$

Thus, LPG migration after 50 years would be only 3.23 m - much less than for the natural gas storage case above.

This minimum distance between the WIPP repository and a hydrocarbon storage reservoir also eliminates other potential impacts on the repository such as increases in permeability in the Culebra Dolomite following the hypothetical collapse of a storage chamber. However, even if the storage chamber was within the Land Withdrawal boundary, the effects of chamber collapse would be the same as for collapse of an area that had been mined for potash, which is already included in performance assessment. Therefore, even if natural gas or LPG was stored underground in the vicinity of WIPP, EPA's analyses indicate that there is little potential for an adverse impact on the repository. Therefore, EPA concludes that both natural gas and LPG storage can be omitted from the performance assessment calculations on the basis of both regulatory requirements and because of the minimal consequences that would occur to the WIPP repository.

Issue Y: Scenarios don't adequately address releases to the Pecos River.

1. DOE has never considered the human consequences of contamination of the Pecos River (part of the accessible environment) by plutonium from the WIPP site. (861)

Response to Comment 8.Y.1:

The claim made in Comment 8.Y.1 that radioactivity will reach the Pecos River is unjustified. Releases from drilling (cuttings, cavings, spallings, brine) will occur immediately above the WIPP and exposure is calculated at that location. Transport of these released materials to the Pecos River is unnecessary for PA because the highest dose possible is above the WIPP and analysis at this location (i.e. at WIPP) is included in PA. If the commenter is referring to radionuclide transport through the Culebra, DOE found that for the entire range of conditions it evaluated, radioactivity in excess of the release stands will not reach the LWA boundary [Chapter 8.1.4 and 8.2.3], much less reach the Pecos River (which is over 10 miles from the LWA boundary) in the 10,000-year analysis period. In addition, for purposes of demonstrating compliance with the regulations, there would be no distinction made between a release to the Pecos River and a release to any other part of the accessible environment. The regulation treats all potential releases to the accessible environment on an equal footing, whether they involve the Pecos River, the water-bearing Salado Formation, or the Salado interbeds at more than 2,000 feet below ground.

Issue Z: Rejection of FEPs based on regulation

1. The concept of rejecting a scenario on the basis of regulation allows the DOE the latitude to eliminate any inadvertent human activity that could result in a consequence greater than that of exploratory drilling (Sandia 1992, 4-4; Silva 1996, 158). (1256)

Response to Comment 8.Z.1:

EPA disagrees with Comment 8.Z.1. The regulations do not give DOE the latitude to reject any scenario that would result in larger releases than exploratory drilling. The regulation [40 CFR Part 194] only allows DOE to reject advertent (intentional) intrusions, such as mining of the waste, and human activities outlined in the rule, such as activities that are not current practice. Air drilling is example of an activity that can be screened out of performance assessment because it is not current practice. [Docket: A- 93-02, V-B-29] As discussed in the introductory information to this general issue, EPA's analysis of DOE's FEP examination indicates that DOE analyzed all human initiated activities pertinent to WIPP and adequately identified those that must be applied to WIPP. This limits the inadvertent human intrusion activities to drilling and mining. The regulation is intended to limit the number of scenarios to those that are reasonable based on past human activities and expected future human activities in the Delaware Basin.

Issue AA: Location of WIPP requires performance assessments to focus on human intrusion.

1. The location of the WIPP site, in an area rich in mineral resources, requires that the focus of the performance assessment is on human intrusion. This is different from most other geological environments considered for radioactive waste disposal, where assessments most often [focus] on an undisturbed case (at 13). (1056)

<u>Response to Comment 8.AA.1:</u>

With regard to Comment 8.AA.1, EPA agrees that an emphasis was placed on human intrusion scenarios in accordance with Section 194.33(b). However, the undisturbed scenario was considered a subpart of PA and was analyzed as equally and as thoroughly as human intrusion scenarios. EPA found DOE in compliance with Compliance Assessment requirements of Section 194.54, as well as the Section 194.55 requirements for compliance with individual and groundwater protection requirements. [See CARDs 54 and 55] The CCA analysis shows that human intrusion is the major mechanism of radionuclide release, as indicated in Docket: A-93-02, II-G-01, Chapter 6.5 and Chapter 8.3.

<u>Issue BB: There's no such thing as the undisturbed condition at WIPP.</u>

1. First of all I'd like to say that the undisturbed scenario, the undisturbed condition for the WIPP site is an oxymoron. There's no such thing as the undisturbed condition. We always hear about the WIPP site being in bedded salt lakes that were created over millions of years, and they've been there for millions of years and that's why it's so good to put this in there because it's been there for so long undisturbed. We now have four giant drill shafts that go through all of these geological structures that have been there for millions of years, and it's fractured all the rock and it's crumpled up and that's what's known as the disturbed rock zone. (312)

<u>Response to Comment 8.BB.1:</u>

EPA disagrees with the statements in Comment 8.BB.1. EPA defines “Undisturbed Performance” in 40 CFR Part 191.12 (p) as “the predicted behavior of a disposal system, including consideration of the uncertainties in predicted behavior, if the disposal system is not disrupted by human intrusion or the occurrence of unlikely natural events.” DOE and EPA believe that the components used to seal the shafts will act as barriers and prevent any flow of fluid through the shafts in the short term. [CARD 14, p. 42-43] Specifically, EPA concurred with DOE’s predictions regarding the consolidation and subsequent decrease in permeability of the compacted salt components of the proposed shaft seals. The compacted salt component will serve as the “primary” long-term shaft seal component, since it will be the largest single component (approximately 560 feet in vertical length) and has an inherent compatibility with the host rock material. The salt will be compacted during seal construction to 90 percent of the density of undisturbed halite. Moreover, approximately 100 to 200 years after construction, the pressure from overlying materials and inward creep of the surrounding Salado should further consolidate the salt plug and reduce its permeability to within an order of magnitude of undisturbed halite. The shaft seal design in Appendix SEAL of the CCA received extensive technical review by DOE and also was subjected to an independent design review. EPA concluded that the shaft seal design is adequate because the system can be built and is expected to function as intended. Furthermore, EPA concluded [CARD 14, p. 42-43] that the salt will creep due to deviatoric stress and will permanently seal the disturbed rock zone in approximately 300 years. This process has been experimentally verified and simulated by numerical models. [Docket: A- 93-02, II-G-1, CCA Ref. # 104]

Issue CC: From a safety perspective, documentation and evaluation of FEPs related to future human actions is incomplete.

1. From a safety perspective, documentation and evaluation of FEPs related to future human actions is incomplete (at 20). (1060)

Response to Comment 8.CC.1:

Comment 8.CC.1 is unclear because it does not specify why the FEPs documentation is incomplete with respect to safety, as the ultimate use of all FEPs is to develop conceptual models for use in PA to assess releases based on standards that are health related. [40 CFR Part 191] Furthermore, the comment is irrelevant to EPA's current decision. EPA's decision is based on the radioactive waste disposal regulations at 40 CFR Part 194 and the compliance criteria at 40 CFR Part 194. DOE evaluated a comprehensive set of FEPs that may affect the future performance of the WIPP. From the initial list of over 900 FEPs, the FEPs were screened down to approximately 240 FEPs that could potentially apply to the WIPP site. Finally, a screening of the 240 FEPs was conducted and the number was reduced to about 80. This final screening eliminated certain FEPs on the basis of reasoned arguments or existing data. The elimination of FEPs at this stage was done on the basis of three criteria: (1) negligible consequences, (2) very low probability (less than one chance in 10,000 of occurring during a 10,000-year period), and (3) regulatory requirements. Approximately 80 remaining FEPs were used in the performance assessment in the CCA. The original list of more than 900 FEPs and the screening to arrive at the final set are documented in the CCA in Appendix SCR, Attachment 1. [Docket: A- 93-02, II-G-1] The entire process has been reviewed by EPA and the Agency concurs with the screening process used and information presented in the CCA.

References

NMBMMR (New Mexico Bureau of Mines and Mineral Resources) 1995. Final Report, Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site [Carlsbad, New Mexico] (Reference No. 460) (Docket: A-93-02, II-G-1)

Peake, Tom, 1996. WIPP - Examination of Mining and Hydraulic, U.S. EPA, January 31 (Docket: A-92-56, IV-B-7).

Issue DD: Fluid injection was not adequately considered in the performance assessment.

1. Screening out fluid injection on the basis of low consequence is not acceptable because EPA's calculated probability of 1 in 667 million that an injection well will leak and impact the repository is based on optimistic anticipated performance of injection wells rather than actual experience. (45)

2. What specific oil and gas activities at the WIPP site did EPA evaluate in preparing the fluid injection analysis TSD (V-B-22)? Was a written record of the survey of well operators in the Basin maintained? (78)

3. There is a risk that injection of pressurized brine for enhanced oil production or brine disposal may fracture the marker beds overlying and underlying the WIPP. The injection brine may flood the repository to various release points. This scenario is not considered in the PA. (137)

4. Despite decades of concerns about major water intrusion into the WIPP site, the major release scenarios have not been adequately analyzed. Water flooding, drilling, gas or bring intrusion must be better analyzed and better mitigation measures must be developed. The possibility of catastrophic failure at WIPP with the release of 100,000 to millions of curies is still present. Tens of thousands of gallons of fluid injection from oil drilling can move laterally into the site from outside current boundaries. The boundaries of the WIPP site should be significantly expanded to prevent drilling on a wider safety zone. (256)

5. The first point is that large water flood operations, the type associated with leaks elsewhere in the region, do not now occur in the vicinity of WIPP, and it is not certain they will in the future. It is also not certain they won't occur either. But even if they do, injection wells will not operate any closer to the WIPP in the boundary controlled area which, at closest, is a mile and a half or more from the waste and most waste is further. . . The second point I want to make is that all the leaks have occurred in projection wells elsewhere in southeastern New Mexico in the past, and that's obvious, these leaks occurred with older wells constructed with relatively primitive methods and without modern casing and cemented techniques. . . The evidence is very clear that modern wells like the ones near the WIPP are far less likely to leak than older ones. The third point I want to make is that Sandia has done computational modeling and I'm speaking here as member of the public and not of Sandia, but I'm very familiar with the modeling work. Even for the worst cases they have examined there was no effect on the repository even if major leaks did occur at injection wells. (286)

6. Remember, there are 120 oil and gas wells right now within two miles of the WIPP site. Three of them have been approved for brine injection. So if this repository floods with high pressure brine that dissolves the 55-gallon steel drums, corrodes them rather and dissolves the waste, you will have a high pressure slurry of brine and waste just waiting to be penetrated by the next drill hole which could bring a large amount of the waste to the surface or to the Rustler formation, which then would travel through underground caverns all the way to the salt lake, which in times of major flooding overflows into the Pecos River. (309)

7. As a former reservoir engineer, it appears to me the petroleum potential of the WIPP area has been very significantly overestimated, as has the potential for human intrusion. The use of fluid injection has been also overestimated. If the site is rejected on the basis of the petroleum issues, I think we will have rejected a sound site for reasons that are fundamentally unsupportable. (443)

8. Of the wells listed in EPA's Petroleum Activity Database (TSD III-B-22 at 34) which have been used for injection, how many have leaked? (1009)

9. Some events and processes not analyzed might deserve consideration from a radiological safety perspective, including water flooding due to nearby brine injection, solution extraction of the salt, solution mining of underground cavities for storage, and extraction boreholes disturbing the flow regime (at 19). (1059)

10. EPA did not evaluate releases from fluid injection, even if it occurred outside the site boundary in "undisturbed performance," let alone fluid injection inside the site boundary that will likely occur in the future. (1130)

11. The CCA fails to include an analysis of the fluid injection scenario in predicting the near-term and long-term integrity of the WIPP site. . . EPA must insist that DOE include fluid injection scenarios and recalculate CCA models to reflect this important data. (1198)

12. [S]tudies on hydrofracture of the interbeds from brine injection to promote secondary and tertiary oil recovery show dramatic fracturing is likely at WIPP. See Linear Elastic Model for Hydrofracture at WIPP and Comparison with BRAGFLO Results, Gerstle and Bredehoeft (1997). Failure to incorporate this fracturing into the Performance Assessment is a gross omission that warrants rejection of the certification application. (1200)

13. The EPA also raised questions regarding DOE's consequence analysis and "concluded that regardless of the consequence argument, the probability of such an injection event that affects WIPP is very low, and so this FEP can be eliminated on the basis of low probability" (EPA Card 32-42). The EPA is relying on an optimistic view of future injection well performance which does not reflect the actual experience of documented water flows in the Salado Formation in water flood areas throughout southeast New Mexico. (1258)

Response to Comments 8.DD.1 through 8.DD.13:

DOE *did* address the fluid injection issue (waterflooding and brine disposal) in the Compliance Certification Application. EPA's initial assessment of DOE's screening results indicated that fluid injection FEPs, including enhanced oil recovery and brine disposal were not appropriately modeled. The screening assessment approach used by DOE appeared to be inadequate for injection-related activities, including liquid waste disposal. Subsequent to the submission of the

CCA, both DOE [Docket: A-93-02, Item II-I-36] and EPA [Docket: A-93-02, V-B-22] performed additional modeling of the injection well scenario. EPA concluded that the combination of DOE's original modeling and additional modeling were adequate to show that fluid injection was appropriately screened out. EPA also concluded that, although scenarios can be constructed that move fluid to the repository via injection, the consequences from such an event are within that modeled in the CCA. Furthermore the probability of such a catastrophic failure occurring, given the necessary combination of natural and human-induced events, is low. For more discussion of fluid injection, see Response to Comments, Section 5, Brine Injection and Hartman Scenario.

In accordance with Section 194.32(c), DOE determined that water flooding (for secondary oil recovery) and brine disposal were the only fluid injection scenarios that were currently occurring at the time the application was submitted to EPA or could be initiated in the near future in the vicinity of the WIPP. DOE identified the Bell Canyon Formation below the Salado and Castile Formations as the primary target for fluid injection for brine disposal. DOE stated that this scenario had the potential to produce brine inflow to the WIPP. DOE modeled the fluid injection scenario using WIPP geology, and also using the geology identified in the Rhodes-Yates Field. [Docket: A-93-02, II-A-32, p. 26] The modeling results, which used conservative modeling assumptions, indicated that limited brine compared to natural inflow could potentially get into the WIPP from fluid injection activities in the WIPP case and more so in the Rhodes-Yates case. [CCA reference 611, section III]

Commenters raised questions about DOE's fluid injection modeling and EPA's review also raised questions regarding DOE's screening analysis of fluid injection. EPA required DOE to use modified values for some input parameters, including the period of simulation, and to model the behavior of the disturbed rock zone consistent with assumptions used in the PA. [Docket: A-93-02, Item II-I-17] EPA also required DOE to provide additional information on the frequency of fluid injection well failures. [Docket: A-93-02, II-I-17] EPA requested the information because the CCA did "not contain adequate justification for eliminating consideration of the occurrence of certain fluid injection scenarios at WIPP." [*ibid.,* p 3]

In supplemental work on fluid injection, DOE addressed all the issues identified by EPA. DOE modified the computer model grid configuration and added a new model to address concerns raised by both EPA and commenters. [Stoelzel and Swift, 1997, WPO # 44158; Docket: A-93-02, II-I-36b] DOE researched injection well operating practices in the Delaware Basin and identified significant differences between those in the vicinity of the WIPP and the Rhodes-Yates Field. DOE found that wells near the WIPP are typically less than ten years old and are constructed to much higher mechanical standards (e.g., multiple casing instead of single casing) than the older wells found in the Rhodes-Yates Field due to better technology and NMOCD requirements. DOE identified a range of well failure scenarios, ranging from undetectable brine flow to catastrophic well failure. DOE's data indicated that the probability of a catastrophic well failure in the vicinity of the WIPP is extremely low. [Docket: A-93-02, II-I-36b, Attachment A, pp. 29-33] DOE modeling confirmed that the presence of the Castile at the WIPP also substantially inhibits injected brine movement into the Salado anhydrite marker beds. This is due to "thief zones" into which brine can flow before reaching the marker beds at the waste horizon.

EPA performed its own independent studies of fluid injection. [EPA Technical Support Document for 194.32: Fluid Injection Analysis, Docket: A-93-02, V-B-22] The results of this analysis show that the permeability in marker beds is generally lower than that used in the PA, and that other factors (such as injection rate, injection interval, etc.) also play a very important role in fluid injection.

In summary, DOE *did* address the fluid injection issue in the Compliance Certification Application and in supplemental information. In addition, EPA conducted its own fluid injection analyses. On the basis of DOE's and EPA's analyses, EPA determined that fluid injection was appropriately screened out of performance assessment on the basis of low consequence. In addition, these separate analyses indicate that catastrophic failures of injection wells are also unlikely to occur.

DOE recognized that anhydrite interbed fracturing could occur as a result of high repository gas pressures, and included that scenario in its performance assessment calculations. DOE's fracturing model was based in part on the results of in situ fluid injection tests into anhydrite interbeds at WIPP, and in part on theoretical considerations. In response to public comments questioning the validity of the fracturing model used by DOE, EPA has reviewed in additional detail the basis for that model and has compared its modeling assumptions with those of an alternative model proposed in public comments. The alternative model is based on LEFM and assumes that the fracture occurs in a previously unfractured, elastic continuum. DOE's model assumes the fracture occurs in a previously fractured medium. While DOE's model predicts the simultaneous creation of multiple fractures, LEFM predicts the creation of a single fracture. For a given increase in permeability, DOE's model predicts a larger porosity increase than the LEFM model. In evaluating the applicability of these models to the anhydrite interbeds at WIPP, EPA notes that the interbeds contain pervasive natural fracturing, open pores and void spaces, as well as natural surfaces of weakness along bedding planes. Further, the *in situ* fluid injection tests at WIPP produced multiple parallel fractures rather than single fractures. [Beauheim et al.,WPO # 27246, Docket: A-93-02, V-B-14; and in Larson et al., WPO # 44704, Docket: A-93-02, II-I-24] Based on actual conditions at WIPP and the results of DOE's *in situ* injection tests, EPA concludes that DOE's fracturing model is adequate for use in performance assessment and more closely represents actual conditions at WIPP than the alternative LEFM model recommended in public comments.

For additional information on EPA's analysis of the fluid injection scenario and the Hartman Scenario, see EPA's Technical Support Document for Section 194.32: Fluid Injection Analysis [Docket: A-93-02, V-B-22] and the Response to Comments, Section 5.

Issue EE: DOE and EPA under estimate potash reserves and therefore under estimate future effects of such mining.

1. However, in the CCA DOE seriously underestimates the areas where potash will be mined in

the future. The underestimate results in an underestimate of the future effects of such mining. (146)

2. If EPA has concluded that the potash above the repository would not be mined under current economic conditions, that judgement should be reviewed. As recently as 1990, the AMAX Mine was operated by Horizon Corp. by opening an apparently sub-economic 4-ft bed of the McNutt after the original 10-ft bed was exhausted. Because its location uniquely serves all agriculture surrounding the Gulf of Mexico, the potash resource over WIPP should be assumed to be exploited as soon as institutional controls cease to prevent mining. (846)

3. The treatment of mining accepted by EPA makes little sense as a projection of the probability of future mining. There is no logic behind the use of a Delaware Basin-wide average, since potash is known to be concentrated near the WIPP in the Known Potash Leasing Area, rather than equally distributed within the Basin. (966)

4. [T]he BLM map shows that underground mining of potash creates long drifts, sometimes miles long, that would constitute a conduit for flow of contaminated brine. Releases by such pathway have not been modeled and should be. (967)

5. The CCA models such mining within the controlled area on the assumption that the regulatory "resources, similar in quality and type to those resources currently extracted from the Delaware Basin" (Section 194.32(b)) are represented in Figure 6-20. The reference materials expressly assume that the regulatory reference to "resources of similar quality" means the 37.5 grade-thickness contour for langbeinite and the 55 grade-thickness contour for sylvite. (MASS Att. 15-5, at 7). However, these CCA contours do not state the limits of currently mineable potash. The BLM map of mineable potash shows the extent of resources that are "of lease quality" (id.). Parameters used by BLM -- the agency responsible for leasing potash for development -- are "four feet of 10 percent K_2O as sylvite [i.e., a contour of 40] or four feet of four percent K_2O as langbeinite [i.e., a contour of 16] or equivalent combination of the two minerals." Since 40 CFR 194.32(b) specifies an assumption that "mineral deposits of those resources, similar in quality and type to those resources currently extracted from the Delaware Basin" will be mined, EPA requires better information than DOE has provided as to the type and quality of minerals currently mined. (997)

6. The potential impacts of mining are not fully discussed in the CCA Vol. 1, because the EPA has restricted the range of effects to be considered in performance assessment (at 15). It would be preferable to see information on the observed effects of potash mining locally (at 16). (1058)

Response to Comments 8.EE.1 through 8.EE.6:

Potash ore is found in the McNutt Potash Zone in the Salado Formation which lies above the repository horizon. Eleven ore zones have been identified in the McNutt, but economic mineralization is not found in all ore zones. In the vicinity of the WIPP the ore lies at depths of

420 meters (m) (1,377.9 feet (ft)) to 530 m (1,738.8 ft) as compared to a repository depth of 655 m (2,148.9 ft). Two different types of minerals are currently mined -- sylvite (KCl) and langbeinite ($K_2SO_4 \cdot 2MgSO_4$).

In the CCA, DOE identified potash mining as an activity that occurs in the vicinity of the disposal system prior to or soon after disposal. [Docket: A-93-02, II-G-1, Chapter 6, Section 6.4.6.2.3] The assumed extent of this mining outside the disposal system was based on three elements:

- Existing potash leases [Docket: A-93-02, II-G-1, Chapter 2, Figure 2-37 or Volume X, Appendix MASS Attachment 15-5, Figure 1];
- Mined out areas in existing mines [Docket: A-93-02, II-G-1, Volume X, Appendix MASS Attachment 15-5, Figure 5]; and
- Offsets from existing hydrocarbon boreholes [Docket: A-93-02, II-G-1, Volume X, Appendix MASS Attachment 15-5, Figure 5].

DOE calculated the mineable reserves within the land withdrawal area using data from 40 cored holes. [NMBMMR, 1995, Docket: A-93-02, II-G-1, Ref. 460, Chapter VII] This data provided sufficient information to calculate the reserves both within the WIPP site and within a one mile band around the site. Even though reserves were calculated outside the WIPP site, this information was not used in the CCA. Rather, existing leases outside the land withdrawal boundary were assumed to be fully mined prior to or soon after disposal.

EPA's review of minable reserves indicated that DOE identified current minable thicknesses and horizons near the WIPP. DOE's estimate roughly corresponds to that identified in an EPA technical memorandum. [Peake 1996] EPA recognized that this estimate is not necessarily representative of the entire Delaware Basin, and it is conceivable that additional reserves could be mined in the WIPP area. However, speculation of this nature would extend to other horizons or reserves, which is beyond the intent of Section 194.32(b). Section 194.32(b) requires DOE to examine only those resources "similar in quality and type to those resources currently extracted from the Delaware Basin;" potash resources of a type or quality that are currently not mineable for either technological or economic reasons need not be addressed in DOE's analysis.) EPA therefore concurred with DOE's approach. [See CARD 32, Section 32.B]

Comment 8.EE.3 questioned the logic of basing the probability of future mining on an average over the entire Delaware Basin since potash is confined to a portion of the Basin. The probability of mining -- and the decision to base the probability of mining on activities in the entire Delaware Basin -- were established in the 40 CFR Part 194 rulemaking, and are not subject to change during rulemaking for the certification decision. The approach selected by EPA for excavation mining was consistent with the approach used for drilling which considered the entire Delaware Basin even though hydrocarbon drilling targets are not uniformly distributed across the Basin.

[Preamble, 61 FR p.5229; and Response to Comments for 40 CFR Part 194, Docket: A-92-56, Item V-C-1, p. 12-8 to 12-9, 12-14] The Delaware Basin provides a definable area with generally consistent regional geology.

EPA notes that, contrary to the statement in Comment 8.DD.2, economic potash resources are not known to exist above the repository; the area above the waste panels has been designated as a "barren" zone by the Bureau of Land Management. The Agency believes that use of current economic conditions to evaluate ore reserves is appropriate. In fact, as discussed above, the Agency's approach for mining over the regulatory time frame is consistent with the Agency's approach to drilling. For drilling, EPA's criteria use oil and gas resources as surrogates for future resources, even though petroleum resources are expected to be depleted within a small fraction of the regulatory time frame; similarly, for mining, EPA requires DOE to examine resources that are currently extracted, even though other resources may become more valuable in the future. [61 FR 5229, 5233] This approach is also consistent with the future states guidance in Section 194.25(a). The economics of mining potash in the future is not known and it would be difficult or impossible to predict the market. The commenter does not substantiate the claim that there will be a sudden increase in demand for potash from the Gulf of Mexico area. While it is possible that such an increase could occur, this is exactly the type of speculation -- about what economic, social, or technological factors might change in the future -- that EPA sought to avoid in issuing the compliance criteria related to future state assumptions and future human activities. It is known that the ore vertically above the repository is of poor quality and thickness (compared to what is being mined today). In any case, EPA does not believe that the example of the 4 feet bed quoted in the comment is relevant to the potash above the WIPP, since opening a new mine based on poor quality and mining locally (small scale) after exhaustion of a thick 12% K_2O grade are two entirely different situations. Moreover, the effects of mining in terms of subsidence and changes in hydraulic conductivity have already been considered. Consistent with the commenter's suggestion, EPA requires DOE to examine the effects on hydraulic conductivity based on the assumption that all the known mineral resources lying in the immediate area of the WIPP (the controlled area) will be extracted when mining is predicted to occur.

EPA believes that the scenario presented in Comment 8.DD.4 showing that mining excavations will act as conduits for contaminated brine flow is speculative and unsupported. Excavated mining drifts are horizontal and will need other mechanisms to come in contact with the repository since the WIPP lies approximately 400 feet below the potash mining operations. Such mechanisms include subsidence-related effects and future drilling in the repository, which can act as vertical pathways. DOE has considered these pathways and modeled them in the performance assessment. [CCA 6.4 Docket: A- 93-02, II-G-I, Docket: A- 93-02, II-A-29] EPA has analyzed the effects of mining and finds that DOE's models are adequate and reasonable. [Docket: A- 93-02, V-B-8]

Regarding Comment 8.EE.6, EPA found that the CCA fully considered the impacts of mining as required by the WIPP compliance criteria. (As discussed in the preceding paragraphs, when issuing 40 CFR Part 194, EPA reasonably restricted the range of mining effects considered in PA in order to be consistent with criteria on both future states and drilling.) In reviewing DOE's compliance with Section 194.32(b), EPA considered whether the CCA included a detailed, accurate, and comprehensive analysis of mined resources in the WIPP area and sufficient information to demonstrate how mining probability was determined. Specifically, EPA examined the validity of DOE's potash reserve estimates, including DOE's assumptions regarding potash reserve location, quality, and minable horizons. EPA also examined the CCA to determine how hydraulic conductivity within supra-Salado units was modified relative to changes that could be caused by mining over the 10,000-year regulatory period. EPA concluded that DOE considered the impacts of mining as required by Section 194.32(b). The information DOE provided on potash mining can be found in the Chapter 6 of the CCA. [Docket: A-93-02, II-G-1] EPA's analysis of potash mining can be found in CARD 32, Section 32.B. [Docket: A-93-02, V-B-2]

<u>References</u>

NMBMMR (New Mexico Bureau of Mines and Mineral Resources) 1995. Final Report, Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site [Carlsbad, New Mexico] (Reference No. 460) (Docket: A-93-02, II-G-1)

Peake, Tom, 1996. WIPP - Examination of Mining and Hydraulic, U.S. EPA, January 31 (Docket: A-92-56, IV-B-7).

<u>Issue FF: DOE did not properly consider solution mining.</u>

1. EPA's dismissal of the potential for solution mining of potash due to a lack of fresh water is contradicted by recently granted rights to large quantities of water. Similarly, suggestions that langbeinite is not readily soluble are irrelevant because the most likely target ore is sylvite, which is readily soluble. (51)

2. <u>EEG Comment</u>: "There are other fluid injection issues that have either not been fully addressed or in which there appears to be a misunderstanding of the issue including, . . . the likely expansion of solution brine wells in the Delaware Basin, and the likely initiation of solution mining activities in maturing potash mines."

[DOE Response] Brine production through solution mining has not taken place near the WIPP site, and there are no plans for wells in this area in the near future. The constraints upon the location of solution mining operations imposed by the availability of water indicate that there is a low probability of brine production through solution mining near the WIPP site in the near future.

Brine production through solution mining near the WIPP site can be eliminated from performance assessment calculations on the basis of low probability of occurrence in the vicinity of the disposal system. . .

Brine production-through solution mining takes place in the Delaware Basin, and the DOE assumes it will continue in the near future.

Despite oil and gas exploration and production taking place in the vicinity of the WIPP site, the nearest operating solution mine is more than 20 miles from the WIPP site. The nearest permitted site is 14 miles from the WIPP site, but the operator has indicated that there are no plans to proceed with drilling at this site. These locations are too far from the WIPP site for any changes in hydrogeology or geochemistry, from subsidence or fresh water or brine leakage, to affect the performance of the disposal system. Thus, the effects of historical, current, and near-future solution mining in the Delaware Basin can be eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

[F]uture brine production from within and outside the controlled area has been eliminated from performance assessment calculations on regulatory grounds. (922)

3. [T]he proposed decision does not consider solution mining of potash, both as to the effects of normal mining operations and as to the effect of accidents in mining. Such mining of potash should be modeled. (968)

4. EPA did not analyze mining scenarios, including solution mining for potash. (1132)

5. The CCA inappropriately eliminates solution mining for potash. DOE relies on current regulations which do not fully cover all scenarios, nor do they prevent solution mining for potash. (1213)

6. [T]he CCA did not address the practice of solution mining of halite for use as brine in the drilling industry. The CCA specifically stated:

> The DOE is not aware of solution mining for potash or other minerals in the Salado within the Delaware Basin at this time (DOE 1996, MASS-87).

EEG (1996) identified seventeen active brine production facilities removing halite from the Salado Formation, three of which were in the Delaware Basin (BW-6, BW-19, and BW-27). EPA notes that Appendix DEL identified a dissolution project approximately 14 miles from the WIPP. Furthermore, EPA notes that DOE submitted additional information which showed that brine production between 1979 and 1991 created a cavity of 3.4 million cubic feet and that it would be longer than 50 years before subsidence would occur. . . there are three solution mining operations for brine production near the city of Carlsbad area and at least 16 miles from the WIPP site. EPA mentions only one about 14 miles from the WIPP Site. Furthermore, EPA does not discuss the trend towards drilling brine production facilities closer to WIPP. (1266)

7. EPA's conclusion that potash solution mining is not likely at WIPP relies on solicited

comments that are factually incorrect and inconsistent with the published scientific literature.

DOE and EPA maintain that excavation mining captures the effects of solution mining on the hydraulic conductivity of the overlying aquifers. However, based on the scientific literature, the prediction of subsidence above solution mines can be much more complex than the prediction of subsidence due to excavation mining. The issue needs to be reevaluated for the final rule for WIPP.

Potash is a resource used for the production of food, therefore it appears to be incorrect to calculate a probability of mining based on past potash production which was inherently dependent on past mineral economics and the availability of high grade ore. It also seems reasonable to assume that low grade potash ores will eventually be mined to meet world demand. (1269)

Response to Comments 8.FF.1 through 8.FF.7:

Solution mining of potash is a method of extracting potash by pumping water underground, dissolving the potash, and pumping the resulting liquid to the surface. The liquid is saturated with the potash ore. Typically two boreholes are used. In order to make solution mining of potash economically successful, solubility, heat (to increase the solubility) and thick ore zones are required.

In the CCA, DOE assumed that potash would be mined by room-and-pillar or other conventional methods and that solution mining of potash would not occur because of mineralogical and economic constraints. [Docket: A-93-02, II-G-1, Chapter 6] However, a permit was recently sought to conduct a pilot study north of the WIPP to assess whether solution mining of potash minerals is a feasible technology. Because this indicates that solution mining might be feasible, EPA requested from DOE more information about the effects of solution mining. [Docket: A-93-02, Item II-I-17]

DOE provided supplemental information [Docket: A-93-02, II-I-31] which concluded that the impacts of solution mining for potash would be the same as those for room-and-pillar mining, and that potential subsidence-induced hydraulic effects in the Culebra would be similar to those for typical mining practices. Solution mining for potash was also addressed in further supplemental information provided by DOE in response to comments from the EEG specifically addressing this issue. [See letter from Robert H. Neill, EEG, February 7, 1996; and Docket: A-93-02, Item II-H-24] DOE stated: "If solution mining for potash were undertaken in the vicinity of the WIPP it could result in subsidence. However, performance assessment calculations already assume that widespread subsidence will occur as a result of potash mining in the near future. The assumed extent of subsidence and its effects on the hydraulic conductivity of the Culebra are independent of the mining methods used (underground excavation or solution mining)." The supplemental information also addresses sub-standard ("not normal") mining operations, stating that "Poor management of the solution mining operations could conceivably result in water losses to hydraulically conductive units above the Salado. Large water losses would result in low potash yields and most likely remedial actions would be taken by the operators. Undetected leakages to the Culebra would be no more severe than leakages that might be speculated to occur during secondary oil production operations (water flooding) or brine disposal in the vicinity of the WIPP. The potential effects of such events have been analyzed by Stoelzel and O'Brien [1996, Docket: A-93-02, II-A-32] and have been shown to be of low consequence to the performance of the disposal system."

EPA has examined information presented by DOE and stakeholders [EEG-68, p. 135-137] and concludes that solution mining may be omitted from the performance assessment on regulatory grounds. Under Section 194.32(b), for mining over the regulatory time frame, DOE must consider the consequences of excavation mining (the general case of "making a hole"), and does not need to examine techniques, such as solution mining, that depend on the specific resource being mined. [61 FR 5229; Docket: A-92-56, Item V-C-1, p. 12-14] For similar reasons, DOE need not assume that solution mining may occur through boreholes that are predicted to be drilled over the regulatory time frame. [Section 194.32(d)] However, Section 194.32(c) requires DOE to consider other activities which are occurring or are expected to occur in the vicinity of the WIPP in the near future. Such activities would include solution mining which occurs before, or is expected to occur soon after, the compliance application is prepared. While solution mining for potash may possibly occur in the future, it is not now occurring in the Delaware Basin, and to assume its occurrence in the future would still be speculative. This is the type of speculation -- about what economic, social, or technological factors might change in the future to make certain activities or events more or less likely -- that EPA sought to avoid when issuing the compliance criteria related to future state assumptions and future human activities. (Section 194.25(a) states that, except where specified otherwise, performance and compliance assessments "shall assume that characteristics of the future remain what they are at the time the compliance application is prepared, provided that such characteristics are not related to hydrogeologic, geologic or climatic conditions." In order to reasonably constrain speculation about future human intrusion events in particular, Sections 194.32 and 194.33 provided further guidance specifically about how mining, drilling, and other human activities should be analyzed.) Because solution mining for potash is not a current practice in the vicinity of the WIPP, and therefore, is not an activity expected to occur prior to or soon after disposal, EPA concludes that it does not need to be included in performance assessment.

EPA also points out that the solution mining "examples" cited by stakeholders are well outside of the Delaware Basin, and were often initiated due to "large inflow" of water or due to the highly distorted nature of strata. [EEG-68, p. 136] Water inflow in Delaware Basin mines is not sufficiently high to mandate a change to solution mining, and Delaware Basin potash strata are not so highly distorted that solution mining is required. The two main minerals within WIPP area ores zones are langbeinite and sylvite. [CCA Table 2.7] Solution mining of langbeinite is not possible because the ore is not soluble to a significant degree. Solution mining of sylvite is technically feasible, as shown in the studies reported by Davis and Shock, 1970. [Solution Mining of Thin Bedded Potash, Mining Engineering, July 1970 included as an attachment in Docket: A-92-03, Item IV-G-39] However, solution mining is not currently practiced probably because the ore beds in the McNutt are too thin for economical processing. [NMBMMR 1995, Chapter 4, *op. cit*.] After reviewing the supplemental information, EPA agrees with DOE's conclusion that even if solution mining is practiced in the future, the subsidence effects would be similar to those from conventional mining. EPA has also independently analyzed subsidence. [See TSD on Potential Effects of Mining on Ground-Water Flow and Radionuclide Transport at the WIPP Site, Section 5.1 for additional discussion, Docket: A-93-02, V-B-8]

Issue GG: Specific solution mining scenarios should have been considered in the PA.

1. We have analyzed the two potentially troublesome scenarios associated with the solution mining of potash. The scenarios involve encountering a borehole during the solution mining. In the first scenario brine flows to WIPP because the pressure of mining fluid injection is 25% above hydrostatic. In the second scenario flow occurs down the first borehole, moves through the repository, and flows out a second borehole. At the maximum borehole permeability used in both PA and PAVT, 10^{-11} m^2, the releases are significant. They are summarized [below]:

> 1 well scenario -- cumulative flow to WIPP -- 2,000 m^3 or 4% WIPP pore volume
>
> 2 well scenario -- cumulative flow out -- 500 m^3 or 5 - ½ EPA units radionuclide (depends on concentration)

This analysis suggests that the results are sufficiently significant that these scenarios should have been included in the PA calculations. The drilling frequency mandated for the analysis of WIPP indicates that the repository will be penetrated a number of times by drilling. PA indicates that 6 drilling hits are not uncommon. Mining of potash is also anticipated in the 10,000 year planning horizon for WIPP. It is likely that this mining will be done through solution techniques. (1049)

Response to Comment 8.GG.1:

EPA determined that solution mining for potash is appropriately excluded from the performance assessment on regulatory grounds. Nonetheless, as added assurance, EPA considered what the potential effects of such mining might be, if it occurred, including the scenarios postulated by the commenter. EPA questions the validity of these scenarios and logical subsequent assumptions. In order for the aforementioned scenarios to occur, one must assume that 1) solution mining activities above the WIPP horizon would encounter a borehole that penetrates through the mined horizon to the WIPP, and 2) the solution mining activities above the WIPP horizon would allow fluid to enter a borehole that penetrates the WIPP horizon, travel through the WIPP, and exit through yet another borehole that penetrates the WIPP. The scenarios postulated by the commenter further assume that a borehole(s) has been drilled and, presumably, plugged prior to the solution mining operation. If solution mining occurs within 200 years after the borehole has been drilled and plugged, the borehole plug at the Rustler/Salado contact (above the McNutt Potash Zone) is expected to remain intact with a permeability of 5×10^{-17} m^2, causing flow to be directed only downward. [CCA,

Appendix DEL, Attachment 7, Docket: A-93-02, Item II-G-1, p. 19] For the proposed scenarios to occur, the well casing must be assumed to have failed even though the borehole plug remains intact. In the CCA PA, the processes of casing corrosion and plug degradation are linked. [Appendix DEL, DEL Attachment 7, p. 9, Docket: A-93-02, Item II-G-1] The commenter does not claim that the CCA assumptions are wrong, and does not explain under what conditions the circumstances would be different from those assumed in the CCA.

In the first scenario, flow into the repository can occur if the repository pressure is less than about 9.3 MPa.[37] As can be seen from Figure 3.3.3 in Helton and Jow, 1996 [Docket:A-93-02, II-G-7], pressures above 9.3 MPa occur in about 18% of the realizations which would preclude solutions from flowing from the McNutt to the repository for the first 200 years after intrusion. In another 2% of the realizations no pathway would exist because a continuous borehole plug would be emplaced through the Salado blocking downward flow. [Docket:A-93-02, II-G-1, Appendix PAR, p. PAR-112] Thus, in about 80% of the realizations it would be possible for solutions to flow from the McNutt into the repository. As shown in Fig. 3.1.5 of Helton and Jow, 1996 [*op. cit.*], cumulative brine flows into the repository range from 5,000 to 140,000 m^3 for either an E1 or an E2 intrusion, which are incorporated into the PA. Thus, even if there were additional inflow of 2,000 m^3 as the commenter asserts, the total brine flow volume is very likely to be within the range included in the CCA. The commenter makes no assertions as to the consequences of this inflow. EPA believes it is reasonable to expect that the consequences of any inflow from potash solution mining would be the same as for brine inflow of comparable volumes from other sources, and therefore, that the effects of such brine are already addressed by the brine volumes encompassed by the CCA.

If solution mining occurred more than 200 years after borehole plugging, the borehole plug at the Rustler/Salado contact is assumed to have degraded (in 98% of the realizations), and solution mining fluid could also flow up an abandoned borehole depending upon hydrologic and borehole plug permeability conditions further limiting flow into the repository. As shown by the commenter's own calculations, brine inflow is only 20 m^3 when the CCA median borehole permeability is used. [Docket:A-93-02, IV-G-39] The commenter states that with 2,000 m^3 of brine inflow, 4% of the porosity will be brine filled. EPA does not agree with that statement. The excavated volume of the repository is 436,000 m^3 and the minimum porosity with no gas generation is about 22%. [Docket:A-92-03, II-G-1, Appendix PORSURF, Figure PORSURF-3] This means that the maximum fraction of volume occupied by brine would be about 2% and, for higher gas saturations on which the commenter's calculation of 2,000 m^3 was based, the fraction would be less than 1% because the porosity would be higher.

The second scenario postulated by the commenter requires that the repository be penetrated by two boreholes prior to solution mining of the potash. Both boreholes would need to intersect the same

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4 Assuming that brine with a density of 1200 kg/m3 is injected at the bottom of the McNutt at 527 m at a pressure 25% greater that the hydrostatic, the injection pressure would be 7.8 MPa. An additional hydrostatic head of 128 m would set the injection pressure at a repository depth of 655 m at 9.3 MPa.

waste panel in order for brine flow to occur as proposed by the commenter. The commenter assumed that the boreholes were 600 m apart. At this spacing the holes could not intersect the same waste panel since a typical panel is 253 m long and 110 m wide. The probability of two or more boreholes intersecting the same waste panel in 200 years is $6x10^{-4}$. [Docket: A- 93-02, II-G-I, Appendix MASS-18]

If the boreholes were drilled more than two hundred years apart, the plug in the first-drilled borehole would have degraded, creating an alternate path to the surface which could divert some of the flow away from the repository. In addition, the consequences of such an event are less than the 5.5 EPA units stated by the commenter. If the release for the second scenario is 500 m^3 as asserted by the commenter and if the maximum concentration of radionuclides in the brine is $5x10^{-3}$ EPA units/m^3 [Fig.5.1.4 in Helton and Jow, 1996, *op.cit.*], then the maximum release for an intrusion at 10,000 years would be 2.5 EPA units. The mean release can be estimated from Fig. 5.1.1 in Helton and Jow, 1996 to be about $0.5x10^{-3}$ EPA units/m^3 which equates to a release of 0.25 EPA units.

The Agency also notes that, if the pressure drop for brine flow through the waste is greater than 2.3 MPa (9.3 MPa less 7.7 MPa hydrostatic head less 0.3 MPa friction loss), there will be insufficient pressure available to drive waste from the borehole assuming that the outflow borehole is brine filled. It is not apparent that the commenter has addressed this possibility. In its modeling of direct brine releases, DOE has shown brine saturations in excess of about 0.4 are required for brine to flow from the waste and up the borehole. [Helton and Jow, 1995, Fig. 5.1.8, *op. cit.*] This only occurs in about 25% of the realizations and would be not be significantly changed by an incremental release of 500 m^3.

Further supporting the unlikely nature of the proposed scenarios is the fact that potash ore reserves in the vicinity of the WIPP will probably be exhausted by the time disposal is complete and active institutional controls have been terminated (in about 135 year). According to the following table most of the mines in the area will be played out in less than 35 years and the longest expected mine life is 125 years. The Agency also notes that under current regulations hydrocarbon drilling into potash areas is either proscribed or allowed only under special circumstances. [Docket:A-93-02, II-G-1, MASS Attachment 15-5, p. 4]

The U.S. Bureau of Mines estimated the expected life of the active potash mines around the WIPP site as summarized in Table 1-2. [TSD on Potential Effects of Mining on Ground-Water Flow and Radionuclide Transport at the WIPP Site, Docket:A-93-02, V-B-8]

Active Potash Mines in New Mexico Showing Estimated Capacity, Average Ore Grade, and Mine Life at the Average 1992 Price of $81.14/st product

Operator	County	Product Capacity (st/yr[1])	Ore Grade (% K_2O)	Mine Life (yrs)
Eddy Potash Inc.[2]	Eddy	550,000	18	4
Horizon Potash Co.	Eddy	450,000	12	6
IMC Fertilizer, Inc.	Eddy	1,000,000[3]	11[3]	33
Mississippi Chemical	Eddy	300,000	15	125
New Mexico Potash[2]	Eddy	450,000	14	25
Western Ag-Minerals[4]	Eddy	400,000	8[5]	30

Data from J.P. Searls, U.S. Bureau of Mines, oral communication, 1993.
[1] May not be operating at full capacity.
[2] Owned by Trans-Resource, Inc.
[3] Muriate, langbeinite, and sulfate combined.
[4] Owned by Rayrock Resources of Canada.
[5] Langbeinite only.

Therefore, EPA concludes that even if solution mining were to occur, the scenarios postulated by the commenter are either unrealistic or have already been accounted for in the PA modeling of brine inflow. However, the Agency emphasizes that, in accordance with the WIPP compliance criteria, solution mining does not need to be included in the PA. As previously discussed, potash solution mining is not an ongoing activity in the Delaware Basin. Section 194.32(b) of the rule limits assessment of mining effects to excavation mining. Thus the solution mining scenarios proposed are excluded on regulatory grounds after repository closure. Prior to or soon after disposal, solution mining is an activity that could be considered under Section 194.32(c). However, DOE found that potash solution mining is not an ongoing activity in the Delaware Basin; and one pilot project examining solution mining in the Basin is not substantive evidence that such mining is expected to occur in the near future. (Even if mining were assumed to occur in the near future, the proposed scenarios would not be possible because, even though solution mining might occur, there would be no intruding borehole to provide a pathway into the repository: active institutional controls would preclude such drilling during the first 100 years after disposal.) Furthermore, Section 194.33(d) states that PA need not analyze the effects of techniques used for resource recovery (e.g. solution mining) after a borehole is drilled in the future.

Issue HH: Future mining activities may impact WIPP.

1. How disruptive are drilling and mining operations near WIPP likely to be? They are going on right now, reported as close as one mile away. With a growing human population we can probably expect more such activity as time goes on--searching for more potash, oil, and natural gas. (827)

Response to Comment 8.HH.1:

The CCA analysis evaluated the oil and gas drilling release scenarios referred to in the comment. These scenarios are described in Chapter 6, Section 6.4.6, and Appendix SCR. [Docket: A-93-02, Item II-G-1] EPA's evaluation of these scenarios can be found in EPA documents such as the Technical Support Document for Section 194.32: Fluid Injection Analysis [Docket: A-93-02, Item V-B-22], and EPA's Analysis of Air Drilling at WIPP. [Docket: A-93-02, Item V-B-29] The CCA assumes that all mineable potash reserves within the LWA will be extracted during the regulatory time frame and that all existing potash leases outside the LWA will be fully mined except for those regions defined by a mining barrier around hydrocarbon boreholes.

With regard to DOE's assumptions on drilling in the area, the criteria at 40 CFR Part 194 allow DOE to assume that current drilling practices in the Delaware Basin will continue in the future, but require them to assume that drilling will occur throughout the entire 10,000-year regulatory time frame (even though oil and gas resources are expected to be depleted within a small fraction of that time). All of the well drilling assumptions in DOE's analysis are based on documented studies of current drilling practices in the Delaware Basin. [CARD 33 -- Consideration of Drilling Events in Performance Assessment, Docket: A-93-02, Item V-B-1] Based on this information, EPA believes that the impacts of drilling and mining are appropriately addressed in the CCA PA.

Issue II: DOE should assume that all potash, within the controlled area, is removed within a century.

1. It is assumed that, after active institutional control is lost, potash resources within the controlled area will be completely removed within a century. DOE should not be allowed to select, randomly or otherwise, the century of the regulatory time frame in which such mining is calculated to occur. The realistic and conservative assumption is that potash mining will occur during the first century, as soon as active institutional control is lost. (1181)

Response to Comment 8.II.1:

The CCA analysis did not select any particular time at which potash mining would occur. In accordance with Section 194.32(b), DOE assumed in the CCA a 1 in 100 probability that mining would occur in each century of the regulatory time frame. DOE evaluated the consequences from 3,000,000 unique future scenarios; some of which included mining and some of which did not. In all of the future scenario calculations, mining was assigned a probability of occurrence and was allowed to happen at different times in different simulations. Based on the results of the 3,000,000 futures that were evaluated, the CCA showed that the containment requirements of 40 CFR 191.13 was satisfied.

With respect to mining (and any other activities), the CCA was not intended to model the worst possible set of conditions or assumptions. The containment requirements in Section 191.13 are stated in terms of probabilities of radionuclide releases. The form of the regulation makes it necessary for DOE to do a probabilistic analysis using a large number of future scenarios. Only then can the results be meaningfully compared to the performance standard in 40 CFR Part 191. EPA found the number of future scenarios and the consequences meet the requirements of 40 CFR Part 194. [CARD 32 (a)] Relative to excavation mining over the regulatory time frame, EPA determined that DOE estimated the probability of occurrence as specified in Section 194.32(b) of the WIPP compliance criteria.

Issue JJ: EPA should have used different brine pocket parameters in the PAVT.

1. The characterization of the potential high pressure brine pocket used in the PAVT is much more accurate than the representation used in the CCA calculations. There are two parameters used in the PAVT that are still inaccurate. First, the PAVT uses a sampled pressure range of 11.1 to 16.5 MPa gage for the Castile brine, based on regional occurrences of brine, rather than the 12.6 MPa gage measured at WIPP-12. WIPP-12 brine almost certainly protrudes under the WIPP repository. However, it was found that the pressure range used in the PAVT leads to prediction of more and larger brine releases than the single value of 12.6 MPa (Rucker, 1998).

Secondly, there is poor justification for the 1% lower end of the EPA range for the probability of encountering a pressurized brine pocket. The 60% upper end is based on an electromagnetic survey of the WIPP site (CCA 2.2.1.2.2) that indicates brine is likely under about 60% of the repository. Most importantly, the probability of hitting brine under WIPP should be based on local WIPP information and not the entire Delaware basin. The calculated size of the WIPP-12 brine reservoir and the existence of boreholes around WIPP-12 that have not encountered brine in the Castile constrain the WIPP-12 reservoir such that the reservoir must extend under the repository (II-H-25). The brine indicated by the electromagnetic survey must be part of the WIPP-12 reservoir. Hence, the probability of encountering brine should be modeled as 60%. Thus, the PAVT under represents the probability of encountering a brine reservoir while overestimating the effect of the reservoir. (1309)

Response to Comment 8.JJ.1:

The EPA Mandated PAVT was conducted by DOE at the direction of EPA in order to verify that the cumulative impact of changes in parameter values identified by EPA and changes to computer codes would not require additional PA runs. The PAVT calculations were conducted similar to the CCA calculations with the exceptions of the parameter changes and the modified computer codes.

The initial pressure of a Castile brine reservoir randomly determined to be encountered beneath the WIPP waste panels was treated by DOE as a sampled parameter in performance assessment with a triangular distribution, a range of 11.1 to 17 MPa, and a mode of 12.7 MPa. [CCA Vol. I, Table

6-26 and CCA Vol. X, Appendix MASS, Attachment 18-1] The mode of 12.7 MPa was the estimated pressure of the WIPP-12 brine reservoir and use of a triangular distribution emphasized pressures approximating that value in random sampling. The range was determined from pressure information from other brine reservoirs that had been encountered in the area, as adjusted for the depth of the WIPP-12 reservoir, which was considered a surrogate depth for a brine reservoir beneath the waste panels. The minimum of 11.1 MPa is the hydrostatic pressure at WIPP-12. The maximum of 17 MPa was based on the maximum ratio of brine pressure to local lithostatic pressure that had been observed in other brine reservoirs. A detailed explanation of the basis for these pressure values is presented in CCA Vol. X, Appendix MASS, Attachment 18-2. EPA agrees with Comment 1.SS.1 that the pressure range of 11.1 to 17 MPa used in performance assessment would lead to prediction of more and larger brine releases than the single value of 12.6 MPa because the higher pressures in the range provide a greater driving force for releases.

EPA carefully evaluated the potential occurrence of brine pockets below the WIPP. EPA found that, on a geostatistical basis, DOE believed the probability of a borehole encountering brine below a waste panel to be 8 percent [Powers et al., 1996], partly because the brine is expected to be in fractures that are oriented vertically or slightly less than vertical. However, EPA noted that DOE's geologic and geophysical basis for the 8 percent probability value appeared questionable. [CCA Vol. I Section 2.1.6.1.3, p. 2-87, and CCA Vol. V, Appendix DEF.2, pp. DEF-1 to DEF-18; Docket: A-93-02, II-G-1] EPA also found that DOE's discussion of the size, orientation, and repressurization potential of the Castile brine reservoirs was not well supported by the CCA. [CCA Vol. I, Section 2.2.1.2.2, pp. 2-107 to 2-108, and CCA Vol. V, Appendices DEF.2, pp. DEF-1 to DEF-18, and DEL.7.5, pp. DEL-81 to DEL-87; Docket: A-93-02, II-G-1] The probability value for encountering a brine pocket was also poorly supported because other DOE data imply this probability could be as high as 55 percent. [CCA Vol I, Section 2.2.1.2.2, pp. 2-107 to 2-108; Docket: A-93-02, II-G-1]

EPA also considered the possibility that the WIPP-12 brine pocket may underlie the entire repository site and therefore the probability of encountering pressurized brine could approach 100%. This consideration is based on the assumption that the WIPP-12 reservoir is cylindrical in shape, which EPA considers unlikely due to brine residing in vertical or subvertical fractures. Although EPA agrees that part of the WIPP-12 reservoir may underlie part of the site, the TDEM survey data (see CCA Vol. I, Section 2.2.1.2.2 [Docket: A-93-02, II-G-1]; Technical Support Document for 194.14: Content of Compliance Application, Section IV C(1)(e) [Docket A-93-02, V-B-3]; and Technical Support Document for 194.23: Parameter Justification Report, Sections 4.1, 4.4, 4.5 [Docket: A-93-02, V-B-14]) do not support speculation of a 100% probability of encounter. In view of the lack of support from the TDEM data and the other concerns expressed above, EPA did not believe that a 100% probability was supported by available data. EPA therefore directed DOE [Docket: A-93-02, II-G-26 and II-G-28] to change the probability of hitting a brine pocket in the PAVT to a range that incorporated low to moderate probabilities (0.01 to 0.6), and to sample that range. The basis for selecting this range has been discussed in response to the Comments 5.J.5, 5.BB.13, and 5.BB.16 and in Docket: A-93-02, V-B-30.

Issue KK: Beginning date for oil and gas development

1. Since potash activities may delay oil and gas production for up to 100 years (TSD III-B-22 at 28), should oil and gas development be deemed to begin 100 years hence in the potash zone? (1008)

Response to Comment 8.KK.1:

Oil and gas production are assumed to occur in the controlled area after the 100 year period when active institutional controls are assumed to cease their effectiveness. Mining could also occur after the 100 years. Cessation of active institutional controls has been incorporated into the performance assessment. [CCA p.6-181,Docket: A- 93-02, II-G-I] DOE has used effectiveness of PICs in performance assessment. They have taken credit of 0.99 as the effect of PIC during the remaining 600 years after AIC. This represents a reduced rate of mining and drilling by factor of 0.01 for this period compared to the post PIC period (remainder of the regulatory period). [Appendix EPIC, Docket: A- 93-02, II-G-I and CCA Vol. I, Chapter 6, p. 6-182] EPA determined that DOE did not derive its estimates of the PICs credit in accordance with the Compliance criteria. [62 FR 58828] Therefore, in the PAVT, credit for PICs was omitted. The PAVT demonstrated that, even without granting credit for PICs, the radioactive waste standards are met. As indicated in the PAVT results [Docket: A- 93-02, II-G-28], the repository meets the regulatory standards at 40 CFR 191.13 using these assumptions about the occurrence of drilling and mining. [Appendix SA, Docket: A- 93-02, II-G-I]

Issue LL: Performance assessment is arbitrary.

1. EPA's specifications as to how to assess future human actions suggests that the performance assessment is arbitrary. The IRG would prefer some discussion of the assumptions and of whether they are conservative (at 10). (1052)

Response to Comment 8.LL.1:

Due to the long regulatory time period, uncertainty is expected in projecting the performance of the disposal system. To address this issue, 40 CFR Part 194 placed some statistical requirements on the results of performance assessment and the standard of "reasonable expectation." [Background Information Document, Docket A-92-56, V-B-1] EPA did in fact determine that some aspects of the performance assessment were arbitrary, for example PICs credit. EPA also determined that some values used in the performance assessment were not sufficiently supported and required DOE to verify of various changes on the calculations by performing the Performance Assessment Verification Test (PAVT). EPA did, however, determine that the DOE met the requirements of Section 194.32 in determining what features, events and processes were relevant to WIPP and accepted the results of the performance assessment. A discussion of conservatism used in the performance assessment can be found in the response to comments, Section 8, Issue J.

Issue MM: Releases more than ten times the limit can occur.

1. There is substantial scientific evidence in the record that releases more than 10 times the release limits can occur (II-H-28, II-D-116, II-D-120, and IV-D-14). EPA should use "good science" and accept these results or require new PA runs with those modeling results and the more reasonable parameters previously described, which will show substantial violations in PA runs. (1163)

Response to Comment 8.MM.1:

Contrary to the commenters claim, there is no substantial and credible scientific evidence to suggest that releases more than 10 times EPA's release limits can occur. The documents referred to in the comment address the consideration and evaluation of fluid injection (Hartman Scenario) and air drilling in the performance assessment. EPA has conducted extensive review and analysis of these scenarios and has determined that they are appropriately omitted from the performance assessment calculations.

Issue NN: Releases are within the compliance limit.

1. EPA finds the probabilities of release from the WIPP as projected 10,000 into the future are well within compliance with the standards of 40 CFR part 191. That's what DOE is required to demonstrate to EPA's satisfaction. The standard is a probabilistic one so the demonstration of compliance is also probabilistic. Projecting 10,000 years into the future, that's the best you can do. We will never know how accurate the projections for modeling are, but they are based on a very well researched geologic formation and current knowledge of geochemistry and material science. (328)

Response to Comment 8.NN.1:

40 CFR Part 194, containment requirements, are probabilistic and account for the cumulative impact of releases 10,000 years into the future. EPA agrees with the comment that projections that far into the future must be based on a complete evaluation of geologic, hydrologic, geochemical, and other technical factors, with the impacts of system performance modeled well into the future. EPA also agrees that DOE adequately characterized the site's geology and geochemistry, and adequately evaluated combinations of features, events, and processes that may occur through the 10,000 year regulatory time frame. The full discussion of EPA's review on these topics are found in CARDs 14, 23, 32 and 33 [A-93-02, III-B-02] as well as responses to comments for these sections.

Issue OO: Waste could form a brine slurry.

1. [T]he underground disposal facility could contain an appreciable volume of water. The co-mingling of water and nuclear waste creates a slurry of waste that invalidates the strategy of disposing of nuclear waste in "dry" salt beds at WIPP. The creep or "self sealing" property of salt is a liability when brine is present because it squeezes the slurry and becomes a means for driving liquid waste to the surface. Waste in a liquid form is likely to carry radioactive material to the biosphere in quantities that exceed environmental standards in the release scenarios required by the EPA. We conclude that there is no assurance that the proposed barriers will isolate and contain liquid waste for the time interval required by environmental standards. We agree strongly with the NAS panel on WIPP that it must be demonstrated that the safety of the repository will not be affected by the inflow of brine and by the potentially rapid movement of radionuclides. (1329)

<u>Response to Comment 8.OO.1:</u>

Although many salt mines are "dry" in the context that what little brine inflow occurs can generally be removed by evaporation in the ventilating air, at WIPP brine inflows over 10,000 years into the sealed repository can be sufficient to saturate the waste. Inflows of brine are expected to come from overlying formations such as the Culebra Dolomite, by flowing down exploratory boreholes with degraded plugs, a minor amount flowing down the sealed WIPP access shafts, brine flowing in through the anhydrite interbeds, brine flowing in through the Salado halite, and brine flowing in from a Castile brine reservoir that has been intersected by an exploratory borehole. All of these sources of brine are included in DOE's performance assessment modeling. See CARDs 23 and 32 for more information on how brine inflows were considered in the performance assessment.

<u>Issue PP: Drillers might abandon a flowing well.</u>

1. DOE states that brine flowing straight up a borehole from a Castile brine pocket would entrain little, if any, waste from the repository. Based on this reasoning, the dose to the driller is assumed in performance assessment to be limited to cuttings, cavings, and spallings. . . It is the <u>second</u> exploratory borehole, in what is known as the E1-E2 scenario, that would tap a pressurized repository and bring radionuclides in excess of EPA standards to the surface. Drillers might indeed abandon such a flowing well, and such an action would release additional radionuclides into the accessible environment. (1182)

<u>Response to Comment 8.PP.1:</u>

The author of Comment 8.PP.1 is correct in stating that brine flowing from a Castile brine reservoir during drilling was not assumed by DOE to entrain waste or contaminated brine from the repository during drilling. This assumption was specifically questioned by DOE's Conceptual Models Peer Review Panel as documented in Section 3.15 of the Panel's July 1996 report. [CCA

Vol. XII, Appendix PEER, Attachment PEER-1; Docket A-93-02, II-G-01] DOE's subsequent response allowed the Panel to conclude that releases by this mechanism would be of low consequence, as documented in Section 3.15 of the Panels December 1996 report. [Docket A-93-02, II-G-12] This conclusion was based on the low probability that Castile brine flowing up the borehole during drilling would mix within the repository, displacing significant volumes of contaminated repository brine which would then flow up the borehole. DOE assumed the velocity of the Castile brine would be so great that it would flow up the borehole and very little would enter the repository proper. Further, the second exploratory borehole would, in the short term of days as implied by the comment, be no different than the first borehole in that the short-term Castile flow will also bypass the waste and move directly to the surface. The assumption made by the comment for short-term Castile flow is thus incorrect. However, it is acknowledged [Chapter 6.4; also see the Technical Support Document for 194.23: Models and computer codes for EPA's review of DOE's multiple intrusion conceptual model] that long-term brine flow could occur from this scenario. In the longer term after drilling was completed and the borehole plugs were assumed to have been emplaced and subsequently degraded, Castile brine was included in performance assessment as contributing to waste releases.

Contrary to the assertion in Comment 8.PP.1, second borehole penetrations were found in performance assessment results to generally release less waste than first penetrations. This was because of the long term venting of repository gas that occurred through degraded plugs in the first boreholes. With lower gas pressures in the repository, the principal driving force was reduced and the releases were smaller. If the first borehole was not degraded when the second borehole intruded, as was the case in some PAVT calculations [Docket: A- 93-02: II-G-26, II-G-28], releases are still within the containment standards, because the conditions in the repository are similar to an undisturbed case.

The possibility that drillers might abandon a flowing well was not considered in performance assessment. Rather, in compliance with Section 194.33(c), DOE assumed that future drilling practices would remain as they are today and that drillers would continue to follow regulations that require them to control flowing wells quickly and to collect and dispose of the brine in a safe manner. Attachment A of CARD 33 presents regulations cited by DOE as pertinent to oil and gas well installation and abandonment. DOE does account for the possibility that it might take some time (up to 11 days) to control a "blowout" as implied in the comment. [Technical Support Document for Section 194.23: Parameter Justification Report, Docket: A- 93-02, V-B-24]

Section 9 Results of Performance Assessments -- Section 194.34

Issue A: Prediction of radioactive releases into the environment

1. Some argue that there's no way to predict or prevent human intrusion into the repository area, which would bring radioactivity into the human environment. The Performance Assessment done for the Second Supplemental Environmental Impact Statement clearly shows there were no releases to the environment under any of the scenarios considered except for waste brought to the surface by multiple drilling. Even those amounts of waste material do not exceed the radioactivity limits of EPA regulations. (170)

Response to Comment 9.A.1:

The performance assessment (PA) and EPA-mandated performance assessment verification test (PAVT) demonstrate to EPA's satisfaction that releases will not exceed the radioactivity limits of EPA's regulations. The containment requirements at 40 CFR 191.13 require that cumulative releases from a disposal system have a likelihood of less than 1 in 1,000 chance of exceeding a normalized release of 10 and a likelihood of less than 1 chance in 10 of exceeding a normalized release of 1. Section 194.34(f) requires the mean of the population of complementary, cumulative distribution functions (CCDFs) to meet the containment requirements of 40 CFR 191.13 at a statistical confidence level of 95 percent. The PA yielded CCDFs with 100 percent of the curves lying orders of magnitude below the 1 in 1,000 probability limit at a normalized release of 10, and approximately 99 percent of the CCDFs lying below the 1 in 10 probability limit at normalized releases of 1. The Agency also required DOE to perform a PAVT to demonstrate that the combined effect of all parameter and computer code changes requested by the Agency and implemented by DOE would not be significant enough to necessitate a new PA. The PAVT yielded CCDFs with 100 percent of the curves lying below a normalized release of 10, and over 90 percent of the CCDFs below the 1 in 10 probability limit at a normalized release of 1. [Sections 34.F.4 and 34.F.5 in CARD 34 -- Results of Performance Assessment]

As mandated by the WIPP LWA [Pub. L. No. 102-579, as amended by Pub. L. No. 104-201] EPA's decision on the certification of the WIPP through the rulemaking process depends on the results of the PA that DOE carried out for the CCA, and not upon work performed for the Second Supplemental Environmental Impact Statement.

Issue B: Use of uncertainties in the performance assessment

1. The motivation for conducting a probabilistic performance assessment is to evaluate the effects of uncertainty in parameters and conceptual models. Although the inclusion of uncertainties in performance assessment calculation is inescapable, using distribution functions rather than fixed values allows the performance assessment to include the uncertainty within the calculations. (203)

Response to Comment 9.B.1:

EPA agrees. The Agency believes that it is appropriate to include quantifiable uncertainties in a performance assessment by sampling parameter values from distribution functions in a statistically valid manner, based upon data that have been reviewed for appropriateness and adequately qualified.

During the Agency's review of the parameters used in models and computer codes in the CCA PA, EPA found that there were some parameters that DOE had not fully documented. [Section 12.4 in CARD 23 -- Models and Computer Codes, Section 34.B.5 in CARD 34 -- Results of Performance Assessments, and EPA Technical Support Document for Section 194.23: Parameter Justification Report, Docket: A-93-02, V-B-14] EPA required DOE to perform additional PA calculations in a PAVT in order to verify that the cumulative impact of all potential problems in codes, parameters, and assumptions incorporated in PA would be small enough that the WIPP would meet the containment requirements of Section 191.13. Of the twenty-four parameters revised in the PAVT, EPA required four parameters that were represented as point values in the CCA to be changed to probability distributions: DRZ_1-PRMX_LOG, the permeability of the disturbed rock zone around the repository; CONC_PLG-PRMX_LOG, the permeability of concrete borehole plugs; GLOBAL-PBRINE, the probability of hitting a brine pocket in the Castile layer underneath the repository; and BOREHOLE-DOMEGA, the angular velocity of a drill entering the repository. [EPA Technical Support Document for Section 194.23: Parameter Justification Report, Docket: A-93-02, V-B-14, p. ES-6] EPA considered probability distributions for these parameters to be more appropriate than constant values because the former incorporated a range of uncertainty that was supported by data.

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2. The other thing that gets dismissed, our ninth paper to the Department of Energy was basically a cry for a error analysis on human errors. . . [DOE assumes] there will never be a human error. (315)

3. DOE says it has included human error because it is already included in selecting the parameters that are plugged into DOE's formulas. CARD believes, however, that the likelihood of human error significantly affecting the probability of containment is high for reasons described below and that it should have its own separate place in DOE's calculations. (903)

Response to Comments 9.B.2 and 9.B.3:

Comment 9.B.3 consists of a paper, entitled Human Error and the Department of Energy, submitted on behalf of CARD. [Docket: A-93-02, Item II-H-33, Attachment 9] The paper is purported to be based largely on a report by William R. Freudenburg entitled Human and Social Factors in the Transportation of Nuclear Wastes, written in 1991 for the State of Nevada. Mr. Freudenburg's report describes "various human and organizational factors that lead to increased risks -- especially in complex technological systems like the WIPP project."

The central thrust of CARD's paper is that things can and do go wrong in large and complex technological systems. CARD describes a number of examples in support of this idea, including: a "rock-on-a-rope" incident at Hanford Reservation in which several people were contaminated in an attempt to unplug a blocked pipe; four accidents at Los Alamos National Laboratory (LANL), including a shooting; delays in opening the Nuclear Materials Storage Facility at LANL because of design flaws; and a waste hoist incident that took place at WIPP in July 1987, despite DOE's calculation of an annual probability of only 1 in 60 million. The paper concludes that "[p]oor management and planning has [sic] left us where we are now -- trying to complete a complex cleanup project without basic knowledge about the waste, the site, and the repository."

EPA agrees with the commenters that the possibility of human error exists and should not be ignored. This is a major reason why EPA required, at Section 194.22, the establishment of an extensive and comprehensive Quality Assurance program (based on the highly stringent National Quality Assurance program developed by the American Society of Mechanical Engineers for the design, construction, and operation of nuclear facilities) to cover activities at the WIPP. While such a program cannot eliminate risk, it puts in place a framework that can greatly reduce the likelihood or severity of the mistakes and accidents that might occur. EPA disagrees, however, that there is a lack of "basic knowledge about the waste, the site, and the repository." DOE has presented, in the CCA and subsequent supplementary materials, substantial information pertaining to the waste, the site, and the repository. Moreover, EPA has identified and gathered substantial information independently.

The issues of primary concern to EPA are the *probabilities* that various types of seriously dangerous events might occur, and the *consequences* if they did. These issues are accounted for and expressed properly in the containment, individual dose, and ground water protection requirements at 40 CFR Part 191, which call for probabilistic performance and compliance assessments that incorporate human error. The probabilistic formulation of the containment requirements at Section 191.13, in particular, and the demonstration of compliance in terms of complementary cumulative distribution functions, required at Section 194.34(a), were called for so as to incorporate uncertainty. This uncertainty includes measures of inhomogeneity or imprecision in physical parameters, along with uncertainty about future human activities that might affect the site (such as drilling or mining), and human error, to the extent that it can be quantified.

EPA's analysis of the CCA and supporting documentation leads the agency to believe that it is unlikely that human error could jeopardize the long-term performance of WIPP. The disposal regulations, and all of the PA calculations, relate to the performance of the disposal system after the shafts are backfilled and sealed. (As mentioned above, EPA's requirements for quality assurance are intended to reduce the possibility of human error in activities prior to disposal, such as backfilling and sealing. During the operational phase, activities at WIPP must also comply with DOE's standards and procedures.) There is little role for human error in the performance of a sealed, isolated, and possibly unattended disposal system. The exception is potential human intrusion, which the PA considers in the manner specified by EPA at Section 194.33. EPA notes that all of the examples discussed in the CARD paper deal with procedures or facilities that are currently operational or underway, and that the human error in these situations was apparently detected and responded to either immediately or within a relatively short time after occurring. There will be 35 years of operation for DOE to detect errors in, for example, the design of the disposal system, sealing of the waste disposal rooms, borehole plugs, waste drums, or waste characterization. Also, during this time EPA will have continued oversight of the facility to further reduce the probability of human error and potentially identify such situations before they occur. If any such problems should arise, they could be reflected in future additional modeling to determine their potential effects on WIPP's performance.

EPA carefully considered DOE's overall approach to assessing the risks from releases of TRU wastes from the repository due to human intrusion, as well as risks from individual doses and concentrations of contaminants in ground water for scenarios not involving intrusions. EPA understands that there are aspects of the relevant modeling data and calculations that could be improved upon with unlimited time and resources. Indeed, a critically important aspect of this rulemaking was the solicitation of comments on all aspects of DOE's application, including ways to improve aspects of the assessment of true hazards associated with the WIPP. Having examined the CCA, related documents, and public comments in great detail, EPA believes that all plausible events that could have a profound influence on the integrity of the repository or on the safety of the citizenry have been incorporated properly into DOE's analyses. In particular, DOE has included its understanding of the "likelihood of human error" to the greatest extent feasible.

In summary, EPA believes that the PA accounts properly for human intrusion events, which are the only scenarios during the regulatory time frame in which human error would reasonably be expected to play a significant role. EPA does not expect that human error will cause departures from the design based on which the facility is certified. If any changes do occur, EPA will evaluate them and determine if a new performance assessment or other modification is necessary, and will conduct a rulemaking accordingly.

Section 10 Active Institutional Controls -- Section 194.41

Issue A: Effectiveness of active institutional controls for 100 years

1. EPA elected not to award DOE any credit for passive institutional controls (PICs) at the WIPP. Why then did EPA accept DOE's active institutional control (AIC) design? (33)

2. There will be active controls at WIPP for the next hundred years. This means that someone will be guarding the site for 100 years. Are we to believe that after that time man will cease to be able to read posted warning signs? (188)

3. EPA agrees with the CCA that active institutional controls (AIC) "will completely prevent human intrusion for 100 years after closure" (at 58826). SRIC notes that such a conclusion can only be drawn by ignoring the actual practice over the past 100 years in which drilling has occurred in areas where it is restricted, and guards and fences have failed to prevent drilling. SRIC believes that AIC one hundred percent credit should not be assumed and that expert elicitation is necessary to support such a conclusion, and no such elicitation was conducted by DOE. (1164)

4. CARD is pleased that DOE has committed to exercising 100 years of active institutional control over the WIPP site. (1176)

5. Under the heading of "potash mining," DOE devotes an entire page to its plans for exercising active institutional control, and never addresses the issue of what happens when active institutional control is lost. (1178)

Response to Comments 10.A.1 through 10.A.5:

EPA's analysis of DOE's compliance with the requirements for active institutional controls [Section 194.41] was separate from that for passive institutional controls. [Section 194.43] Accordingly, EPA's decision not to allow DOE to take credit for passive institutional controls (PICs) did not affect the Agency's consideration of the active institutional controls (AICs) credit. As is explained in CARD 43 -- Passive Institutional Controls, EPA decided not to grant DOE's proposed PICs credit for the following reasons: (1) DOE did not employ expert judgment to derive the credit, as EPA clearly intended, and (2) DOE's analysis did not account persuasively for the uncertainty associated with forecasting the effectiveness of PICs.

PICs are qualitatively different from AICs. Generally speaking, PICs are intended to function without maintenance. AICs, however, involve direct human oversight and intervention to prevent human intrusion into the WIPP. AICs, as prescribed by the Compliance criteria, may only be assumed to contribute to a reduction in predicted human intrusions for 100 years. The limitation of 100 years for credit for the effectiveness of AICs in performance assessment calculations is required by Section 191.14(a) which provides "performance assessments that assess isolation of the waste from the accessible environment shall not consider any contribution from active institutional controls for more than 100 years after disposal."

DOE proposed to employ the following AICs: to place a perimeter fence and road around the WIPP's "footprint," to post warning signs at the site, to conduct routine surveillance, and to repair the fence and signs as needed. DOE noted that both construction of long-term site markers and maintenance of the legal ban on resource extraction activities at the WIPP site would effectively serve as AICs. In addition, DOE plans to monitor parameters related to disposal system performance for some time after decommisioning. [CARD 42 -- Monitoring, Section 42.D.1] These activities are consistent with the definition of AICs established by the disposal regulations. [Section 191.12(f)]

DOE argued in the CCA that the proposed AICs could be maintained for 100 years, and that regular surveillance could be expected to detect a drilling operation in a prohibited area that is set up in defiance or ignorance of posted warnings. EPA recognizes that 100 percent effectiveness of AICs over 100 years cannot be established with certainty. For example, whether a warning sign will be understandable 100 years from now is no less relevant than whether the sign will even be in place; but since it is actively controlled, signs can be replaced, if missing, or updated should changes in language occur. Nevertheless, the proposed AICs are fully within DOE's present capability to implement and may be expected to be enforceable for a period of 100 years. Based on public comments and the Agency's own analysis, EPA concluded that a similar statement could not be made with regard to the proposed PICs credit.

Neither EPA nor DOE has suggested that a system of AICs that is effective for 100 years after disposal will cease to be effective at 101 years. The Compliance criteria require DOE to employ active institutional controls at the WIPP site, but do not specify a period for which they must continue. However, DOE may not assume in a performance assessment that AICs contribute to a reduction in human intrusion for longer than 100 years after disposal. In this regard, DOE stated in the CCA that "DOE is committed to retaining active control over the site for as long as is practicable, but at least for 100 years." [CCA Chapter 7, p. 7-31]

One commenter states that EPA's acceptance of the AICs credit ignores failures during the last 100 years whereby active institutional controls did not prevent drilling events. However, the commenter does not identify a specific failure whereby a drilling activity occurred in an area with protections comparable in any respect to those that will be maintained at the WIPP. EPA notes that the Environmental Evaluation Group (EEG) independently issued a report describing lapses in a permitting arrangement between DOE and the Bureau of Land Management [Docket: A-93-02, Item II-A-41, EEG-55], as well as a report showing that a well was inappropriately drilled on a lease owned by DOE. [Item II-E-34] Given the definitions of active and passive institutional controls in 40 CFR 191.12, EPA found that governmental control over land use and resource exploration at the WIPP site should be treated as a passive control and so considered EEG's reports in that context. Even so, the failures identified by EEG pertain to leases outside the WIPP Land Withdrawal Area. The area to be circumscribed by the proposed AICs (i.e., the repository "footprint" -- is significantly smaller than the Land Withdrawal Area. The commenter has not explained why signs, fencing, and routine patrols would be insufficient to detect and avert a drilling operation at the repository footprint. EPA is not aware of any instance in which a drilling event occurred at the anticipated WIPP repository footprint, which to date has not been marked by signs or fencing.

The same commenter also states that an expert judgment elicitation would be necessary to support one hundred percent effectiveness of AICs. Section 194.41 does not require AICs credit to be derived by expert judgment elicitation, though DOE may elect to use that approach. [Response to Comments Document for 40 CFR Part 194, p. 13-2] DOE did not use expert judgment, as the commenter notes. Nevertheless, EPA found DOE's argument to be satisfactory to justify use of the proposed AICs credit in the performance assessment because the controls may reasonably be expected to detect a drilling operation near the WIPP, and because the effectiveness of AICs is fully within DOE's power to control. [62 FR 58826] For further explanation of this decision, see CARD 41 -- Active Institutional Controls. EPA does not consider DOE's choice not to employ expert judgment to be a sufficient basis to determine not to grant credit for AICs.

Another comment questions how DOE accounted for mining after AICs cease to be maintained. DOE proposed that AICs will be maintained at the WIPP site for a minimum of 100 years after disposal. Since the performance assessment was required to assume that active institutional controls must cease to be effective after 100 years, potash mining was assumed to resume within the controlled area at that time. EPA required DOE to model the effects of potash mining on the performance of the repository over 10,000 years, both with and without the contribution of AICs during the first 100 years. DOE completed this modeling and demonstrated that the WIPP complies with the disposal standards regardless of the use of AICs credit. For an explanation of EPA's analysis of DOE's modeling, see CARD 23 -- Models and Computer Codes. For an explanation of DOE's incorporation of mining into the performance assessment, see CARD 32 -- Scope of Performance Assessments.

Section 11 Monitoring -- Section 194.42

Issue A: Adequacy of the environmental monitoring plan

1. There were some major problems with the draft WIPP Environmental Protection Implementation Plan (EPIP) that I thought were important to correct (as outlined within my draft CAO Corrective Action Report, 97-001). . . It turns out that a 72 hour radon "cool-down" that was in the draft EMP, for initiation of decay counting of air monitoring filters, had been removed from the final version without my knowledge from section 5.3.2. I also reviewed all of the associated operational procedures to find an absence of a "cool-down" specified. . .There are two radon isotopes, radon-220 and radon-222. The problem that radon causes with air monitoring of radionuclides suspended in the atmosphere is due not to radon itself, but to its decay daughters. Radon is a gas, but its decay daughters are electrically charged and adhere to air sampling filters. This condition requires a radon "cool-down" of at least 48 hours prior to the initiating a decay count of the filter to obtain accuracy. Radon-222 is not a problem due to the half-lives of its decay daughters totaling less than one hour. However, radon-220's decay daughter half-lives total close to eleven hours, therefore -- the radon "cool-down." (737)

2. Basically, I just want to affirm that we have a very good program in monitoring the environment, and we comply with the 100 millirem limit for the public, and if there is -- even 1,000 percent closer to that limit, we take administrative, as well as ecological action; that is, we do our best to develop the best available technology on the screening for the radionuclides. (159)

Response to Comments 11.A.1 and 11.A.2:

In the CCA, DOE presents an environmental monitoring plan to comply with requirements of DOE Orders and the Agreement for Consultation and Cooperation between the State of New Mexico and DOE. [DOE 1981] The radiological portion of the environmental monitoring plan includes environmental radiation analysis of liquid effluent and air emissions from the WIPP. EPA did not conduct an evaluation of this plan because it is not required by 40 CFR Part 194. The environmental monitoring plan discussed by DOE in the CCA is not related to the analysis that was performed to determine which parameters could and should be monitored to assess the performance of the repository. Radon is not a parameter that DOE has committed to monitor to comply with the requirements of Section 194.42; therefore a radon "cool down" is not part of this monitoring plan. Radium 226, the parent to Radon, is a radionuclide that will be monitored in the environmental monitoring plan.

Issue B: DOE should monitor some parameters for a longer period of time.

1. Table MON-1 of the CCA indicates that all pre-closure monitoring by DOE at WIPP will be conducted in the open areas of the repository only. During the 35 year operational phase of WIPP additional geotechnical information could be obtained from instrumentation located in the filled rooms. (1220)

2. Prior to sealing Panel 1, remote sensors could be placed in the rooms of Panel 1 to measure moisture content, CO_2, room closure or other parameters and detectors hooked to cables located outside Room 1. One could obtain 10 years worth of highly detailed data on the actual behavior of the repository. (1300)

3. Non-invasive detectors could be located outside the Panel 1 seal to monitor parameters inside Panel 1 rooms. One could obtain 35 years worth of data on the actual behavior of the repository. (1300)

Response to Comments 11.B.1 through 11.B.3:

DOE states that the use of remote sensing techniques would not be useful for monitoring WIPP because the changes in the repository are too small in scale, too far from the surface and too slow to be detectable using remote techniques. [p. 7-50] DOE discusses the option of telemetry systems and concludes that there are too many equipment issues and concerns about interpreting the results to make this an option for monitoring WIPP. [p. 7-50] EPA agrees with DOE's assessment that little useful information would be gained from additional geomechanical monitoring of the panel rooms. Over the years, DOE has extensively monitored the rock mechanics of the disposal rooms. DOE has used this extensive geomechanical database to make predictions about the creep closure process. EPA believes that there is little additional knowledge that will be gained from an additional 10-35 years of monitoring the panel rooms. EPA found that the details of the pre-closure monitoring plan, including the monitoring time frames, fulfill the requirements of Section 194.42(c). [CARD 42, p. 20]

Issue C: The WIPP monitoring plan does not meet RCRA requirements.

1. Appendix MON of the CCA states that "Typically the RCRA regulations require ground water monitoring in the uppermost aquifer located directly below a hazardous waste management unit." The DOE has identified the Water Quality Sampling Program (WQSP) well as pre and post-closure monitoring wells for the WIPP repository. However, the WQSP wells are completed into the top of the Culebra Formation which is not an aquifer below the hazardous waste management unit. (1222)

Response to Comment 11.C.1:

The monitoring requirements of Section 194.42 do not require DOE to establish a monitoring plan that complies with RCRA regulations, only that they be complementary with other regulations. The commenter does not claim, nor has EPA found, the CCA plan to not be complementary with RCRA requirements. [40 CFR 194.42(d)] EPA found the ground water monitoring plans in the CCA adequate to comply with the assurance requirement. The intended purpose of this assurance requirement is to monitor parameters that are considered to be significant to the containment of the waste or to the verification of predictions about future performance of the repository.

Issue D: The WIPP monitoring plan does not meet the NRC HLW requirements.

1. NRC (10 CFR Section60.140) requires that the HLW site to provide a plan which monitors repository conditions during pre-closure operations and relate any monitoring results to repository performance. NRC 10 CFR Section60.141 requires DOE to perform pre-closure monitoring of subsurface conditions, rock deformations, water inflow locations, rock pore pressures, changes in ground water conditions and thermomechanical response of the rock. These conditions must be used to confirm that the repository is performing within design limits. Tables MON-1 and MON-5 in appendix MON of the CCA indicates that DOE/WIPP will monitor 1) creep closure in open areas of the repository, 2) extent of deformation in open areas of the repository, 3) initiation of brittle deformation, and 4) displacement of deformation features in open areas of the repository. Useful information could possibly be gained during the WIPP operational phase about brine inflow into areas of the repository that are closed to ventilation. Unlike the HLW regulations there are no EPA requirements in 40 CFR 191 or DOE commitments in the CCA (Table MON-1 & Table MON-5) to perform water studies. . . EPA has no equivalent requirement in 40 CFR 191 for pre and post-closure monitoring of brine flowing into the WIPP repository. (1223)

Response to Comment 11.D.1:

In accordance with Section 194.42(c) the pre-closure monitoring plan for WIPP shall be conducted, to the extent practicable, on disposal system parameters identified as being significant to the ability of the repository to contain waste. DOE has identified creep closure and stresses, extent of deformation, initiation of brittle deformation, and displacement of deformation features as parameters that will be monitored during the pre-closure period. DOE did not identify the amount of brine in the repository, during operations, as related to important disposal system concerns or as describing an important disposal system feature. The commenter has presented no additional information indicating that DOE was incorrect in such conclusion. EPA has no reason otherwise to believe that the amount of brine in the repository during the pre-closure monitoring phase will be significant enough to impact the containment of waste or the predictions made about the future performance of the repository. Further, the WIPP facility is not required to conform to either NRC regulations or EPA's High Level Waste (HLW) standards. The geology of Yucca Mountain is different from the WIPP and the HLW standards were developed specifically for the unique requirements at Yucca Mountain, which is exempt from the requirements of EPA's disposal regulations found at 40 CFR Part 191.

Issue E: DOE should not be allowed to conduct a qualitative evaluation to develop monitoring plans.

1. The approach allowed by EPA in the final criteria is to permit DOE to assess the usefulness of monitoring by a qualitative evaluation of the impact of improving our knowledge of the potential behavior of the repository. This is contrary to the intended purpose of the assurance requirements. It does not make sense to exempt DOE from the assurance requirement for monitoring based on a qualitative evaluation that depends on the containment calculations being correct. (1299)

Response to Comment 11.E.1:

Section 194.42(a) requires DOE to perform an analysis of the effects of parameters on the containment of waste in the disposal system. DOE is required to use the results of this analysis to establish pre-and post-closure monitoring plans. Section 194.42(a) does not stipulate the type of analysis that is required. EPA disagrees with the commenter that DOE is exempt from the assurance requirement for monitoring based on the qualitative analysis performed as evident by the pre- and post-closure monitoring plans. While quantitative assessments could be used (as in the case of compliance with Section 194.45), they are not necessary to implement the assurance requirements. EPA promulgated the assurance requirements as part of 40 CFR Part 191 to complement the quantitative containment requirements. [50 FR 38079] Thus, the qualitative assurance requirements "ensure that cautious steps are taken to reduce the problems caused by the uncertainties of projecting the behavior of natural and engineered components for thousands of years.' [*Ibid.*]

Issue F: DOE should monitor additional parameters.

1. EEG believes there are a number of parameters that can be monitored in both the pre- and post-closure period that could help verify predictions of the future behavior of the disposal system. (1300)

> A. Drilling practices in the Delaware Basin of air drilling, CO_2 injection and other underbalanced drilling should be monitored as well as borehole diameters and mining practices such as shaft diameters.
>
> B. Continued investigation of non-invasive techniques to monitor brine migration, gas generation and radionuclide movement. While DOE acknowledges (CCA, p. 7-50) that remote techniques to determine characteristics of the earth have been well established in measuring resistivity, acoustic velocity, magnetism, density, temperature, moisture control, and radioactivity, they conclude that changes in the repository will be too small or too slow to be detectable using remote techniques. EEG sees no evidence to warrant this conclusion.
>
> C. Ground water quality of the Dewey Lake and Santa Rosa Formations should be monitored.

Response to Comment 11.F.1:

Section 7.2.3.4 [p. 7-62] of the CCA states that monitoring plan includes verifying the location of drilling, monitoring drilling and completion activities, and noting abandonment and plugging. The Delaware Basin drilling monitoring plan will monitor drilling rates and practices in the Delaware basin. [Appendix DMP] Significant drilling practices, such as borehole diameters, plug and abandonment practices, drilling techniques, Castile brine occurrence, and injection well use for potential impacts of the disposal system performance. Any significant deviations noted will be reported to EPA and can be addresses in the recertification process.

DOE does state that remote sensing techniques would not be useful in monitoring WIPP because the changes in the repository are of too small a scale, too far from the surface and too slow to be detectable. The typical parameters that DOE indicates that remote sensing is useful for (resistivity, acoustic velocity, magnetism, density, temperature, moisture control, and radioactivity) are not parameters that were identified as significant to the containment of waste or to the predicted performance of the repository. EPA agrees with DOE that, at this time, remote monitoring of the pre-closure parameters will not provide useful information on the performance of the disposal system. However, EPA does agree with the commenter that there is a benefit in the continued investigation of pre- and post-closure monitoring because it could provide additional information that can be applied to DOE's recertification applications.

According to Chapter 7 of the CCA [p. 7-59] and Appendix GWMP [p. 10], the ground water of the Dewey Lake Redbeds will be monitored. The Santa Rosa Formations are surficial deposits in the vicinity of the WIPP. The Santa Rosa Formation is not expected to yield useful information for the monitoring program because of the negligible amounts of water that have been found in the formation, inside the controlled area. [Appendix USDW-27] EPA believes that any information relevant to the containment of waste or to the predictions of the performance assessment would be found first by monitoring the Culebra. Because the Santa Rosa Formation is not a continuous aquifer, troubling radionuclide data in the Santa Rosa Formation that is not found in the Culebra would likely be attributable to some surficial activity -- not something at the repository level.

Section 12 Passive Institutional Controls -- Section 194.43

Issue A: DOE's proposed PICs credit should not be granted.

1. DOE has projected that its proposed system of monuments and markers will almost entirely deter future drilling into the repository for at least 700 years. However, the projections ignore risks that the markers may never be built or may be destroyed, that future people may misunderstand their message, or that people using future drilling technology may miss the message entirely. Thus, DOE's projection is based on sheer speculation. (142)

2. SRIC agrees with EPA that no credit can be given for passive institutional controls (at 58828). (1165)

3. CARD is also pleased that EPA has awarded DOE no credit for passive institutional controls 100 years after closure, when active institutional control is assumed to be lost. (1177)

4. DOE has included no assurance that markers will be built, that documentation will be filed in government offices, or that future populations will either understand or avail themselves of the warning. CCNS remains convinced that passive institutional controls are essential to a conservative approach to permanent disposal, but that the CCA can take no quantitative credit for including passive institutional controls. (1210)

5. Title 40 CFR 191.14(c) requires designation of the repository site by the most permanent markers, records, and other passive institutional controls (PIC) practicable to indicate the dangers of the wastes and their location. The EPA proposes to require WIPP to implement the system of PICs but proposes to deny taking credit for PICs in the performance assessment for the containment requirements. The EEG agrees with this determination and urges EPA to remain

steadfast in denying credit for PICs for reasons stated by the EPA in U. S. EPA (1997), as well as for reasons that EEG has previously submitted to the EPA (see Appendix 8.2-Passive Institutional Controls). (1301)

Response to Comments 12.A.1 through 12.A.5:

EPA proposed to deny DOE's application for PICs credit for two reasons. First, DOE did not employ expert judgment to derive the credit. EPA stated in the preamble to 40 CFR Part 194 that "the degree to which PICs might reduce the future drilling rate can be reliably determined only through expert judgment." [61 FR 5232] Instead, DOE developed a proposal and submitted it to a peer review panel of three experts. EPA does not view peer review as equivalent to expert judgment, as explained in EPA's response to comments on the proposed Compliance criteria: "Expert judgment and peer review are two separate activities, subject to the exclusions and restrictions of different sections of the rule. Peer Review [Section 194.27] is applied to completed studies and activities as a means of providing validation, while Expert Judgment [Section 194.26] is conducted when such studies or activities cannot reasonably be performed." [Response to Comments Document for 40 CFR Part 194, p. 8-5] Thus, the assessment of a conjectural determination, such as the degree to which PICs might reduce future drilling rates at the WIPP, requires expert judgment.

Second, EPA found that DOE's analysis did not account persuasively for the uncertainty associated with forecasting the effectiveness of PICs. EPA does not concur with the conclusion of the PICs peer review panel that DOE's proposed credit is reasonable. Among other issues, EPA considers DOE's assertion that every aspect of the PICs design is virtually certain to endure and be understood for the proposed period to be contrary to EPA's specification in Section 194.43(c) that "[i]n no case. . . shall passive institutional controls be assumed to eliminate the likelihood of human intrusion entirely." [61 FR 5243] This topic is discussed in greater detail in Section 194.43(c) of CARD 43 -- Passive Institutional Controls.

EPA does not agree, however, that DOE gave "no assurance" that markers may never be built, that DOE "ignored" potential failure scenarios, or that the proposed credit was based on "sheer speculation." First, DOE must complete all passive institutional controls identified in the CCA and approved by EPA, including construction of site markers. If DOE fails to take the promised actions, EPA has the regulatory authority to suspend or revoke the WIPP's certification. [40 CFR 194.4] Second, as discussed in CARD 43, Section 194.43(c), DOE clearly considered numerous failure scenarios for PICs in the CCA. Consequently, while EPA concurs with certain commenters that DOE probably underestimated the potential for PICs to fail to communicate with future generations, the Agency does not concur that DOE "ignored" obvious potential failure scenarios.

Finally, when promulgating the final WIPP Compliance criteria, EPA acknowledged that predictions of PICs' effectiveness are unavoidably speculative. Nevertheless, the Agency left open the possibility that DOE could produce a reasoned argument for credit based on the judgment of experts. [61 FR 5231-32] EPA's rejection of the proposed credit for performance assessment in the CCA should not be interpreted as a statement that PICs are not likely to serve a useful purpose for hundreds of years, if not longer.

Issue B: DOE's proposed PICs credit should be granted.

1. EPA's first concern was that DOE did not determine its estimate of the appropriate credit for PICs through use of the procedures for expert judgment set forth in section 194.26. EPA ignored the expert elicitation process on PICs that DOE conducted prior to the promulgation of 40 CFR Part 194. The CCA fully described this prior expert elicitation process during which DOE convened two panels to address future states of society and the design of permanent markers. Although undertaken prior to EPA's promulgation of Part 194, the manner in which these panels conducted their evaluations was consistent with the requirements EPA would subsequently establish in section 194.26 and with standard practice for expert panels at that time. (941)

2. EPA's second reason for denying credit for PICs is that "EPA believes that the assertion that PICs are virtually certain (i.e., 99.9 percent) to endure and be understood is equivalent in effect to assuming that they eliminate the likelihood of human intrusion entirely." DOE did not claim 99.9% effectiveness for PICs; it claimed that they would be 99% effective. As noted by EPA in the proposed rule "the DOE bounded the failure rate (of 0.001) at 1% for the sake of conservatism." DOE did not use the term "virtually certain" to deter inadvertent human intrusion to mean that human intrusion would be completely eliminated. . . DOE defines "virtually certain" as "used to indicate a high level of confidence while recognizing a possibility, no matter how remote, that an alternative conclusion may occur." The use of 99% effectiveness for 600 years (from 100 to 700 years after closure) in the PA calculations, rather than 100% effectiveness is consistent with this definition of "virtually certain." (942)

3. The third reason that EPA denied DOE any credit for PICs is that "DOE's estimate of the effectiveness of PICs does not adequately account for the considerable uncertainty associated with quantifying the effectiveness of PICs for use in the PA." The range of uncertainty associated with the effectiveness of PICs was incorporated into DOE's estimate of their effectiveness by increasing the estimate of their potential for failure beyond what is reasonable. This treatment of uncertainty as to the effectiveness of PICs is consistent with DOE's treatment of other uncertain parameters in the CCA. Uncertainty was incorporated by selecting a bounding value of 1% for potential failure, which EPA considered conservative; therefore, the uncertainty does not need to be assessed again. (943)

4. EPA's final reason for denying DOE any credit for PICs is that "EPA found that the issue of quantitative credit for PICs is of little consequence for the purpose of evaluating the WIPP's performance." The fact that the impact of credit for PICs on the performance assessment is not significant is not a valid reason for rejecting credit. . . EPA should revise this section of the preamble to make it clear the EPA will reconsider the issue of credit for PICs during any

recertification of the repository if DOE chooses to present additional information obtained through expert elicitations conducted pursuant to Section 194.26. (944)

Response to Comments 12.B.1 through 12.B.4:

The commenter makes four points, which will be addressed in order:

- ♦ Prior expert judgment elicitations by DOE with regard to future states of society and the design of permanent markers for the WIPP site effectively complied with Section 194.26; therefore EPA should not deny PICs credit on the basis that the PICs credit was not derived by an expert judgment elicitation.

- ♦ DOE's assertion that PICs are "virtually certain" to endure and be understood for the proposed period is not equivalent to an assertion of 100 percent effectiveness, since DOE conservatively bounded the success rate at 99 percent. EPA erred in stating that DOE proposed a success rate of 99.9 percent.

- ♦ DOE assigned a bounding value of one percent for potential failure of PICs, which accounts satisfactorily for uncertainty and which "EPA considered conservative." Therefore, EPA should not deny PICs credit on the basis that DOE did not adequately account for uncertainty.

- ♦ The fact that PICs credit has no significant impact on the WIPP's compliance is not a valid reason for rejecting the credit. EPA should indicate whether it will consider future PICs credit proposals during a recertification.

First, the expert judgment exercises to which the commenter refers were conducted prior to the issuance of the final Compliance criteria. DOE did not attempt to demonstrate in the CCA that these exercises complied with Section 194.26, which established requirements for the conduct of expert judgment elicitation. In addition, DOE did not attempt to demonstrate in the CCA that the proposed credit for PICs had been developed by either of the earlier elicitations (it was not). The conceptual design for PICs does make extensive use of an expert panel's general recommendations regarding the types and characteristics of markers and messages at the WIPP site. DOE used these recommendations as the foundation for its own original design of specific markers, which EPA considers an appropriate approach. However, the credit proposal in the CCA was not the result of the "Markers Panel" or of any formal expert judgment elicitation conducted following the issuance of 40 CFR Part 194. Therefore, EPA has been provided with no basis to state that the proposed PICs credit was the result of an expert judgment elicitation.

Second, EPA acknowledges that the preamble's reference to the proposed PICs credit as 99.9 percent was incorrect. EPA stated, "EPA believes that the assertion that PICs are virtually certain (i.e., 99.9 percent) to endure and be understood is equivalent in effect to assuming that they eliminate the likelihood of human intrusion entirely." [62 FR 58828-29] EPA also stated earlier in the preamble, "DOE bounded the failure rate (of 0.001) at 1.0 percent for the sake of conservatism." [62 FR 58828] In fact, DOE estimated a maximum failure rate of 0.00001, which was then increased to 0.01 "to provide a bounding value for performance assessment calculations." [CCA Chapter 7, p. 7-88] DOE actually proposed a credit of 99 percent effectiveness.

EPA also agrees that 99 percent effectiveness is not numerically equivalent to 100 percent (i.e., total) effectiveness. Nevertheless, given the highly qualitative and speculative nature of the analysis supporting the PICs credit estimate, EPA does not see a meaningful distinction between 99 percent and 100 percent effectiveness. DOE's analysis repeatedly states the conclusion that each feature of the conceptual design is "virtually certain" to endure and be understood for 700 years after the WIPP's closure. Having examined all elements of the PICs design and found them "virtually certain" to be effective, DOE attempted to quantify a failure rate based on one failure scenario:

> No failure mechanisms compatible with a prudent extrapolation of today's societal conditions have been identified. . . that could destroy all of the Deterrent Components associated with the WIPP. Because these PICs components are expected to perform so well for the 700 years of regulatory interest, [DOE] decided to examine an existing PICs component (control of land use) for which failures are known to exist. [CCA Appendix EPIC, p. 6-13]

By calculating the failure rate from a single failure scenario, DOE in effect (though not explicitly) assumed that all other failure rates had been found to be zero. DOE may have defined "virtually certain" as indicating "a high level of confidence while recognizing a possibility, no matter how remote, that an alternative conclusion may occur," but DOE did not in practice attempt to quantify that possibility each time it arose. EPA therefore concluded that, as played out in DOE's methodology for quantifying the potential failure rate for PICs, "virtually certain" was in practical terms equivalent to "certain."

Third, EPA has not stated that bounding the estimated PICs failure rate to one percent was conservative. As EPA stated in CARD 43, "DOE asserted that rounding. . . to 99 percent more than adequately compensates for the uncertainty associated with land use controls plus any additional sources of uncertainty. . . EPA does not agree that this approach is conservative, particularly for purposes of PA calculations." [CARD 43, Section 43.E.5] EPA does not concur in particular that DOE's rounding of uncertainty goes beyond "what is reasonable" in the case of the WIPP. As suggested in the Compliance Application Guidance [p. 60], any justification of a numeric PICs credit must be qualitative in nature. Because assumptions about the future must be made, the number that results will necessarily be arbitrary to some extent. The uncertainty associated with a proposed PICs credit can and must be estimated, but there is no confirmed methodology for estimating uncertainty in this context nor any precise standard that may be used to confirm whether the uncertainty is accurate. For this reason, EPA believes that it would be difficult to err on the side of conservatism when rounding to a "reasonable" level of uncertainty -- particularly in the case of the WIPP, since it is located in an area of resource exploitation.

Thus, the question is not whether DOE's rounding of uncertainty was conservative, but whether it was conservative enough, based on consideration of the WIPP's location and the specific justification submitted by DOE to support the proposed credit. EPA's judgment, which was supported by many public comments on this issue, is that DOE's proposed PICs credit did not account conservatively for uncertainty. EPA found that DOE had given due consideration to the ways in which PICs could fail and had accounted for them sufficiently in the conceptual design. [CARD 43, Section 43.D.5] Despite this finding, EPA believes that there is an unavoidable possibility that (1) DOE overlooked a potential failure scenario, (2) DOE underestimated the likelihood that any given failure scenario could occur, or (3) DOE's assumptions regarding the factors affecting PICs' effectiveness (such as language comprehension over time) may prove incomplete or even incorrect. EPA does not agree with DOE that deriving uncertainty solely from drilling in the wrong location on a correct lease -- the only failure scenario "for which failures are known to exist" -- was sufficient to account for this possibility. Given the relative complexity of the permitting process, the potential for this process to change, and the level of interest in resources near the WIPP, one may reasonably conclude that permitting is an area of greater potential error than DOE has attributed to it.

Finally, EPA did not intend to imply in the preamble of the proposed certification decision that the fact that PICs credit was "of little consequence" to the WIPP's performance was a reason for denying DOE's proposal. EPA did not allow the PICs credit because DOE did not employ expert judgment in the manner required by EPA and because the Agency disagreed with DOE's assessment of overall uncertainty. EPA agrees with the commenter that a PICs credit proposal should not be judged according to its effect on the performance assessment. DOE may present additional information related to PICs in a recertification application; however, the Agency cannot comment as to whether any future PICs credit proposals will be accepted following a modification rulemaking.

Issue C: It would be more defensible to demonstrate compliance without attempting to take credit for passive institutional controls.

1. It would be more defensible to demonstrate compliance without attempting to take credit for passive institutional controls (at 12). (1054)

Response to Comment 12.C.1:

As explained in the proposed certification decision, EPA required DOE to conduct the Performance Assessment Verification Test (PAVT) to account for corrections to computer coding problems and modifications to parameter values and distributions that had been used in the performance assessment. [62 FR 58823] One of the changes DOE made in the additional modeling was to remove the proposed PICs credit. DOE satisfactorily demonstrated during the PAVT that the WIPP will comply with the disposal regulations without use of the proposed PICs credit. For a description of the changes involved in the PAVT, see EPA Technical Support Document: Overview of Major Performance Assessment Issues. [Docket: A-93-02, Item V-B-V]

Issue D: DOE did not propose a definitive design for important aspects of the disposal system.

1. The CCA contains no definitive design for shaft seals, panel closures, active institutional controls or passive institutional controls. (147)

Response to Comment 12.D.1:

EPA agrees that the CCA did not specify which of four panel closure design options DOE intends to use. EPA considered "Option D," modified to incorporate Salado mass, to be the most robust of the four options and the option that best supports DOE's assumption that disturbed rock zone permeability may remain fixed in the performance assessment. For this reason, EPA requires in Condition #1 of the certification that DOE employ a panel closure consisting of Salado mass concrete.

EPA does not agree that DOE failed to provide "definitive" designs in the CCA for shaft seals, active institutional controls, or passive institutional controls. First, DOE's design for seals in each of the WIPP's four shafts was explained in Chapter 3 and Appendix SEAL of the CCA. The shaft seal system has thirteen elements with high density and low permeability, including concrete, clay, compacted salt, cementitious grout, and earthen fill. Appendix E of Appendix SEAL includes drawings of the seal components of all four shafts. EPA considers the information in Appendix SEAL to be sufficient to explain what the shaft seal design consists of and how the design is intended to function relative to the WIPP's containment of radioactive waste.

Second, DOE's design for active institutional controls (AICs) was explained in Chapter 7 and Appendix AIC of the CCA. These materials were augmented by supplemental information from DOE that elaborated on the implementation, maintenance, surveillance, and replacement of AICs. [Docket: A-93-02, Item II-I-07] The AICs that DOE will undertake consist mainly of a barbed wire fence surrounding the surface "footprint" of the repository, signs that warn against disturbing the site, and an unpaved roadway that will permit routine surveillance of the site. The supplemental information described minimum standards for the fencing. While DOE has not yet arrived at an arrangement with local authorities to provide for site patrols, the Department discussed the minimum requirements that will be expected of patrollers and established that such requirements are within the scope of local capabilities. EPA considers the information provided by DOE to be sufficient to explain what the AICs design consists of and why such measures are reasonable and practicable. See Section 41.A.6 in CARD 41 -- Active Institutional Controls for further discussion of DOE's design for AICs.

Third, DOE's design for passive institutional controls (PICs) was explained in Chapter 7 and Appendix PIC of the CCA. Appendix PIC contains specific information regarding the types and dimensions of the markers that will be placed around the WIPP site and the messages that will be inscribed on them. These markers consist of a large earthen berm, 48 tall granite markers, a surface room of granite walls, two buried rooms, and small buried markers, among other features. Appendix PIC also identifies the documents that DOE will preserve and the various archives, record centers, and other organizations who will be sent those documents. In response to a request from EPA, DOE provided supplemental information regarding implementation of these PICs. [Docket: A-93-02, Item II-I-07] However, EPA determined that this information left open certain questions about the practicability of the PICs design. For this reason, EPA requires in Condition #4 of the certification that DOE: (1) submit a revised schedule for implementing PICs, (2) provide further evidence that granite markers can be constructed as described, (3) demonstrate that the specified archives and record centers will accept DOE documents, and (4) demonstrate that other recipients of WIPP information will accept and use it in the manner described by DOE. See Sections 43.A.6, 43.B.5, and 43.C.5 in CARD 43 -- Passive Institutional Controls for further discussion of DOE's design for PICs.

EPA considers these designs sufficient to demonstrate DOE's compliance with the relevant Compliance criteria, provided that the conditions described above are fulfilled. EPA's certification of the WIPP obligates DOE to implement the measures in question as they were presented in the CCA. To the extent that DOE wishes to add to or alter these designs, the Department must submit such changes to EPA for approval. [40 CFR 194.4]

Issue E: There is or is not sufficient reason to believe that the PICs proposed by DOE will be effective deterrents of future human intrusion.

1. In addition, the final rule requires that DOE show that the PICs will "endure and be understood by potential intruders" for the relevant time period. Now does anybody think we can make a sign that will be understandable in 10,000 years in this room? Does anybody have an idea what human intelligence or any kind of intelligence on the Planet Earth will be like in 10,000 years. I think right there that you've got a serious problem. What people have been going back to over and over again is the 10,000 year standard, which really should be a million years. (290)

2. I have a Ph.D. in English, and I was trying to make a point that language changes and it would not be possible to warn people away from the site for 10,000 years. I see now in your response to some of my comments. . . that you're not so concerned with passive control our ambition seems to be to control actively for the first 100 years, and then after that allow the natural barriers, an engineered barrier, to do the work no matter who intrudes. I'm glad to hear in a way that you gave up on your faith in passive control. (357)

3. Is it lack of funds that has kept the DOE from presenting a plan describing how they would keep the site secure for even the first 100 years after closure? The DOE has lost contact with records on the existence of two active oil and gas leases and one gas well within the WIPP site, even though the well was visible from the highway. If records on current activities are not given any attention, how likely are they to be looked at 100 or 1,000 years from now? (541)

4. I know that Westinghouse and DOE only are responsible for that place for 700 years, and after 700 years then it's like who cares what happens to WIPP. We're not responsible any longer. We only have a commitment for 700 years when the waste lasts for 40,000 years. So that's a big gap. (438)

5. Second we talked about passive institutional controls and the fact it is impossible to communicate with people 10,000 years in the future. (451)

6. I see the assurance requirements as a backup or a redundancy in the process. It makes sense. Our evaluations of compliance with the containment requirements could be flawed. There could be problems again because we're dealing with things that are highly uncertain in some cases. Even if our containment requirement assessments are flawed, the assurance requirements remain. They give us added confidence that WIPP will be safe. (389)

7. The only way any material buried 2500' down in the salt deposit can get out is by drilling for some geologic deposit. . .There is no way the amount of drilling can be controlled after the national will to protect the site is lost. We must depend on the fact that the material is sealed deep in an otherwise useless salt deposit and the good sense of future civilizations to watch what they are doing! (673)

8. The DOE merely proposes to put signs around the WIPP area, as if signs will prevent profit-hungry prospectors from taking advantage of the rich deposits in the WIPP area! Scientists predict a safety breach within a mere 5 years after WIPP's opening because of the rampant drilling in the area. But the DOE has no plans to attend to the possibility of leakage if someone disregards the posted warnings and punctures a WIPP storage area. (1093)

Response to Comments 12.E.1 through 12.E.8:

As discussed in the disposal regulations at 40 CFR Part 191 [50 FR 38079], the purpose of the assurance requirements is to ensure that cautious steps are taken to reduce the problems caused by uncertainties in numerical projections of a disposal system's performance over thousands of years. In other words, the assurance requirements consist of additional, qualitative measures that increase confidence in the ability of a disposal system to meet the containment requirements at 40 CFR 191.13. [40 CFR 191.14]

The rationale for employing the PICs specified at Section 194.43(a) has been treated in the rulemakings for the disposal regulations and the final compliance criteria and does not need to be repeated here. [Response to Comments Document for 40 CFR Part 194, pp. 15-1 to 15-4] The existence of site-specific markers and records, designed to be durable over long periods of time, will greatly improve the chances that future generations will retain knowledge of the hazard posed by waste stored at the WIPP. EPA has never asserted that PICs, as an assurance measure, could or must be sufficient to prevent human intrusion into a site entirely or for a specified period (such as 10,000 years).

The Compliance criteria limited any proposed PICs credit to “no more than several hundred years.” [40 CFR 194.43(c)] This limitation does not mean, however, that PICs will not be effective for a longer period. DOE was required to explain the period of time that PICs are expected to endure and be understood by potential intruders. [40 CFR 194.43(b)]

EPA finds that DOE has developed markers that meet the requirements of Section 194.43. DOE solicited relevant expertise and considered available (including international) research in developing a conceptual design. The design itself incorporates important features that will serve to promote the endurance and comprehensibility of PICs over time. Some of those features are monuments made from granite (a proven, durable material), messages in different languages and with different levels of complexity, widespread dissemination of information to different types of institutions, and multiplicity of monuments and messages. Also, the CCA clearly discusses the manner in which DOE attempted to account in the design for possible, realistic failures. The design proposed by DOE may reasonably be expected to endure and be understood by potential intruders for hundreds of years, and potentially much longer. A description of EPA’s analysis of the PICs design is contained in Sections 43.A.6, 43.B.5, and 43.C.5 in CARD 43 -- Passive Institutional Controls.

Issue F: The proposed period of effectiveness of PICs would extend for an insignificant period.

1. You have said I think that the best that the DOE could do was to proclaim that it was virtually certain that its proposed warning markers would endure and be understood for at least 700 years. I would point out that's an infinitesimal portion of the radioactive wastes's 240,000 year half life. It's an insignificant part of the 10,000 year regulatory horizon. (394)

Response to Comment 12.F.1:

Section 194.43(c) of the Compliance criteria limits the period of time that DOE may assume that PICs will prevent some or all human intrusion to “no more than several hundred years.” DOE proposed that PICs would be "virtually certain" to prevent human intrusion for at least 700 years. As discussed in CARD 43 -- Passive Institutional Controls, EPA disagreed with important aspects of DOE's conclusion and so decided not to allow the credit. Had EPA granted the credit, its sole effect would have been to remove the possibility from the performance assessment calculations that human intrusion would occur during the first 700 years after closure of the WIPP.

DOE was separately required to estimate the amount of time that PICs are expected to endure and be understood. [40 CFR 194.43(b)] As indicated by the Agency's Compliance Application Guidance [pp. 59-60], EPA expected that DOE's demonstration of compliance with this requirement would be qualitative in that it would rely on assumptions. An important assumption made by DOE is that "analogs of structures, media, and messages that have withstood the test of time represent design characteristics that allow DOE to design for success." [Appendix EPIC of the CCA, p. 3-11] In order to estimate the period of PICs' effectiveness, DOE compared its PICs design to relevant historical analogues, such as Stonehenge and the Vatican Archives. DOE also considered the features of these analogues that enabled them to endure and be understood for long periods and incorporated those features in the PICs design. DOE assumed that, given modern technology, its own design could function at least as long as its analogues. [Appendix EPIC, Section 5]

DOE concluded that, even though the proposed PICs credit was limited to 700 years, the PICs designed by DOE are likely to endure and be understood for longer than 700 years, and perhaps as long as several thousand years in some cases. EPA considers this conclusion reasonable, based on DOE's consideration of relevant historical analogues and incorporation of design features to compensate for probable intrusion scenarios. EPA recognizes that predictions of PICs' duration and effectiveness are largely speculative. This concern led EPA to restrict the period of any PICs credit proposed for use in the performance assessment. [50 FR 5231] Nevertheless, EPA's intent is that PICs should be designed to last as long as possible; thus, markers must be "as permanent as practicable." [40 CFR 194.43(a)(1)] As discussed in Section 43.A.6 in CARD 43, EPA has determined that the PICs design put forth by DOE satisfies this criterion.

Section 13 Engineered Barriers -- Section 194.44

Issue A: Waste should/should not be treated before being placed in the repository.

1. Take the time to develop the technology, to neutralize, vitrification, whatever else you have to do. It hasn't been done. It hasn't been done because the policy makers have not wanted to do it. (535)

2. We believe the waste should be treated to make it more difficult to be dispersed in the environment in case of a breach. (485) (191)

3. The waste should be treated to make it more difficult to be disbursed in the environment in case of the breach of the repository. (352)

4. First of all, let me say I personally believe that highly radioactive hazardous material should be vitrified and isolated from the biosphere we live in. (355)

5. PSR remains unhappy about the decision not to shred, route and repackage all the waste. The best way of reducing the likelihood of human intrusion into the site is to lower the human interest in what will be found. Current barrels filled with clothes and tools of the 20th century will be a gold mine for future archaeologists. . . Shredding the materials would also handle problems with gas generation, reduce risk of handling and transportation and give us decades of retrievability should problems or better options develop. (257)

6. EEG notes that DOE has already planned to treat much of the existing TRU waste in its complex before shipment to WIPP. These treatment processes have nothing to do with WIPP's

compliance with EPA's 40 CFR 191 and 40 CFR 194 regulations. EEG's recommendation that EPA require DOE to treat the yet-to-be generated waste will not add more assurance. (661)

7. The EEG recommends that additional confidence in predicting the behavior of the waste over 10,000 years can be obtained by processing the waste. Hence, EPA should encourage the DOE to process the waste before shipment to WIPP. (711)

8. The waste should be treated to make it more difficult to be dispersed in the environment in case of a breach. (717)

9. In summary, of the existing 104,400 m^3 of CH-TRU waste, DOE has plans to treat or repackage 88,900 m^3 or 85%. Of the 15,500 m^3 not being processed, 3,000 m^3 is intended for shipment to meet a scheduled commitment between DOE and the State of Idaho. The EPA should recognize DOE's efforts in stabilizing the waste and encourage DOE to also fix the yet-to-be generated waste. (1303)

Response to Comments 13.A.1 through 13.A.9:

Commenters state that treatment of waste could serve to provide additional confidence in the safety of the disposal system, beyond that demonstrated by the performance assessment, based on the assumption that waste treatment would reduce the potential effects of a repository breach. The commenters therefore urge EPA to encourage DOE to treat the waste in order to add additional "assurance" in the predicted performance of the WIPP. Commenters also have identified DOE documents that show that DOE plans to process some amount of waste destined for disposal in the WIPP. DOE in fact intends to treat waste destined for the WIPP in order to comply with the requirements of other regulatory agencies (e.g., the Department of Transportation). EPA does not consider it necessary to require DOE to treat waste prior to emplacement. However, EPA agrees that waste treatment or additional barriers may further enhance the containment ability of the WIPP. If in the future, DOE were to select a new treatment option that differs from the option in the most recent CCA, DOE must provide us with a new performance assessment which demonstrates compliance with the disposal standards. EPA will evaluate any information provided by DOE and determine if it is necessary to modify our certification. Otherwise, we have no evidence that waste treatment will improve or worsen containment of the disposal system. As EPA stated during the Compliance criteria rulemaking, "It is DOE's role as facility owner and operator to propose the engineered barrier(s) to be used at the WIPP and to justify and support the choice(s). It is EPA's role as regulator to evaluate the adequacy of DOE's decision. . . EPA believes it is inappropriate to require the use of specific barriers without an evaluation of their impact on the overall system." [Response to Comment Document for 40 CFR Part 194, p. 16-4, Air Docket: A-92-56, V-C-1]

Section 194.44 of the Compliance criteria requires DOE to perform a comparison of the benefits and detriments of waste treatment options (referred to as "engineered barriers" by EPA and as "engineered alternatives" by DOE). DOE's comparison incorporated such treatment methods as vitrification and shredding. DOE chose to propose magnesium oxide backfill as an engineered barrier based on the comparative study that constitutes Appendix EBS of the CCA.

DOE and others performed calculations showing that the WIPP complies with the containment requirements with or without the use of MgO as an engineered barrier. [Air Docket: A-93-02, IV-D-12, IV-G-7] If DOE were to select a new treatment option (such as vitrification) that differs significantly from what is included in the most recent compliance application, DOE must inform EPA prior to making such a change. [40 CFR 194.4] If EPA determines that such a change is significant, then EPA would conduct a public rulemaking to either modify or revoke the WIPP's certification. [40 CFR 194.65]

One commenter suggests that EPA should require DOE to shred waste to reduce its potential archeological value and achieve other positive effects on gas generation and retrievability. EPA agrees that the potential archeological value of the waste may be reduced by altering its physical form. As explained above, however, EPA does not believe it is appropriate to require DOE to use specific engineered barriers without due consideration of their effects on the disposal system. Also, DOE considered future archeological activity when designing a system of passive institutional controls for the WIPP site. [CARD 43 -- Passive Institutional Controls, Section 194.43(b)] DOE will build surface and near-surface stone markers that warn against such exploration. Given the location of these markers, it is likely that archeologists would encounter them before uncovering any materials in the deeper repository. For archaeologists to dig nearly a half mile underground in search of mid- to late-20th century laboratory clothing and tools strongly suggests that they have knowledge of the location of the WIPP and the hazards posed by its contents. Within the framework of the Compliance criteria, this scenario constitutes a deliberate intrusion into the WIPP repository. EPA does not require DOE to compensate for deliberate intrusions in the design of the WIPP.

In regard to the positive effects of shredding posited by one commenter, EPA notes first that shredding on its own does not constitute an engineered barrier, since it does not prevent or delay radionuclide migration or otherwise increase confidence in the WIPP's performance. Rather, shredding typically is combined with other waste treatment options, such as compaction, polymer encapsulation, or cementation in order to achieve such an effect. Second, EPA believes that the impact of shredding on gas generation would lead to adverse consequences for the WIPP's performance, while simultaneously increasing the radiation exposure of workers, the overall volume of waste to be disposed of (including equipment used for shredding), and the risk of accidental radiation release during the shredding process.

Section 194.44(b) requires only that shredding be included as an alternative in DOE's benefit/detriment analysis and that the results of this analysis be used to justify the decision to include or exclude potential barrier alternatives. DOE considered shredding in combination with other options in the Engineered Alternatives Cost Benefit Study [Appendix EBS to the CCA] as part of its demonstration of compliance with 40 CFR 194.44(b); see, for example, Options #5-9,

#15, #66-70, #86-91, #93-94, and #101. DOE did not propose these options as engineered barriers for the WIPP, opting instead to use magnesium oxide backfill. Therefore, EPA found that DOE's consideration of shredding as a treatment option was appropriate and sufficient for compliance with Section 194.44(b). See CARD 44 -- Engineered Barriers for further discussion of DOE's compliance with this requirement.

Issue B: DOE failed to consider alternatives to the proposed 55-gallon steel waste drums that would reduce releases.

1. EPA is obligated to enforce the requirement for engineered barriers in the disposal regulations. EPA has decided to allow DOE to put waste into WIPP contained in, simply, 55-gallon steel drums. EPA's decision is based on DOE's study of engineered alternatives, but DOE's study completely fails to ask whether different waste containers would reduce the impact of fluid injection or air drilling or stuck pipe or direct brine releases. (406)

2. Waste form modifications, specifically, elimination of the gas-generating steel waste drums, must be reconsidered by DOE and EPA. (715)

3. DOE's Engineered Alternative Cost/Benefit Study (II-A-14) entirely omits to consider spallings or similar releases or air drilling releases. Consequently, that study essentially examines the releases that do not matter in selecting engineered barriers and alternative waste forms. (1046)

4. EPA should also incorporate the effects of real engineered barriers, including waste treatment and containers to mitigate the gas pressurization problems of the existing steel drums, to demonstrate that such barriers dramatically reduce projected releases in many of the human intrusion scenarios. (1145)

Response to Comments 13.B.1 through 13.B.4:

DOE did in fact consider various aspects of waste packages in the engineered barrier study. Section 194.44(b) of the Compliance criteria requires that DOE's evaluation of engineered barriers consider "improved waste containers." During the process of evaluating barriers, DOE identified "improved waste containers" as Option #105. [Appendix A of Appendix EBS, p. 4] In Appendix C of Appendix EBS [p. 6], DOE explained that "improved waste containers" were found to duplicate Options #63, "Change Waste Container Shape," and #64, "Change Waste Container Material." The Agency concurs with DOE's decision to screen out Option #105 as duplicative. Both Options #63 and #64 passed DOE's initial screening and were retained for further consideration. [Appendix B of Appendix EBS, p. 7] Appendix D of Appendix EBS explains that Options #63 and #64 were combined for purposes of analysis because their effect on improving disposal system performance would be similar. Appendix A of Appendix EBS [p. A-10] states that the "improved waste container" options scored low in a qualitative assessment because of their minimal ability to improve conditions with respect to waste solubility and shear strength.

These options were therefore eliminated from further consideration. EPA agrees that changing the material of the waste container will not increase the shear strength of the waste and changing the shape of the waste container will not improve its solubility. See CARD 44 -- Engineered Barriers for further discussion of DOE's compliance with 40 CFR 194.44(b).

Section 194.44(c) requires that the comparative evaluation of engineered barriers be performed using nine factors, including "(ix) the effects on mitigating the consequences of human intrusion." One commenter states that DOE, in demonstrating compliance with this requirement, failed to consider four human intrusion scenarios: fluid injection, air drilling, stuck pipe, and direct brine release. Another commenter states that DOE's consideration of engineered barriers in relation to human intrusion did not include scenarios that would result in spallings, and so included only scenarios that "do not matter."

As explained in CARD 44, DOE examined the effects of engineered barriers on the long-term performance of the WIPP using the Design Analysis Model (DAM):

> The DAM is a simplification of the PA that was intended to provide a relative comparison of the potential benefits of the different barriers on the performance of the repository. There was no attempt to determine the absolute effect of the barriers. . . since the objective of the study was only to provide DOE with information for use in the selection or rejection of additional engineered barriers to provide assurance in the performance calculations. [CARD 44, Section 44.C.4]

The comparative study of barriers was sufficient to demonstrate compliance with Section 194.44(b) and (c) because, it was not necessary for DOE to show the "real" effect of each barrier on the WIPP's performance in the face of a specific human intrusion scenario such as air drilling. Rather, it was sufficient for DOE to consider the *relative ability* of barriers to prevent or delay radionuclide migration in the event of human intrusion and not necessary for DOE to analyze the package option for absolute performance relative to the four intrusion scenarios identified by the commenter in order to comply. To achieve this purpose, DOE compared the effects of different engineered barriers given three generalized intrusion scenarios in the Design Analysis Model. These scenarios in effect incorporated subcategories such as air drilling and stuck pipe that could lead to spallings releases. An independent peer review panel reviewed DOE's methodology for comparing barriers in relation to human intrusion scenarios. The objective of the peer review was to assess the validity of the study's assumptions and conclusions and the adequacy of DOE's technical approach. The panel evaluated and reported on: adequacy of requirements and criteria, validity of assumptions, alternate interpretations, uncertainty of results and consequences if wrong, appropriateness and limitations of methodology and procedures, adequacy of application, accuracy of calculations, and validity of conclusions. The conclusions of the panel were that DOE's approach was valid, the conclusions drawn were reasonable and the analysis was conducted in accordance with Section 194.44 requirements. [Appendix PEER.4 of the CCA] EPA thoroughly reviewed the results of the independent peer review report on the Engineered Alternatives Cost/Benefit Study. The report documented a thorough and detailed review of the Engineered

Alternatives Cost/Benefit Study. Based on the scope and depth of the independent panel's review, EPA agreed with the conclusions reached by the panel that DOE considered an appropriate range of effects and developed a quantitative performance measure adequate to compare the effectiveness of engineered barriers and thus concurred with the approach taken by DOE in modeling the relative effect of engineered barriers on human intrusion scenarios. For further information on the conduct of independent peer review, see CARD 27 -- Peer Review.

Some commenters requested consideration of alternatives to steel waste drums in order to reduce formation of gas in the repository due to the degradation of carbon. This issue is addressed in the Compliance criteria at Section 194.44(b) which requires consideration of "improved waste containers." As discussed above, DOE explicitly included this alternative in the study as #64, "Change Waste Container Material." DOE prioritized a total of 54 engineered barriers based on a qualitative evaluation of their effectiveness relative to four factors important to the performance of WIPP: (1) mitigating the consequences of human intrusion; (2) reducing waste permeability; (3) reducing actinide solubility; and (4) reducing the volume of gas generated. These scores are documented in Table D4-1 of Appendix D to Appendix EBS. [p. D4-1] While alternative #64 scored very high at reducing gas generation, it also scored very low in other areas, particularly reduction of actinide solubility. (In contrast, the addition of a chemical buffering agent such as MgO scored very highly in reducing actinide solubility.)

Because of its low scores in several areas and the high cost and risks associated with repackaging waste, DOE chose not to pursue changing the waste container material. EPA found this decision acceptable because removing steel drums from WIPP waste has no positive contribution to mitigating the consequences of human intrusion and does not reduce waste permeability or actinide solubility. In addition, repackaging waste comes with significant detriments, including:

- Increased risk of radiation exposure to workers who remove waste from steel drums, repackage it, and analyze and characterize the drums to ensure that they do not contain residues of TRU waste.

- Increased risk to the public and the environment from the potential release of radiation during the process of removing waste from the drums.

- Increased cost of the operation of removing the steel drums from the waste stream and the cost of disposing of the drums themselves.

- Increased cost and uncertainty associated with developing and implementing a replacement for the steel drums.

Issue C: "Containment" and "assurance" requirements have been improperly combined.

1. The other suggestion made by the EEG (in EEG-61) is to compensate for siting the repository in a mineral resource rich area by incorporating robust engineered barriers in the WIPP's design. The DOE has Magnesium Oxide backfill as an engineered barrier, but that is needed for assuming low actinide solubility to show compliance with the containment requirement. The "containment" and the "assurance" requirements of the EPA standards thus have not been kept separate, as was intended by the EPA standard, 40 CFR 191. (710)

2. MgO backfill is not necessary to demonstrate compliance with the EPA standards. DOE included MgO as a backfill as a true assurance measure. As EPA knows, the no-backfill PA calculations conducted for the conceptual models peer review panel (documented in WPO# 43220) clearly demonstrated that MgO was not necessary to reduce the actinide solubility to meet the containment limits. In addition, EEG's own analysis (Figure 1 of Enclosure 1 to the December 31, 1997 EEG letter to EPA) demonstrates that "no-backfill" case meets the EPA limits. (660)

3. The EEG has steadfastly claimed that MgO backfill cannot be simultaneously claimed for compliance with assurance requirements and containment requirements, despite clear and straightforward language in 40 CFR 194 that obligates the DOE to account for the solubility effects of MgO in the calculations performed to address containment requirements. There is no rational scientific or regulatory basis for the EEG's assertions that the MgO backfill emplacement plan and its treatment in the CCA models does not satisfy both the original intent and the letter of the assurance requirement regulations. (913)

4. The EEG view is that while there are still some questions about the efficacy of the chemical buffer aspect of the magnesium oxide (MgO) backfill...this engineered feature has been selected primarily to enable DOE to use numerical values of certain parameters in the containment requirement calculations. The MgO backfill may not therefore be considered to satisfy this assurance requirement in a strict sense of the philosophy of these requirements. Incorporation of backfill in the WIPP design is nevertheless a good idea and the EEG has been recommending a salt/clay mixture as backfill for years. A pure MgO backfill does not have the benefit of the chemical retardation of radionuclides that clays afford, but may help keep the repository chemical environment stable. The EEG would prefer addition of clays such as commercially available bentonite to the backfill, but is willing to accept emplacement of MgO backfill for the sake of operational ease and efficiency. (1302)

Response to Comments 13.C.1 through 13.C.4:

EPA disagrees that the radioactive waste disposal regulations at 40 CFR Part 191 imply any conclusion to the effect that assurance requirements are independent of and separate from the containment requirements. EPA addressed this issue explicitly during the 40 CFR Part 194 rulemaking. A number of commenters, including EEG, stated in regard to the proposed Compliance criteria that engineered barriers, as an assurance requirements, are independent of the containment requirements. EPA categorically rejected the notion that the two categories of requirements necessarily are independent of one another:

> While engineered barriers are required pursuant to the assurance requirements at Section 191.14(d), engineered barriers are not necessarily required to meet the containment requirements at Section 191.13. However, DOE may choose to use an engineered barrier(s) to meet compliance with the containment requirements.
>
> By definition, in Section 191.12(a), "[d]isposal system means any combinations of engineered and natural barriers that isolate spent nuclear fuel or radioactive waste after disposal." Thus, performance of the disposal system is not evaluated by examining discrete elements independently, but by evaluating the disposal system as a whole.
>
> Consistent with the requirements found in Section 191.13, that DOE analyze the performance of the complete disposal system, any engineered barriers that are implemented at WIPP must be considered by the Department, and, ultimately, by EPA when evaluating compliance with both the containment requirements in Section 191.13 and the assurance requirement in Section 191.14(d). The effects of engineered barriers employed at the WIPP must be considered in performance assessments; excluding such barriers from consideration would result in inaccurate modeling of the disposal system as defined in Section 191.12(a). [Response to Comments for 40 CFR Part 194, pp. 16-10-13, Air Docket: A-92-56, V-C-1]

Therefore, the separation of the requirements is valid only to the extent that engineered barriers *may* be used to meet the containment requirements, but *must* be used to meet the assurance requirements. The effects of all engineered barriers employed at the WIPP must be considered in performance assessments. Excluding such barriers from consideration would result in inaccurate modeling of the disposal system, which is defined in Section 191.12(a) to include engineered barriers.

Nonetheless, as indicated by Comment 2, DOE and others performed calculations that support the conclusion that DOE has demonstrated that the MgO backfill is not required for the repository to comply with the containment standards. While these calculations were not used by EPA in determining compliance with the Compliance criteria, they are instructive as to whether MgO is needed for the WIPP to meet the release limits.

Issue D: EPA did not adequately assess the effects of engineered barriers on compliance with the disposal standards.

1. EPA should repropose its decision, this time dealing with all of the significant violations of the disposal standards, and assessing how engineered alternatives would reduce those violations. EPA should take public comment before making its final decision. That kind of process would allow independent scientists and anybody who happens to have any expertise to speak to you and be heard. (408)

Response to Comment 13.D.1:

EPA conducted a thorough review of all aspects of the WIPP as required by the Compliance criteria at 40 CFR Part 194. Based upon this review, and EPA's determination that either (1) DOE has demonstrated compliance with the requirements of the Compliance criteria, or, in certain instances, (2) EPA has independently confirmed DOE's compliance with Compliance criteria, EPA concludes that the WIPP will comply with the disposal regulations at 40 CFR Part 191. Thus, EPA proposed to certify that the WIPP would meet the requirements of the disposal regulations at 40 CFR Part 191 (contingent upon DOE's compliance with specific conditions enumerated). This commenter has not identified the specific "significant violations" of the disposal standards referred to in the comment. It is not possible to respond to such a generalized assertion of deficiency.

Moreover, in conducting the current rulemaking EPA provided extraordinary opportunities for public participation. EPA (1) published an Advanced Notice of Proposed Rulemaking (ANPR), soliciting public comment for 120 days on "all aspects" of DOE's compliance certification application (CCA) upon its receipt [61 FR 58499, 58500, November 15, 1996]; (2) held meetings with major public stakeholders and a series of public hearings throughout New Mexico [62 FR 2988, January 21, 1997]; (3) extended the 120-day ANPR comment period until August 8, 1997, resulting in a comment period of **[267]** days [62 FR 27996, May 22, 1997]; (4) published a notice of proposed rulemaking (NPRM) announcing the proposed determination to certify that the WIPP will comply with the 40 CFR Part 191 disposal regulations and soliciting public comment for 120 days on this proposed certification [62 FR 58791, October 30, 1997]; (5) held meetings with major public stakeholders and a series of public hearings throughout New Mexico [62 FR 64334, December 5, 1997]; and (6) made available for public comment EPA's analysis of a specific human intrusion scenario that had been identified by public comment as a potential future problem for the repository. [63 FR 3863, January 27, 1998] The purpose of this process was to ensure that the public was fully involved in all aspects of this critical determination. Any "independent scientists" and other persons with expertise have been afforded substantial opportunity to be heard.

Issue E: The performance of magnesium oxide backfill is not supported by experimental evidence.

1. DOE's last minute inclusion of magnesium oxide backfill to control the pH of the brine and so retard actinide solubility is based on conceptual logic and not backed by experimental data. Moreover, DOE based its conclusions on erroneous projections of plutonium stabilization in the WIPP repository. Therefore, EPA must require from DOE experimental support for its assertions about the benefits of magnesium oxide backfill. (1204)

Response to Comment 13.E.1:

DOE performed experiments to validate the predicted performance of MgO, the results of which were used to support modeling assumptions used in the performance assessment. [Docket: A-93-02, Items II-I-10, Enc. 2g, and II-I-15] As discussed in Section 44.A.5 of CARD 44 -- Engineered Barriers, these experiments showed that MgO will function as a pH buffer and will effectively remove carbon dioxide from the disposal system. Even though DOE's experiments did not indicate a "stabilization" of plutonium within the WIPP repository, the effect of MgO is to narrow the potential range of solubility associated with plutonium isotopes, which significantly reduces the uncertainty associated with establishing that range of solubilities.

Issue F: EPA's regulations for engineered barriers differ from NRC's regulations.

1. The definition of engineered barriers in 40 CFR 191, in contrast to 10 CFR 60, includes shaft and panel seals. DOE relies on this inclusion for its fulfillment of the engineered barriers requirement and fails to include consideration of waste modification or facility design improvements. Thus DOE is not conservative in its consideration of engineered barriers. (1207)

2. NRC 10 CFR Section 60.2 defines engineered barrier systems as "waste packages and the underground facility." 10 CFR Section60.143 requires an extensive waste package testing program during the operations phase as a part of the performance confirmation program. EPA (40 CFR 191.12) defines a barrier as ". . . a geologic structure, a canister, a waste form. . . that significantly decrease the mobility of radionuclides." However, the EPA guidance (40 CFR 194.42) makes no reference to canister monitoring or canister testing during pre or post-closure monitoring at WIPP. [Note, some canisters were corrosion tested in brine located in the WIPP repository during the 1980s. The results of those discontinued studies are unknown.] (1224)

3. DOE intends to "process" a significant portion of the TRU waste to be placed in the WIPP, either through solidification or repackaging. NRC requires low level radioactive waste destined for disposal to have a 300 year waste form or container. EPA should encourage DOE to take similar steps to decrease the solubility/mobility of TRU waste. (151)

Response to Comments 13.F.1 through 13.F.3:

The rationale for EPA's definition of engineered barriers has been treated in the rulemakings for the disposal regulations and the final compliance criteria, and it is inappropriate to address these issues in detail in the present rulemaking. EPA's rationale for defining engineered barriers as it did in Part 191 is addressed in the responses to comments on the proposed Part 194. [Response to Comments Document for 40 CFR Part 194, 16-6 to 16-7, Air Docket: A-92-56, V-C-1] 40 CFR 191.14 requires the use of one or more engineered barriers. 40 CFR 194.44 implements 40 CFR Part 191 by requiring DOE to evaluate and propose in its compliance application engineered barriers that serve to comply with the containment and assurance requirements of 40 CFR Part 191. The WIPP Land Withdrawal Act does not require EPA to implement NRC's regulations regarding waste form barriers.

EPA requires DOE to account for all waste constituents and all other elements of the disposal system that could affect the performance of the disposal system in the predictive modeling used to establish the WIPP's compliance with EPA's disposal regulations. For purposes of conservatism, DOE took no credit in this modeling for the contributions of waste containers (mostly 55-gallon drums) toward containment of radioactive waste. However, DOE did consider the potential negative effects on containment of the presence of carbon steel drums in the waste stream. Under 40 CFR 194.44(b), DOE also completed a comparative analysis of over 100 types of waste modification technologies and other engineered barriers, as documented in Appendix EBS of the CCA and discussed in Sections 44.B.4 and 44.B.5 of CARD 44 -- Engineered Barriers. These activities by DOE were necessary in order to demonstrate compliance with EPA's requirements. EPA's guidance was intended to specify the types of information needed in the Compliance Certification Application, not to establish additional requirements related to the performance of specific disposal system features.

Section 14 Consideration of the Presence of Resources -- Section 194.45

Issue A: The WIPP site has not been shown to have favorable characteristics that compensate for the risks from nearby resources.

1. WIPP is a blind site especially so because it's in an area surrounded by oil and gas and potash which also lie within the boundaries of the site which lead to short term and long term problems with the facility. (226)

2. The EPA has said that if a site lies in an area where valuable resources are present or where there has been or will be mining for resources or where there's a large amount or rare resources, the site must be shown to have favorable characteristics that outweighed the risks associated with those resources. We are all aware of the oil, natural gas wells and potash mines in the WIPP area. DOE has not shown the site to have those potentially favorable characteristics mentioned just earlier. (336)

3. EPA has refused to adequately consider the consequences of the WIPP site being surrounded by oil and gas wells. (559)

4. Testimony given by the EEG regarding the resource disincentive was misleading and incomplete. . . . In determining compliance with the containment requirements of 40 CFR 191.13, the DOE's analysis includes the rate and effects of resource exploitation as it is currently conducted in the Delaware Basin and extends these activities into the future. Since the compliance calculations show releases below the limits specified in the standard, the favorable characteristics of the site have indeed been demonstrated to outweigh any additional risks posed by the exploitation of these resources. (835)

5. ANA opposes the proposed certification, because the WIPP is clearly a flawed site, especially so because of the oil, gas, and potash resources within the site boundary and in the surrounding accessible environment. (1106)

6. WIPP does not meet EPA containment requirements, partly because it is located in a known mineral district and is vulnerable to human intrusion. (1175)

7. The EEG believes that in allowing the resource disincentive requirement of the EPA standards to be satisfied if the numerical containment requirements (40 CFR 191.13) are satisfied (through 40 CFR 194.45), the EPA deviated from the basic philosophy of the multiple barrier "belt-and-suspender" approach inherent in the assurance requirements of the standards. Faced with the fait accompli of promulgation of 40 CFR 194, the EEG recommended (Neill et al., 1996) that at least the actual conditions at the site related to the presence of natural resources be fully and conservatively assumed in projecting compliance with the numerical containment requirements. This does not appear to have been done in the CCA, judging from the DOE resistance to consideration of fluid injection, air drilling, and mining scenarios. The "containment" and the "assurance" requirements of the EPA standards thus have not been kept separate, as was intended by the EPA standards, 40 CFR 191. (1304)

<u>Response to Comments 14.A.1 through 14.A.7:</u>

The presence of resources and resource-related activity in the vicinity of the WIPP does not necessarily disqualify it from use as a radioactive waste disposal facility. In adopting the final radioactive waste disposal regulations at 40 CFR Part 191, EPA declined to prohibit use of a site based simply on the presence of resources. EPA concluded that a site near resources could have compensating characteristics that might make it a suitable candidate site for radioactive waste disposal. Thus, the final disposal regulations provide that:

> Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites . . . . Such places shall not be used for disposal unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future. [Section 191.13(e)]

In promulgating the WIPP compliance criteria [40 CFR Part 194], EPA clarified that performance assessments are the appropriate tool to weigh the compensating features of a site against the increased potential for future human intrusions:

> The final rule further provides that the requirements of Section 191.13(e) and Section 194.45 will be fulfilled if performance assessments, taking into account human intrusion, predict that the numerical release limits of the disposal regulations will be met. This approach reasonably implements Section 191.13(e) at the WIPP because performance assessments must account for the increased potential for human intrusion into the disposal system due to the presence of resources, based on historical rates of drilling and of mining in the vicinity of the WIPP. Analysis of human intrusion must consider exploratory and developmental drilling of all resources in the Delaware Basin, as well as mining, consistent with the disposal regulations, which state that performance assessments must consider events that may affect the disposal system during the regulatory time frame.

[Response to Comments Document for 40 CFR Part 194, 17-1]

The commenter is mistaken in implying that EPA intended that the containment and assurance requirements must be kept separate. EPA addressed this issue explicitly in promulgating the 40 CFR Part 194 compliance criteria, where a number of parties (including the New Mexico Environmental Evaluation Group, Comment A.5 above) commented on the 40 CFR Part 194 proposed rule to the effect that engineered barriers, as an assurance requirement, are independent of the containment requirements. EPA rejected the notion that the two categories of requirements necessarily are independent of one another:

> While engineered barriers are required pursuant [sic] to the assurance requirements at Section 191.14(d), engineered barriers are not necessarily required to meet the containment requirements at Section 191.13. However, DOE may choose to use an engineered barrier(s) to meet compliance with the containment requirements.
>
> By definition, in Section 191.12(a), "[d]isposal system means any combinations of engineered and natural barriers that isolate spent nuclear fuel or radioactive waste after disposal." Thus, performance of the disposal system is not evaluated by examining discrete elements independently, but by evaluating the disposal system as a whole.
>
> Consistent with the requirements found in Section 191.13, that DOE analyze the performance of the complete disposal system, any engineered barriers that are implemented at WIPP must be considered by the Department, and, ultimately, by EPA when evaluating compliance with both the containment requirements in Section 191.13 and the assurance requirement in Section 191.14(d). The effects of engineered barriers employed at the WIPP must be considered in performance assessments; excluding such barriers from consideration would result in inaccurate modeling of the disposal system as defined in Section 191.12(a).
>
> [Response to Comments Document for 40 CFR Part 194 (EPA 402-R-96-001), at 16-13 (January 1996)]

Performance assessments are required to address the likelihood of human intrusion according to specific criteria at Sections 194.32 and 194.33. Analysis of human intrusion activities in performance assessments must account for the type of resources exploited in the Delaware Basin (the geologic formation in which the WIPP is located), and the frequency of intrusive activities related to such resources, over the past 100 years. These requirements were developed under rulemaking procedures with input from many parties. EPA believes that the final human intrusion criteria in 40 CFR Part 194 represent a reasonable method for DOE to address potential human intrusion in the near future and over the regulatory time frame. For more information on how performance assessments analyze human intrusion, see Response to Comments for Sections 194.32 and 194.33.

Section 15 Removal of Waste -- Section 194.46

Issue A: Waste will not be retrievable once it is emplaced in the repository.

1. The record, however, shows there's a great likelihood that the waste proposed to be in place in WIPP will not be retrievable after the test phase. I think that's still true today. (289)

2. Even though the way that it is stored now is not very good, there's no sense in putting it where it's not going to be retrievable, where it can enter the aquifers. (435)

3. WIPP is designed to fail because it is designed to be something that can't be fixed. Because, believe you me, after 25 years of operation, when they decommission the above-ground facility, and they turn out the lights, and they plug the shafts, and they walk away from WIPP, there's no force of nature, human or otherwise, that is going to be able to get down in there into that collapsed facility with all that lovely backfill and clean up the mess that's been made down there. (464)

4. What if something is found to reverse in the future the toxicity of plutonium? This plutonium will be irretrievable because it will be crushed, it will be part of the environment, and that is a problem too. (515)

5. And always I've been so concerned about retrievability, and now the time frame, instead of 10,000 years or a thousand years, you're talking about 15 to 100 years, you need that retrievability possibility. (564)

6. Why are you considering it to be necessary to retrieve this after it is planted down there? (566)

7. Until a plan is formed for retrieval of this waste, please don’t consider giving your approval for its opening. (653)

8. Burial may seem most expedient at the moment. But long-lived (and toxic) radioactive substances which become part of air or soil or water cannot be retrieved. (819)

9. If waste is buried near Carlsbad and something goes terribly wrong underground and people start getting inexplicably sick can the waste be adequately retrieved after five years? 25? 100? 500? 1,000? 5,000? 10,000? (829)

10. Everyone agrees: no one ever gets a complex project 100% right the first time. Knowing this, competent technical people create concepts and designs where failures can be easily detected and corrected. With this view, it is really astounding that any non-retrievable concept has come so far. There is no way practical way to correct the problems that will inevitably occur. (1196)

Response to Comments 15.A.1 through 15.A.10:

EPA found, in reviewing Chapter 7 of the CCA, that DOE does meet the requirements of Section 194.46; i.e., DOE must demonstrate that it is feasible to remove waste from the repository for a reasonable period of time after disposal. In the CCA, DOE presented procedures that would be necessary for removal of waste after disposal is complete, described the technology that could be used in implementing these procedures and estimated how long it will be technologically feasible to remove the waste. DOE proposed a five-phase approach for removing waste from the repository that is projected to be feasible during the entire regulatory time frame, including: planning and permitting; initial above-ground set-up and shaft sinking; underground excavation and facility setup; waste location and removal operations; and decontamination and decommission of the facility. The CCA provided sufficient detail to enable EPA to establish that the five phases involved in waste removal could be implemented. The proposed activities, techniques, and equipment that would be necessary to remove the waste all are presently feasible. These procedures are discussed at length in WRAC.6. EPA found that the five phases described for waste removal provide an orderly sequence of planning and implementation procedures that would be followed to remove the waste from the repository after disposal is complete. The CCA discusses several existing mining techniques that could be used to remove waste from the WIPP: continuous mining, drill and blast, solution mining, small-scale mechanical excavation techniques, and remote mining. DOE determined that although all the proposed mining techniques are viable, small-scale remote continuous mining and small-scale mechanical excavation are likely to be the most appropriate for the WIPP. [p. WRAC-40 to 41]

DOE's assessment of how long waste removal might be feasible depended heavily on the assumption that present technology would not be lost. EPA agreed that waste removal would be feasible as long as current technology remains available, but did not believe it is reasonable to assume that the technology will remain available over the entire regulatory time frame. To estimate the length of time waste removal would be feasible, EPA considered how long the technology described in the CCA might remain available and concluded that, as long as our present society remains stable, it is reasonable to conclude that there will likely be a continuity or advancement of technology which would allow waste removal to occur. EPA identified 100 years after disposal as a realistic but conservative limit on how long active controls could be assumed to be effective; i.e., how long present institutions would remain in place continuously to enforce such controls. [50 FR 38080] EPA believes that the maintenance of active institutional controls (AICs) at the site indicates a stable society. DOE committed to maintaining AICs for 100 years after the end of the operational period. EPA found that it is reasonable to assume that the technology for removal of waste will remain available during the 100-year period when AICs are in effect. EPA concluded that 100 years constitutes a reasonable period of time after disposal and that waste removal will remain feasible for that time. Although the eventual disposition of the waste is an important environmental concern, 40 CFR Part 194 does not require DOE to speculate on the possible location or hazards of the waste once it is removed from the repository.

Issue B: EPA and DOE should acknowledge the limitations of the removal of waste plan.

1. As a practical matter, however, the EEG believes that attempts to remove the waste from the repository, even 10 years after first emplacement, will be so hazardous and expensive that it is not a reasonable option. The EPA and the DOE should clearly acknowledge that fact. (1305)

Response to Comment 15.B.1:

The preamble for 40 CFR Part 191 [50 FR 38082] states that, "to meet this assurance requirement, it only need be technologically feasible (assuming current technology levels) to be able to mine the sealed repository and recover the waste -- albeit at substantial cost and occupational risk." In Chapter 7 of the CCA, DOE makes several assumptions in the development of the removal of waste strategy:

- ♦ The reason for removing the waste is the result of some future insight or discovery into the storage of waste, not a cataclysmic event;
- ♦ There are no cost or time limits on the process to remove waste;
- ♦ The eventual disposition of the waste upon removal is not important;
- ♦ The length of time the repository has been closed at the time of removal is known;
- ♦ The contact-handled transuranic waste containers have been breached by the time of waste removal; and
- ♦ Contamination that may have migrated beyond the disposal region will not be removed.

EPA reviewed the six assumptions made by DOE in developing the removal of waste strategy and found these assumptions to be reasonable because the information to satisfy most of these assumptions should be readily available at the time of removal. Therefore, both EPA and DOE have acknowledged the hazard and expense that may be associated with the removal of waste.

Section 16 Individual and Groundwater Requirements -- Sections 194.51, 194.52 & 194.53

Comment Issue Page #

Issue A: Concentrations of radionuclides released to a USDW in the undisturbed scenario would not exceed EPA limits.

1. EEG believes the concentrations of radionuclides due to an undisturbed release from WIPP in any possible USDW will be somewhat less than the Maximum Concentration Limits (MCLs) in 40 CFR 141. This conclusion is based on the belief that while some contamination could occur between anhydrite beds and USDWs the amount of dilution that would be needed in order to maintain a TDS concentration in a USDW aquifer below 10,000 mg/l would more than offset uncertainty in estimating radionuclide concentrations. (1307)

Response to Comment 16.A.1:

EPA agrees with the commenter that releases to a hypothetical underground source of drinking water (USDW) under undisturbed conditions would not exceed EPA's limits. As EPA stated in CARD 53 -- Consideration of Underground Sources of Drinking Water:

> EPA determined that the outcome of the bounding analysis, which employed the tracer exercise and the flow field generated by BRAGFLO, was reliable and the assumptions were conservative. The gross alpha activity -- even if the highest realization values for each radionuclide are summed -- was less than 10 picocuries per liter, which is below the standard of 15 picocuries per liter. The maximum annual dose for all alpha, beta, and gamma radiation (0.47 millirem) was about an order of magnitude less than the 4 millirem per year dose standard for beta and gamma radiation alone.
>
> EPA noted that the bounding concentration of alpha radionuclides (about 9 picocuries per liter) does not allow for a large margin of error, being less than a factor of two under the MCL of 15 picocuries per liter for alpha emitters. Similarly, the calculated maximum

annual exposure for all radiation (0.47 millirem) is only one order of magnitude less than the standard, and this relatively small margin of error could be significantly reduced if changes have to be made to the performance assessment containment requirements or results. However, DOE's calculated concentrations took into account numerous conservative assumptions (e.g., direct accessibility to a USDW of brine at the subsurface boundary of the accessible environment). As such, EPA concluded that the margins of error between DOE's estimates and the standards are acceptable. [CARD 53, Section 53.A.6]

Issue B: EPA must consider existing levels of naturally occurring radionuclides in USDWs near the WIPP.

1. The CCA provided no information on existing concentrations of radionuclides in the possible USDWs and EPA did not ask for this information. Natural system compliance with the MCLs should not be assumed. EEG measured radionuclide concentrations in 3 Dewey Lake wells just south of the site in 1989 and 1990. One of the four samples measured 37 pCi/l gross alpha, 13.6 pCi/l uranium, and 2.4 pCi/l ^{226}Ra + ^{228}Ra (EEG-47). EPA needs to either obtain existing radionuclide concentrations in the possible USDWs in order to show compliance with 40 CFR 191.24 or explain why this requirement is not applicable. (1308)

Response to Comment 16.B.1:

The commenter expresses concern that if an USDW already exceeds maximum contaminant levels (MCLs) for radionuclides, no additional contamination would be tolerable. However, EPA does not believe it is necessary to require DOE to identify existing radionuclide concentrations in Dewey Lake or other potential USDWs.

As discussed in Section 53.A.6 of CARD 53 -- Consideration of Underground Sources of Drinking Water, DOE identified three potential rock units in the WIPP area that could contain USDWs: the Culebra member of the Rustler Formation, the Dewey Lake Formation, and the Santa Rosa Sandstone of the Dockum Group. DOE's performance assessment showed no transport of radionuclides from the WIPP to these potential USDWs even under disturbed conditions. Rather, the only possible release of radionuclides to the accessible environment results from contaminated brine flowing into the Salado Formation interbeds. DOE assumed that water within the Salado interbeds was available for immediate consumption at the boundary of the accessible environment. This is a highly conservative assumption because water in the Salado interbeds is actually a highly concentrated brine that would have to be diluted with pure water sufficiently to bring down the total dissolved solids from an average of 324,000 mg/L to 10,000 mg/L, which is the level EPA considers acceptable for a potential source of drinking water. The same dilution of total dissolved solids with a USDW by a factor of 32 would also apply to any concentrations of radionuclides in the brine.

Despite the use of conservative assumptions intended to maximize releases in the PA, the highest concentration of alpha emitters encountered in Salado interbed brine was only 5.9 pCi/L (see Table 1 of CARD 51/52 -- Consideration of Protected Individual/Exposure Pathways), less than half the EPA MCL value of 15 pCi/L established at 40 CFR Part 141.15(b). Factoring in the dilution effect, it is apparent that even if brine did somehow manage to reach a USDW near the WIPP, the increment in concentration of alpha-emitters would be approximately 1 percent of the MCLs. EPA finds this amount to be negligible, and certainly below the level of radioanalytic detection.

Issue C: DOE's consideration of potential USDWs near the WIPP

1. There have been a number of encounters of fresh water, drinkable water in and near the WIPP site in both the Dewey Lake Red Beds and the Rustler Formation. Now, the Department of Energy says this doesn't matter because their computer models show that radiation will never get into these under ground water aquifers and, therefore, they are not potential pathways. It does not matter whether this water is drinkable or not. (303)

2. Another example of conservatism in the process is the approach DOE took in evaluating compliance with the drinking water protection provisions in Subpart C of Part 191. Even though available data don't conclusively show that an underground source of water is present near the site, one is assumed to be there. (392)

Response to Comments 16.C.1 and 16.C.2:

Sections 194.51 through 194.55 provide criteria that DOE must meet in order to demonstrate compliance with the ground water and individual protection standards of the disposal regulations. Section 194.53 requires that the WIPP comply with the ground water protection requirements at 40 CFR Part 191, Subpart C, and specifies the factors that compliance assessments must consider when analyzing doses resulting from exposure to radioactive contaminants in USDWs. Compliance assessments pertain to scenarios in which the WIPP remains undisturbed throughout the regulatory period (i.e., there is no human intrusion such as drilling or mining). DOE must assume that doses can be received from any USDW in the accessible environment (i.e., outside the controlled area), provided that a connective pathway could be expected to be established via ground water transport. EPA, however, does not intend for DOE to expend resources analyzing USDWs located large distances from the repository. [50 FR 5232]

In CCA Appendix USDW, DOE presented an assessment of the potential sources of ground water in the vicinity of WIPP. DOE then conducted a bounding assessment of contaminant concentrations that could potentially occur in the hypothetical USDW (which could include the Dewey Lake Redbeds) and doses that could be received by drinking from this contaminated source. DOE did not discount these formations as potential sources of drinking water in the bounding analysis for USDWs. DOE's modeling results showed that radionuclide concentrations in any USDW would be less than half of the EPA ground water protection standard. For further discussion of DOE's consideration of USDWs, see Section 53.A.5 in CARD 53 -- Consideration of Underground Sources of Drinking Water.

Issue D: DOE should have assumed a smaller gallon per minute pumping rate.

1. The assumption by DOE that a 5 gallon per minute pumping rate was necessary to supply 25 persons is non-conservative. Water consumption may average 282 gallons per capita per day in nearby communities where there is a water system that can supply additional water for lawns, gardens, swimming pools, etc. However, in a rural community where nearby water sources are limited, persons can live quite well on 100 gallons per capita per day. Thus, a pumping rate of 2 gpm should be adequate for 25 persons. (1306)

Response to Comment 16.D.1:

The rate of ground water production used by DOE to characterize a USDW is based upon actual consumption data. [CCA Appendix USDW, p. USDW-2] DOE's calculation was based on EPA's regulatory definition of a USDW [40 CFR 191.22] as well as representative data of local water consumption for the area. [Wilson 1992]

40 CFR 191.22 defines a USDW as "an aquifer or its portion which: (1) Supplies any public water system; or (2) Contains a sufficient quantity of ground water to supply a public water system." A public water system is defined as "a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals."

The rate of water consumption that DOE calculated was based on the average of five sampling centers around the WIPP, including Artesia, Loving, Carlsbad, Hobbs, Lovington, and Roswell. Of the two criteria given in Section 191.22 to characterize a "public water system," DOE employed the second (i.e., serves at least 25 individuals) in the calculation, resulting in an estimate of approximately 5 gallons per minute. [Appendix USDW, p. USDW-6] This quantity is less than that calculated using the "fifteen service connection" criterion and thus more conservative.

Data for this calculation were taken from U.S. Bureau of Census and the New Mexico State Engineers Report. [Wilson 1992] Data are unclustered and are based on a regional survey that focused on actual usage data in areas around the WIPP. The data are therefore unbiased and representative of typical water use in the region. By assuming possible water usage well below the measured water usage supported by actual data, EPA would be presuming a hypothetical value unsupported by available data that would not be representative of measured conditions. The commenter suggests that it is possible for rural water use to be less than 100 gpm. EPA notes that it is also possible for such water usage to be greater than the "average" value of 282 gpm if a rural user has a garden, livestock, or other non-urban uses. EPA therefore concludes that DOE appropriately evaluated the rate of water consumption in the region.

Moreover, the bounding analysis conducted by DOE assumed that USDWs are present, even though sources meeting the criteria of 40 CFR 191.22 have not been established. The results of these calculations were that a hypothetical USDW will have a contaminant concentration less than half of EPA's ground water protection limits, and because of the dilution that must accompany any water taken from such a USDW, the maximum potential dose to a receptor who drinks from this would be greatly reduced.

References

Wilson, B.C., "Water Use by Categories in New Mexico Counties and River Basins, and Irrigated Acreage in 1990," Technical Report 47, New Mexico State Engineer's Office, Santa Fe, New Mexico. 1992. (CCA Reference #695)

Issue E: DOE failed to consider Laguna Grande de la Sal as a possible concentration point for plutonium releases.

1. DOE denies that anything beyond the WIPP site boundary is part of the accessible environment. The argument is that plutonium concentrations in ground water would be diluted as it travels away from the WIPP site boundary, and therefore would be of less consequence to the victim. . . [However] large amounts of Rustler ground water, nearly 600 million cubic feet per year, flow into Laguna Grande de la Sal. . . Laguna Grande de la Sal has no outlet, either at the surface or underground, and plutonium entering Laguna Grande de la Sal would concentrate in the lake sediments until [it] overflows into the Pecos River during times of major flooding, at which times actual victims downstream would be affected. (876)

Response to Comment 16.E.1:

In the CCA's description of ground water flow in units above the Salado, DOE acknowledged that Nash Draw and the Pecos River are areas where discharge of ground water to ground surface occurs, and specifically identified Surprise Springs and the saline lakes in Nash Draw. [Chapter 2.2.1.4, p. 2-114] Total discharge to Laguna Grand de la Sal is probably over 50 times less, and discharge from major springs (e.g., Surprise Springs) over 2,000 times less, than the 600 million cubic feet per year suggested by the commenter based on the assumption that inflow is due exclusively to ground water discharge. [Hunter, pp. 30-32, and CCA Appendix HYDRO, p. 49] DOE determined that the sources of water in Laguna Grande de la Sal are precipitation, surface drainage, ground water inflow from upper units above the brine aquifer, and possibly inflow from mining activities that take place further north in Nash Draw. DOE further indicated that discharge of ground water into Laguna Grande de la Sal is by flow of seeps and springs, particularly along the northern end of the lake, and Surprise Springs is specifically identified by DOE as a potential ground water discharge point.

However, DOE found that the Culebra and the Rustler-Salado contact residuum is not the source of water in Surprise Springs, because sodium and chloride concentrations in Surprise Spring samples and samples of Culebra and Rustler-Salado contact residuum water that were collected from test-hole WIPP-29 (located near Surprise Springs) were different. [CCA Appendix HYDRO, p. 49] DOE also found that the discharge point for the ground water within the Culebra and the Rustler-Salado contact residuum is located south of Laguna de la Sal, near Malaga Bend. [Appendix HYDRO, pp. 53 and 61] As a result, DOE acknowledged in the CCA that sources of water in Laguna Grande de la Sal included discharge of ground water from the units above the Salado, but did not necessarily agree that the Culebra is the sole source of this discharge. EPA accepts DOE's characterization of discharge to Laguna Grande de la Sal based on the extensive study of the hydrology of the Rustler Formation by DOE and other parties (e.g., Robinson and Lang, 1938 (CCA Reference #553) and Theis and Sayre, 1942, as cited in Appendix HYDRO) that is documented in Appendix HYDRO.

DOE also examined the possibility of plutonium transport through supra-Salado units, which could ultimately discharge in the Laguna Grande de la Sal area. DOE assessed radionuclide transport in the Culebra because it is the first very permeable pathway that a contaminated brine release (through an intrusion borehole) would encounter; exhibits relatively higher permeability than surrounding rock units; and as a water-bearing interval within the WIPP site boundary, is more laterally continuous than other water-bearing units (e.g., Dewey Lake). [CCA Chapter 6, pp. 6-122 to 6-123 and 6-147 to 6-149] DOE modeled radionuclide transport assuming that brine released through human intrusion contains radionuclides, is transported through the Culebra to the boundary of the accessible environment, and is somewhat attenuated via partitioning to Culebra rock matrix. [Chapter 6, pp. 6-122 to 136] DOE concluded that "the mean CCDF for subsurface releases resulting from ground water transport [in the Culebra] is not shown [on Figure 6-41, which presents releases along the different release modes] because those releases were less than 10^{-6} EPA units and the CCDF cannot be shown at the scale of this figure." [Chapter 6, p. 6-216]

DOE calculated that direct drilling releases from both deep and shallow drilling by removal of brine from a contaminated Culebra plume was only about 9×10^{-5} normalized EPA units. [CCA Appendix SCR, p. SCR-114] This release is insignificant, which supports DOE's decision to screen out shallow drilling on the basis of no consequence. Because the quantity of radionuclides that would be transported through supra-Salado beds is well below EPA's release limit, EPA concludes that the commenter's concerns regarding the possibility of plutonium accumulation in Laguna Grand de la Sal is unwarranted.

In summary, DOE stated in the CCA that sources of water in Laguna Grande de la Sal included discharge of ground water from the units above the Salado. However, the source of this water is not attributable exclusively to ground water flow from the Rustler, but also to water from surface run-off, mine effluent, etc. EPA also notes that DOE modeled the ground water basin well beyond the LWA boundary -- even though DOE was only required to examine contamination at the WIPP boundary -- in order to ensure that the model domain adequately captures flow in the WIPP region. EPA concludes that the commenter's concern about plutonium accumulation in Laguna Grande de la Sal sediments is unfounded, since calculations of radionuclide transport indicate that only a very small quantity of actinides may cross the WIPP site boundary within the Culebra, much less be transported to Laguna Grande de la Sal.

References

Hunter, R.L., "A Regional Water Balance for the Waste Isolation Pilot Plant Site and Surrounding Area, SAND84-2233. Sandia National Laboratories. (CCA Reference #320)

Appendix A List of Commenters[38]

Comment ID Number	EPA Docket Number	Commenter
1	IV-E-8	Southwest Research and Information Center (SRIC)
2 - 5	IV-E-8	Concerned Citizens for Nuclear Safety (CCNS)
6 - 8	IV-E-8	SRIC
9 - 26	IV-E-8	Citizens for Alternatives to Radioactive Dumping (CARD)
27	IV-E-8	Myla Reson
28 - 33	IV-E-8	SRIC
34 - 59	IV-E-8	Environmental Evaluation Group (EEG)
60 - 85	IV-E-8	New Mexico Attorney General (NMAG)
86 - 103	II-H-48	EEG
104 - 117	II-H-50	Department of Energy (DOE)
118 - 127	II-H-53	NMAG
128 - 131	IV-D-1	NMAG
132 - 134	IV-D-2	David & Burleigh Shepard
135 - 136	IV-D-3	Critz H. George
137 - 156	II-H-29	NMAG
157	II-H-33	CARD
158 - 217	IV-F-1	Carlsbad Public Hearings (see Appendix B)
218 - 394	IV-F-2	Albuquerque Public Hearings (see Appendix B)

[36] Some comment ID numbers will not be found in this document. Most of these ID numbers represent numbering errors in the processing of comments, comments that did not contain enough information for EPA to make a response, or comments that referenced other materials.

Comment ID Number	EPA Docket Number	Commenter
395 - 642	IV-F-3	Santa Fe Public Hearings (see Appendix B)
643 - 644	IV-G-1	*Name Illegible*
645 - 646	IV-G-2	Howard Cady
647 - 648	IV-G-3	Alfred Fuller
649	IV-G-4	Alan Merritt
650 - 652	IV-G-5	Scott Thomas
653	IV-G-6	Florence Cromwell
654 - 661	IV-G-7	DOE
662 - 663	IV-G-8	Ross Kirkes
664 - 667	IV-G-9	Mel Marietta
668	IV-G-10	Ron Morgan
669	IV-G-11	James and Ina Coulter
670	IV-G-12	Steve Matthews
671	IV-G-13	James Van Hecke, Jr.
672 - 673	IV-G-14	William Stratton
674	IV-G-15	Freda Grote
675	IV-G-16	John Hart
676	IV-G-18	Theresa Sheehan
677 - 679	IV-G-19	Ruth Weiner
680 - 711	IV-D-12	EEG
712 - 715	IV-D-14	NMAG
716 - 722	IV-F-4	EEG
723 - 725	IV-F-5	Jim McWhinney
726 - 727	IV-F-6	Donovan Mager
728	IV-F-7	M. Katherine Knowles

Comment ID Number	EPA Docket Number	Commenter
729 - 731	IV-F-8	Ross Kirkes
732 - 735	IV-F-9	Charles Loftus
736 - 737	IV-F-10	Tod Rockefeller
738 - 809	II-H-48	EEG
810	IV-G-20	Carlene Plouk
811	IV-G-21	Paul & Colette Dugan
812	IV-G-22	Lawrence Bruckner
813	IV-G-23	Ruby Meaders
814 - 815	IV-F-13	J. Hunt Burress
816 - 827	IV-F-15	Dolores Pierson
828 - 830	IV-F-16	Michael Truax Collins
831	IV-F-17	D. Raymond Schmidt
832 - 833	IV-F-18	William Whiting
834 - 837	IV-F-19	Bryan Howard
838 - 885	IV-G-17	CARD
886 - 888	IV-G-25	Robert Villarreal
889 - 890	IV-G-26	Bonnie Mandoe
891	IV-G-27	Marvin Lewis
892 - 893	IV-G-28	Burleigh and David Shepard
894	IV-G-29	M.P. Gonzales
895	IV-G-30	Mary Lou Keiger
896	IV-G-31	Stephen Stoddard
897 - 905	IV-G-32	Deborah Reade
906	IV-G-33	Frank Yates
907 - 933	IV-G-34	DOE
934 - 935	IV-G-35	W.F. Lawless

Comment ID Number	EPA Docket Number	Commenter
936 - 938	IV-G-36	DOE
939 - 949	IV-G-37	DOE
950 - 1048	IV-G-38	NMAG
1049 - 1050	IV-G-39	NMAG
1051 - 1065	IV-G-40	NMAG
1066 - 1075	IV-G-41	NMAG
1076	IV-G-42	Nicholas Crawford
1077 - 1088	IV-G-43	EEG
1089	IV-G-44	Dorothy and Robb Minor
1090 - 1096	IV-G-45	Penelope McMullen
1097	IV-G-46	Thomas Morgan
1098 - 1099	IV-G-47	Steve Wagner
1100	IV-G-48	Polly Davis
1101	IV-G-49	Julie Sutherland
1102 - 1104	IV-G-50	Mansi Kern
1105	IV-G-51	Sherry Magee
1106 - 1110	IV-G-52	Alliance for Nuclear Accountability
1111	IV-G-54	Frederick Sica
1112 - 1171	IV-G-53	SRIC
1172 - 1192	IV-G-55	CARD
1193 - 1194	--	--
1195 - 1197	IV-G-56	David Gold
1198 - 1219	IV-G-57	CCNS
1220 - 1223a	IV-G-59	EEG
1223b - 1224a	IV-G-43	EEG

Comment ID Number	EPA Docket Number	Commenter
1224b	IV-G-59	EEG
1225 - 1316	IV-G-43	EEG
1317	IV-G-61	Senator Craig, Senator Kempthorne & Representative Crapo
1318	--	--
1319 - 1329	IV-G-63	CARD
1330 - 1346	--	--
1347 - 1353	IV-G-38	NMAG

Appendix B List of Testifiers: EPA Public Hearings -- January 5 - 9, 1998[39]

Location/Date	Comment ID Number(s)	Commenter/Testifier
Carlsbad: 1/5/98 - 1/6/98	158	Michael McFadden
	159	Benny Hooda
	160 - 161	Gary Perkowski
	162 - 163	Tracy Hill
	164	Rep. John Heaton
	165 - 167	Chris Pflum
	168 - 170	Senator Carroll Leavell
	171	Mike Brown
	172	Paul Robinson
	173 - 174	Charles Loftus
	175	Bruce Baker
	176 - 177	Ross Kirkes
	178 - 179	Kathy Knowles
	180	Frank Hansen
	181	Paul Sanchez
	182	Joe Archuleta
	183	Mary Ellen Klaus
	184	Jeff Neal
	185 - 186	Betty Richards
	187 - 188	Vicky Black
	189 - 194	Robert Neill
	195 - 197	Joe Epstein

37 Some comment ID numbers will not be found in this document. Most of these ID numbers represent numbering errors in the processing of comments, comments that did not contain enough information for EPA to make a response, or comments that referenced other materials.

Location/Date	Comment ID Number(s)	Commenter/Testifier
Carlsbad: 1/5/98 - 1/6/98	198 - 202	Anthony Hakl
	203 - 204	Richard Anderson
	205	Phil Carroll
	206	Chuck Wiggins
	207	Dee Armstrong
	208	Mike Simpson
	209	Senator Don Kidd
	210	Tim Sweeney
	211 - 212	Jim Mcwhinney
	213	Tom Quintela
	214	Tom Bearden
	215	Michael Kearney
	216	Roger Nelson
	217	Jerome Holderness
Albuquerque: 1/7/98 - 1/8/98	218 - 220	Kent Hunter
	221	Don Olsen
	222 - 223	Mark Miller
	224	John Lee
	225	Dan Funchess
	226 - 234	Don Hancock
	235	Susan Pickering
	236	--
	237	Hank Theiry
	238 - 239	Lilly Zaragoza
	240	Katherine Montano
Albuquerque: 1/7/98 - 1/8/98	241 - 243	Ed Zaragoza

Location/Date	Comment ID Number(s)	Commenter/Testifier
	244	Lily Rendt
	245 - 246	Ernest Garcia
	247 - 249	Joe Tilleison
	250 - 251	Roberto Ribal
	252	Ann Halter
	253	Robert F. Hoffman
	254	Pat Tyrell
	255 - 257	Dr. Dan Kerlinsky
	258 - 260	Don Schrader
	261	Gil Brassell
	262 - 263	Steven Melzer
	264	Ted Cloak
	265	Dr. Matthew Silva
	266	Don Kimball
	267	Geraldine Amato
	268 - 271	Emmet Garrity
	272 - 274	Jeffrey Rich Munos
	275	Terry Sullivan
	276	Andy Stanley
	277	Sharon Williams
	278 - 279	Dennis Brown
	280 - 283	Will Beems
	284 - 285	Ms. Pia Diegos
	286	Peter Swift
Albuquerque: 1/7/98 - 1/8/98	287 - 288	Hong-Nian Jow
	289 - 290	John McCall

Location/Date	Comment ID Number(s)	Commenter/Testifier
	291 - 309	Dr. Richard Hayes Phillips
	310 - 311	Eric Rajala
	312 - 317	Dave Mitchell
	318	Joan Woodard
	319	Allan Cooper
	320	Dave Pace
	321 - 322	Kathy O'Neill
	323	Harry Willson
	324 - 325	Margaret Chu
	326 - 327	Louise Pribble
	328 - 329	Ruth Weiner
	330	Janet Greenwald
	331 - 332	Jay Evans
	333	Jenny Van Winkle
	334 - 336	Penny Maynes
	337	--
	338	Robert Anderson
	339 - 340	Michael Mauzy
	341 - 342	Julie Ahern
	343 - 344	Rich Weiner
	345	--
	346 - 347	Jack Urrick
	348	Maria Santelli
Albuquerque: 1/7/98 - 1/8/98	349	Lorraine Allen
	350	Larry Coalson
	351 - 354	Lokesh Chatervedi

Location/Date	Comment ID Number(s)	Commenter/Testifier
	355 - 356	Brian Rees
	357 - 359	Geri Rhodes
	360	Richard Clark
	361 - 362	Thomas Clemnents, Jr.
	363	Clifford Howard
	364	John Dimas
	365	Ronald Firestone
	366 - 368	Dale Rucker
	369 - 371	Madeleine Aron
	372	--
	373 - 374	Bob Kehrman
	375	--
	376 - 380	Melody Stevens
	381	Alan Solow
	382	Dr. Ted Davis
	383	Kris Kron
	384 - 386	James Lewis
	387	Virginia Corazon
	388	Sharla Bertram
	389 - 392	John Hart
	393	Steve McCutcheon
	394	Jeff Radford
Santa Fe: 1/8/98 - 1/9/98	395 - 399	Carol Miller
	400	Dominique Mazcong
	401 - 408	Attorney General Tom Udall
	409 - 411	Jennifer Salisbury

Location/Date	Comment ID Number(s)	Commenter/Testifier
	412	Jimmy Joe Gonzales
	413	David Arms
	414	Richard Halford
	415 - 417	Deborah Reade
	418 - 420	John Otter
	421 - 422	Earl Potter
	423	Michelle Baca
	424	Shawn Gormerly
	425	A.J. Tony Fiorina
	426	Robert Ortiz
	427	Charlie Griego
	428	Deborah Altshuler
	429 - 430	Bennie Atencio
	431 - 432	Pamela Baumgarter
	433 - 435	Bonnie Bonneau
	436	Julie Southerland
	437 - 439	Anna Hanson
	440	M.G. Lockhart
	441	Patti Bushee
	442 - 443	Deidre Boak
	444	Jeremy Boak
Santa Fe: 1/8/98 - 1/9/98	445 - 446	Audrey Curry
	447 - 449	Michael Collins
	450	Tim Curry
	451 - 452	John McCall
	453 - 454	Polly Roddick

Location/Date	Comment ID Number(s)	Commenter/Testifier
	455 - 456	Wendell Wert
	457	Priscilla Logan
	458	John Dendahl
	459	Stanley Tenorio
	460	Dolores Baca
	461	Amy Manning
	462	Mike Dempsey
	463 - 465	Sasha Pyle
	466	Les Shephard
	467	Greg Mello
	468	Alfred Fuller
	469	Harper F. Brewer
	470 - 471	Jose Villegas
	472	Amy Sollman
	473	Elizabeth West
	474	Stanley Logan
	475	Parrish Staples
	476 - 477	Jean Nichols
	478	Jay Shelton
	479	Tracy Hughes
Santa Fe: 1/8/98 - 1/9/98	480	Jai Lakshman
	481	Jean Wheeler
	482	George Dials
	483	Leif Eriksson
	484 - 489	Jim Channell
	490 - 494	Dr. Erica Elliot

<u>Location/Date</u>	<u>Comment ID Number(s)</u>	<u>Commenter/Testifier</u>
	495 - 498	Mel Marietta
	499	Myla Reson
	500	Arthur Fields
	501 - 505	Margret Carde
	506	Kevin Donovan
	507	Bonney Wittington
	508 - 512	Robin James
	513 - 518	Lucienda Lynch
	519 - 526	Lovato Anhara
	527	Charles Fairhurst
	528	Dr. Sanford Clarke
	529 - 530	Jean Altshuler
	531 - 532	Shannyn Sollitt
	533 - 536	Lalo Silva
	537 - 538	Virginia Miller
	539 - 544	Lety Seibel
	545 - 546	Tom Seibel
	547	Edgar Stein
	548 - 549	Norbert Rempe
Santa Fe: 1/8/98 - 1/9/98	550	Joe Archer
	551 - 552	Eduardo Zaragoza
	553	Nova Priest
	554 - 556	Margaret Ann Hesch
	557 - 560	Rick Lass
	561	Peggy Prince
	562 - 565	Barbara Stevens

Location/Date	Comment ID Number(s)	Commenter/Testifier
	566 - 567	Nancy Park
	568	Howard Vasquez
	569 - 570	Al Elder
	571 - 572	Louise Balm
	573	Peggy Coyne
	574	--
	575 - 577	Kirk Larson
	578	Ray Stevens
	579	Robert S. Light
	580	Ann Dasburg
	581	Ike DeVargas
	582	Lucy Cutter
	583 - 585	Judy Goldberg
	586 - 587	Corrine Sanchez
	588	John Beasley
	589	Ernie Carlson
	590	Bob Murray
	591	Marian Naranjo
Santa Fe: 1/8/98 - 1/9/98	592	Mark Lee
	593	Karrey Prince
	594	Bill Whiting
	595 - 597	Bob Yearout
	598	Lauren McClenegan
	599	Mary Lou Cook
	600 - 603	Richard Fabrick
	604 - 609	Dr. Richard Hayes Phillips

Location/Date	Comment ID Number(s)	Commenter/Testifier
	610	Bill St. John
	611	Bob Forrest
	612	Richard Doss
	613	Jack White
	614	Terry Marshall
	615	Michael Boniuto
	616	Mika Boniuto
	617 - 618	Beverly Garcia
	619 - 620	Harriet Elkington
	621 - 622	Gilbert Sanchez
	623	Bryan Howard
	624	Amy McKay
	625	Billie Jenkins
	626	Henry Castaneda
	627	Rachel Darnell
	628 - 629	Ruth Stogstad
	630 - 631	Harrison Minor
Santa Fe: 1/8/98 - 1/9/98	632	Debbie Benjamin
	633	Bernice Boyd
	634	Richard Balicci
	635	John Hoag
	636	James Hotch
	637	Joe Sharpe
	638	Eddie Lyons
	639	Elliott Skinner
	640	WIPPy the Clown

Location/Date	Comment ID Number(s)	Commenter/Testifier
	641	Lyndia Rollins
	642	Gloria Barnes

Appendix C List of Acronyms

AEA	Atomic Energy Act [42 U.S.C. Section2011 *et seq.,* as amended]
AIC or AICs	Active Institutional Controls
ANPR	Advance Notice of Proposed Rulemaking
ASME	American Society of Mechanical Engineers
BID	Background Information Document
CAG	Compliance Application Guidance
CARD	Compliance Application Review Document
CCDFs	Complementary Cumulative Distribution Function
CFR	Code of Federal Regulations
CH	Contact Handled
CWA	Clean Water Act [33 U.S.C. Section *1251 et seq.,* as amended]
DOE	Department of Energy
DOT	Department of Transportation
DRZ	Disturbed Rock Zone
EB	Engineered Barriers
EEG	Environmental Evaluation Group
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FEP	Features, Events, and Processes
FR	Federal Register
ICRP	International Commission on Radiation Protection
LANL	Los Alamos National Laboratory
LHS	Latin Hypercube Sampling
LWA	Land Withdrawal Act [Public Law 102-579, 1992]
MCL	Maximum Contaminant Levels
MTHM	Metric Tons Heavy Metal
NACEPT	National Advisory Council for Environmental Policy and Technology
NAS	National Academy of Sciences
NEPA	National Environmental Protection Act
NPRM	Notice of Proposed Rulemaking
NQA-1	*Nuclear Quality Assurance*
NRC	Nuclear Regulatory Commission
NUREG	NRC Regulation
OMB	Office of Management and Budget
ORIA	Office of Radiation and Indoor Air, EPA
OSW	Office of Solid Waste, EPA

PA	Performance Assessment
PAVT	Performance Assessment Verification Test
PIC or PICs	Passive Institutional Controls
QA	Quality Assurance
QAMS	Quality Assurance Management Staff
RCRA	Resource Conservation and Recovery Act [42 U.S.C. Section6901 *et seq.,* as amended]
RH	Remote Handled
SDWA	Safe Drinking Water Act [42 U.S.C. Section 300f *et seq.,* as amended]
SEIS	Supplemental Environmental Impact Statement
SNL	Sandia National Laboratory
TDEM	Time Domain Electromagnetic
TRU	Transuranic
USDW	Underground Sources of Drinking Water
VOC	Volatile Organic Constituent
WIPP	Waste Isolation Pilot Plant
WQSP	Waste Quality Sampling Plan