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Aldrich Chemical Company. 1994. Aldrich Catalog Handbook of Fine Chemicals, 1994-1995. Milwaukee, WI: Aldrich Chemical Co.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Al-Hussaini, M. 1981. "Tensile Properties of Compacted Soils," Laboratory Shear Strength of Soil, Eds. R.N. Yong and F.C. Townsend, ASTM Special Technical Publication No. 740 American Society for Testing and Materials, Philadelphie, PA. pp. 207-225.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Altman, W.D., Donnelly, J.P., and Kennedy, J.E. 1988. Peer Review for High-Level Nuclear Waste Repositories Generic Technical Position. NUREG-1297, Division of High-Level Nuclear Waste Management, Office of Nuclear Material Safety and Safeguards. U.S. Nuclear Regulatory Commission, Washington, D.C.

ABSTRACT, p iii;

" This document provides guidance on the use of the peer review process in the high-level nuclear waste repository program. The applicant must demonstrate in the license application that the applicable health, safety, and environmental regulations in 10 CFR Part 60 have been met. Confidence in the data used to support the license application is obtained through a quality assurance (QA) program as described in 10 CFR Part 60, Subpart G.

Peer reviews may be used as part of the QA actions necessary to provide adequate confidence in the work being reviewed. Because of several unique conditions inherent in the geologic repository program, expert judgement will need to be utilized in assessing the adequacy of work. Peer reviews are a mechanism by which these judgements may be made.

This document provides guidance on areas where a peer review is appropriate, the acceptability of peers, and the conduct and documentation of a peer review."

Anderson, R., Vaughn,P.L., Stoelzel, D., and O'Brien, D. 1996. "Justification of Brine Pocket Volume Uncertainty." Memorandum to Margaret Chu, July 22, 1996. Sandia National Laboratories, Albuquerque, NM.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Bachman, G.O., 1985. Assessment of Near-Surface Dissolution At and Near the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico, SAND84-7178, Sandia National Laboratories, Albuquerque, NM. WPO 24609.

ABSTRACT, p. 3;

" The area at and near the WIPP site was examined for evidence of karst development on the geomorphic surface encompassing the site. Certain surficial depressions of initial concern were identified as blowouts in sand dune fields (shallow features unrelated to karstification). An ancient stream system active more than 500,000 years ago contained more water than any system since. During that time (Gatuña, Middle Pleistocene), many karst features such as Clayton Basin and Nash Draw began to form in the region. Halite was probably dissolved from parts of the Rustler Formation at that time. Dissolution of halite and gypsum from intervals encountered in Borehole WIPP-33 west of the WIPP site occurred during later Pleistocene time (i.e., <450,000 yr ago). However, there is no evidence of active near-surface dissolution within a belt to the east of WIPP-33 in the vicinity of the WIPP shaft."

Bachman, G.O., 1987. Karst in Evaporites in Southeastern New Mexico, SAND86-7078, Sandia National Laboratories, Albuquerque, NM. WPO 24006.

ABSTRACT;
" Permian evaporites in southeastern New Mexico include gypsum, anhydrite, and salt, which are subject to both blanket and local, selective dissolution. Dissolution has produced many hundreds of individual karst features including collapse sinks, karst valleys, blind valleys, karst plains, caves, and breccia pipes. Dissolution began within some formations during Permian time and has been intermittent but continual ever since. Karst features other than blanket deposits of breccia are not preserved from the early episodes of dissolution, but some karst features preserved today--such as breccia pipes--are remnants of karst activity that was active at least as early as mid-Pleistocene time. Rainfall was much more abundant during Late Pleistocene time, and many features visible today may have been formed then. The drainage history of the Pecos River is related to extensive karstification of the Pecos Valley during mid-Pleistocene time. Large-scale stream piracy and dissolution of salt in the subsurface resulted in major shifts and excavations in the channel. In spite of intensive groundwater studies that have been carried out in the region, major problems in groundwater in near-surface evaporite karst remain to be solved. Among these are determination of recharge areas and time of recharge."

Bates, R.L., and Jackson, J.A., eds. 1987. Glossary of Geology, 3rd ed. American Geological Institute, Alexandria, VA.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Beauheim, R.L. 1987a. Analysis of Pumping Tests of the Culebra Dolomite Conducted at the H-3 Hydropad at the Waste Isolation Pilot Plant (WIPP) Site. SAND86-2311. Sandia National Laboratories, Albuquerque, NM. WPO 28468.

ABSTRACT;

" Two pumping tests were conducted in the Culebra Dolomite Member of the Rustler Formation at the H-3 hydropad at the Waste Isolation Pilot Plant (WIPP) site. The first test was in 1984, with well H-3b3 pumped for 14 days at an average rate of 4 gpm. The second test, the H-3 multipad test, was in late 1985 and early 1986, with well H-3b2 pumped for 62 days at an average rate of 4.8 gpm. Both tests provided information on the hydraulic properties of the Culebra at the H-3 hydropad. The second test provided information on average Culebra hydraulic properties on a much larger scale; responses were observed up to 8000 ft from the pumping well.

The interpretation of these tests had three principle objectives. The first was to determine the most appropriate conceptualization of the nature of the Culebra flow system around the H-3 hydropad. The pumping well responses during the H-3 tests appear to be those of wells completed in a double-porosity medium with unrestricted interporosity flow. In such a system, fractures provide the bulk of the permeability, while matrix pores provide the majority of the storage capacity. The importance of fracture flow is indicated by the speed with which the observation wells on the H-3 hydropad respond to pumping and the nearly identical behaviors of these wells and the pumping well. The similarity between pumping- and observation-well behavior on the H-3 hydropad is so pronounced that the responses of all three wells on the hydropad can be interpreted only by using pumping-well analytical techniques, not observation-well analytical techniques. H-3b1 and H-3b3, in particular, appear to be very well connected by fractures.

The second objective was to quantify the hydraulic properties of the Culebra in the vicinity of the H-3 hydropad. The total-system (fractures plus matrix) transmissivity of the Culebra derived from the first test is 2.9 ft^2/day; that from the second test is 1.7 ft^2/day. The lower value derived from the second test probably represents lower transmissivity (lower fracture connectivity) at H-3b2 than at H-3b3, and/or lower average transmissivity of the volume of Culebra stressed in the multipad test as opposed to the smaller volume stressed in the first test. The fracture-to-total-system storativity ratios derived from the various analyses range from 0.03 to 0.25, indicating a relatively high degree of storage within the fractures. The highest storativity ratios were consistently found at H-3b1. Wellbore skin values are highly negative, indicating direct wellbore connection with fractures.

The third objective was to quantify the average hydraulic properties of the Culebra between the H-3 hydropad and more-distant observations wells. Meeting this objective . . ."

Pg. 100 Table A-3

Table A-3. Water Levels and Pressures in Observation Well DOE-1 During the 1984 H-3 Pumping Test

Day	Hr	Min	Elapsed Time (hr)	Depth to Water (ft)	Pressure* (psi)	Comments
101	16	32	-305.970	499.18	47.69	
108	14	10	-140.330	499.21	47.67	
110	8	55	-97.583	499.31	47.63	
110	14	5	-92.417	499.08	47.74	
110	15	44	-90.767	499.21	47.67	
111	12	45	-69.750	499.18	47.69	
114	8	45	-1.750	499.74	47.42	
114	12	7	1.617	499.61	47.48	PUMP ON AT H-3B3
115	9	42	23.200	499.61	47.48	114:10:30
117	13	46	75.267	499.41	47.58	
118	13	40	99.167	500.00	47.30	
121	13	17	170.783	500.75	46.95	
122	13	20	194.833	500.85	46.90	
123	11	52	217.367	501.05	46.80	
124	9	24	238.900	501.35	46.66	
125	10	6	263.600	501.51	46.59	
128	13	48	339.300	502.46	46.14	

*Pressure = (600 ft - Depth to Water) x 0.473 psi/ft

Beauheim, R.L., 1987b. Interpretations of Single-Well Hydraulic Tests Conducted At and Near the Waste Isolation Pilot Plant (WIPP) Site, 1983-1987, SAND87-0039, Sandia National Laboratories, Albuquerque, NM. WPO 27679.

1. INTRODUCTION; p. 17, col. 1, para. 1;

" This report presents the results of single-well hydraulic tests performed in 23 wells in the vicinity of the Waste Isolation Pilot Plant (WIPP) site in southeastern New Mexico (Figure 1-1) between 1983 and 1987.

Most of the tests discussed in this report were performed in the Culebra Dolomite Member of the Rustler Formation. The Culebra was tested at wells H-1, H-4c, H-8b, H-12, H-14, H-15, H-16, H-17, H-18, WIPP-12, WIPP-18, WIPP-19, WIPP-21, WIPP-22, WIPP-30, P-15, P-17, P-18, ERDA-9, Cabin Baby-1, DOE-1, and Engle. The Forty-niner, Magenta, and Tamarisk Members of the Rustler were tested in H-14 and H-16. The unnamed lower member of the Rustler Formation was tested in H-16. The Dewey Lake Red Beds were tested in H-14. Alluvium of Cenozoic age was tested in the Carper Well. The Castile and Salado Formations were tested in WIPP-12. With the exception of additional testing performed at DOE-2 that has been previously reported by Beauheim (1986), this report discusses all single-well testing initiated by Sandia and its subcontractors at the WIPP site from 1983 through 1987."

p. 100, col. 1, para. 1;

" Two type-curve matches are shown with the test data on Figure 5-71. The early-time data were best fit by a type curve characteristic of damaged (i.e., having a positive skin) wells, whereas the late-time data were best fit by a type curve characteristic of undamaged (i.e., having a neutral or no skin) wells. The two type-curve matches also provide contrasting transmissivity estimates. The transmissivity derived from the early-time match is about 4 x 10-3 ft^2/day, while that from the late-time match is about 7 x 10-5 ft^2/day (Table 5-3). These observations indicate that the P-18 wellbore may be poorly connected hydraulically to a small portion of the culebra having a higher transmissivity than more-distant portions. The contrast between the transmissivity of the Culebra and that of the well "skin" may decrease as the transmissivity of the Culebra decreases with distance from P-18, resulting in the neutral skin shown by the late-time data. The fact that the slope of the data on Figure 5-71 changes abruptly as opposed to smoothly appears to indicate that the change in transmissivity is discrete rather than gradational. Drilling of the borehole may have caused minor fracturing of the formation around the hole, which may have led to a slightly enhanced transmissivity in the immediate vicinity of the hole. Casing, cementing, and perforation may have resulted in a poor connection between the wellbore and the surrounding formation, resulting in the positive skin observed.

Given the peculiarities in the response to the P-18 slug test and the uncertainties as to their cause, the transmissivity of the Culebra at P-18 remains poorly defined. The estimate provided by the early-time type-curve match does not appear to be valid beyond the immediate vicinity (a few feet?) of the well. The transmissivity estimate provided by the

late-time type-curve match may not be quantitatively reliable because the time match between the data and the type curve, which defines the transmissivity, would probably be greater, thus indicating a lower transmissivity, if the hydraulic response of the Culebra had been more consistent (i.e., homogeneous). In summary, the transmissivity estimate from the early-time data, 4 x 10-3 ft^2/day, is probably unrealistically high, but is reliably a maximum value. The estimate from the late-time data, 7 x 10-5 ft^2/day, is probably more representative of the Culebra in the vicinity of P-18, but cannot be interpreted as a minimum value."

Beauheim, R.L. 1989. Interpretation of H-11b4 Hydraulic Tests and the H-11 Multipad Pumping Test of the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site. SAND89-0536. Sandia National Laboratories, Albuquerque, NM. WPO 24154.

ABSTRACT, p. 3;

" Drillstem tests, slug tests, a small-scale pumping test, and a large-scale pumping test of the Culebra Dolomite Member of the Rustler Formation were performed in 1988 at the H-11 hydropad at the Waste Isolation Pilot Plant (WIPP) site in southeastern New Mexico. The drillstem, slug, and small-scale pumping tests were conducted in well H-11b4 to evaluate well and aquifer properties in preparation for a tracer test. The large-scale pumping test, known as the H-11 multipad test, was performed by pumping well H-11b1 in the southern part of the WIPP site at a rate of six gpm for 63 days and monitoring drawdown and recovery responses in three other wells on the H-11 hydropad and at 11 observation wells within a three-mile radius. Responses were observed in 10 of these distant wells. The H-11 multipad pumping test complemented the H-3 and WIPP-13 multipad pumping tests conducted in the central and northern portions of the WIPP site in late 1985 and early 1987, respectively.

Individual well tests at various locations around the WIPP site have demonstrated that the Culebra is a laterally heterogeneous water-bearing unit. The responses measured at observation wells to pumping tests in heterogeneous systems cannot be rigorously interpreted using standard analytical (as opposed to numerical) techniques developed for tests in homogeneous results in evaluations of average hydraulic properties between pumping and observation wells that are nonunique 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 both hydraulic properties and heterogeneities or hydraulic boundaries with the tested area.

The interpretations of the responses at the test and observation wells provided the following information: The Culebra is a fractured, double-porosity system at H-11 with a transmissivity between 27 and 43 ft^2/day and a storativity between 3.4 x 10^{-5} and 1.5 x 10^{-4}. Drawdown during the multipad test appeared to be largely concentrated to the north and south of H-11; wells to the east and west showed relatively low-magnitude responses. The rapid and high-magnitude responses observed at DOE-1, H-3b2, and H-15 during the multipad test are believed to reflect the presence of a fracture network extending to the north from H-11. Numerical simulations indicate that the fracture network extends south of H-11. but no wells are currently situated within it.

Double-porosity hydraulic behavior was observed at DOE-1 during the multipad test, and at both DOE-1 and H-3b2 during other pumping tests performed at those locations. The fractures appear to continue past DOE-1 to the north toward H-15, although H-15 itself lies in a lower transmissivity, apparently single-porosity zone. Apparent transmissivities in the region north of H-11 range from 7.1 to 9.0 ft^2/day and apparent storativities range from 2.4 x 10^{-6} to 8.4 x 10^{-6}. Apparent transmissivities between H-11 and observation wells to the

west, southwest, and southeast, where fracturing in the Culebra decreases and single-porosity hydraulic behavior is observed, range from 6.0 to 21.0 ft^2/day and apparent storativities range from 1.8×10^{-5} to 6.5×10^{-5}. Interpretation of the responses to the multipad test observed at the western and southern wells was complicated by an anomalous and widespread rise in water levels of unknown origin.

Thus, the analyses of the responses measured at observation wells to the H-11 multipad pumping test are consistent with a conceptualization of two distinct domains within a heterogeneous portion of the Culebra south of the center of the WIPP site: a fractured region having low storativity extending to the north and south from H-11, and a relatively unfractured region west, southwest, and southeast of H-11 having higher storativity. This conceptualization is being refined using numerical-modeling techniques to simulate the H-11 multipad test and other tests at the WIPP site, in an attempt to define a distribution of hydraulic properties that will reproduce the response observed."

Bechtel National, Inc. 1979-1980. Waste Isolation Pilot Plant Title I Design Report, Bechtel National Inc., San Francisco, CA. (This 32 volume set in on file in the Nuclear Waste Management Library, Sandia National Laboratories, Albuquerque, NM as UN00597.)

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Berglund, J.W., and Lenke, L.R. 1995. "One Dimensional Experiments of Gas Induced Spall." NMERI 1995/3. prepared for Sandia National Laboratories. New Mexico Engineering Research Institute, University of New Mexico, Albuquerque, NM, WPO 27589.

ABSTRACT, p. ii, para. 1;

" An investigation of 1-dimensional outgassing from cohesive granular media and resultant induced spall are described in this report. An experimental laboratory program was developed to model sudden outgassing and resultant spall from a waste repository breached by a rotary drilling bit. A simple 1-dimensional geometry was employed in order to obtain a better understanding of the phenomenology of transient gas flow from porous media at an unsupported free boundary. The experimental results suggest that, in addition to the permeability and porosity of the porous media, the tensile strength of the cohesive granular media dictates the spall resistance of such materials. Based on the knowledge gained from this geometry, a simple bounding model is proposed for predicting the volume of waste released in the event of inadvertent intrusion by a drilling operation."

2.1 Material Selection, p. 4, para. 2;

" Butcher (1994) has proposed a model for estimating the properties of released waste. His model is based on the premise that a precise definition of the end states of the biological and chemical waste degradation processes in the WIPP repository are difficult, if not impossible, to define. One extreme of the model is that microbiological degradation may reduce all the cellulosics to a small amount of inert residue, while corrosion processes may alter all ferrous materials to a high-strength oxide. Butcher suggests that such a material would be highly resistant to erosion. At the other extreme, the combination of cellulosics degradation and metal corrosion could produce a mixture of low shear strength with little resistance to erosion. One would surmise that similar arguments would apply to the response of these materials to transient out gassing and resultant spall, i.e., materials with a high resistance to spall and those having virtually no resistance to spall.

Butcher states that there is no known method to replicate these long-term chemical processes in the laboratory and produce such complex waste mixtures. Instead, the selection of well chosen surrogate materials which are representative of various decomposition and corrosion states is proposed. At the low shear strength extreme, a clay material is used to represent the soft, perhaps "soapy," amorphous substances that may be typical of some stages of microbial degradation. Clay is also considered to represent the "slimy" hydrated or unhydrated iron hydroxide ($Fe(OH)_2$) corrosion products. Quartz sand is proposed to represent the other extreme of corrosion products, namely, those with higher shear strength. This sand is believed to be a good surrogate for end products such as iron oxide (Fe_3O_4) because it is relatively incompressible and its chemical composition is less important that particle size and shape and resultant mechanical properties of relatively inert end products.

In summary, samples of sand and clay were used in this experimental program as waste surrogates for partially corroded and decomposed waste mixtures. A kaolin clay and select silica sand gradation were chosen as waste surrogate materials."

2.3.3.1 Direct Tension Tests, p. 13, para. 4;

" The sample geometry employed for most conventional tensile testing is one with a high length to width aspect ratio. Such geometry is not practical for low strength soil samples. It was decided to keep the geometry similar to that of conventional soil strength tests with a sample length twice that of the diameter. The cylinders used for permeability lend themselves nicely to preparing samples 2 inch (50 mm) in diameter by 4 inch (100 mm) in length. Samples were prepared by compacting lifts to the specified density using a Harvard compaction tamper (Wilson, 1970). Early tests were conducted using prismatic cylindrical endcaps. Because of stress concentrations at the soil-endcap interfaces, failure invariably occurred at this point.

Because of the non-uniform stress field in the cylindrical samples, efforts were then made to develop a "dog-bone" shape sample. Such a sample is shown in Figure 2-7 along with a section view of the mold used for sample preparation. This sample, 2 inch diameter by 4 inch long (50 mm by 100 mm), tapers uniformly from the 2 inch diameter at a distance of 0.25 inch (6.4 mm) from each end to a diameter of 1.6 inch (40.6 mm) at the center. This sample geometry was used in all subsequent tensile tests. The sample is prepared in a split mold having the same shape as the sample of Figure 2-7. The upper half of the sample is compacted first. A cylindrical plug 1.6 inch (40.6 mm) in diameter and 2 inch (51 mm) long is placed at the bottom of the sample mold. The top of the sample is then compacted in three lifts (labeled 1, 2, and 3 in Figure 2-7). The plug is then removed and the sample is inverted with compaction of the remaining three lifts. Upon completion of compaction, the split sample mold is removed leaving an intact tensile specimen.

FIGURE 2-7 NOT INCLUDED IN TEXT

The prepared tensile specimen is secured to two aluminum end caps (2 inch (50 mm) diameter) using a gap-filling slow-set cyanoacrylate adhesive, i.e., "super glue." It was found that a drill press works rather nicely for aligning the end caps with the specimen and provides a means of lightly clamping the specimen while the adhesive sets. Once the end caps are properly aligned and clamped in place, a super glue accelerator is sprayed at the specimen endcap interface which cures the super glue almost instantaneously.

The end caps each have spherical bearings placed on their center lines. These bearings assure that the specimen will maintain a vertical alignment during the actual test resulting in a uniform tensile field within the sample. The complete test setup is shown in Figure 2-8. A bolt passes through the top spherical bearing which is clamped in the chuck of the drill press. A similar bolt with a small diameter cable through a small hole on center line is placed in the lower bearing. Attached to this cable is a light weight pail (paint can). Once the sample is in this configuration, lead shot is slowly poured in the pail via a long funnel. When the sum weight of the lead shot, pail, bottom end cap and lower half of the failed sample causes failure the test is complete. This weight is then determined and is used

to calculate the tensile strength based on the actual area corresponding to the failure plane.

2.3.3.2 Indirect Tension Tests, p. 15, para. 2;
" An additional verification of the tensile properties of the waste surrogate was made by testing a cylindrical sample indirect tension. This test, also known as a diametrical tension test, produces a fairly uniform tensile stress along the vertical axis of the sample."

p. 17, para. 1;
" Figure 2-10 compares results from both direct and indirect tensile tests of 15% clay-sand blends prepared at a dry density of 107 pcf (1715 kg/m^3) and moisture content of 7.5%."

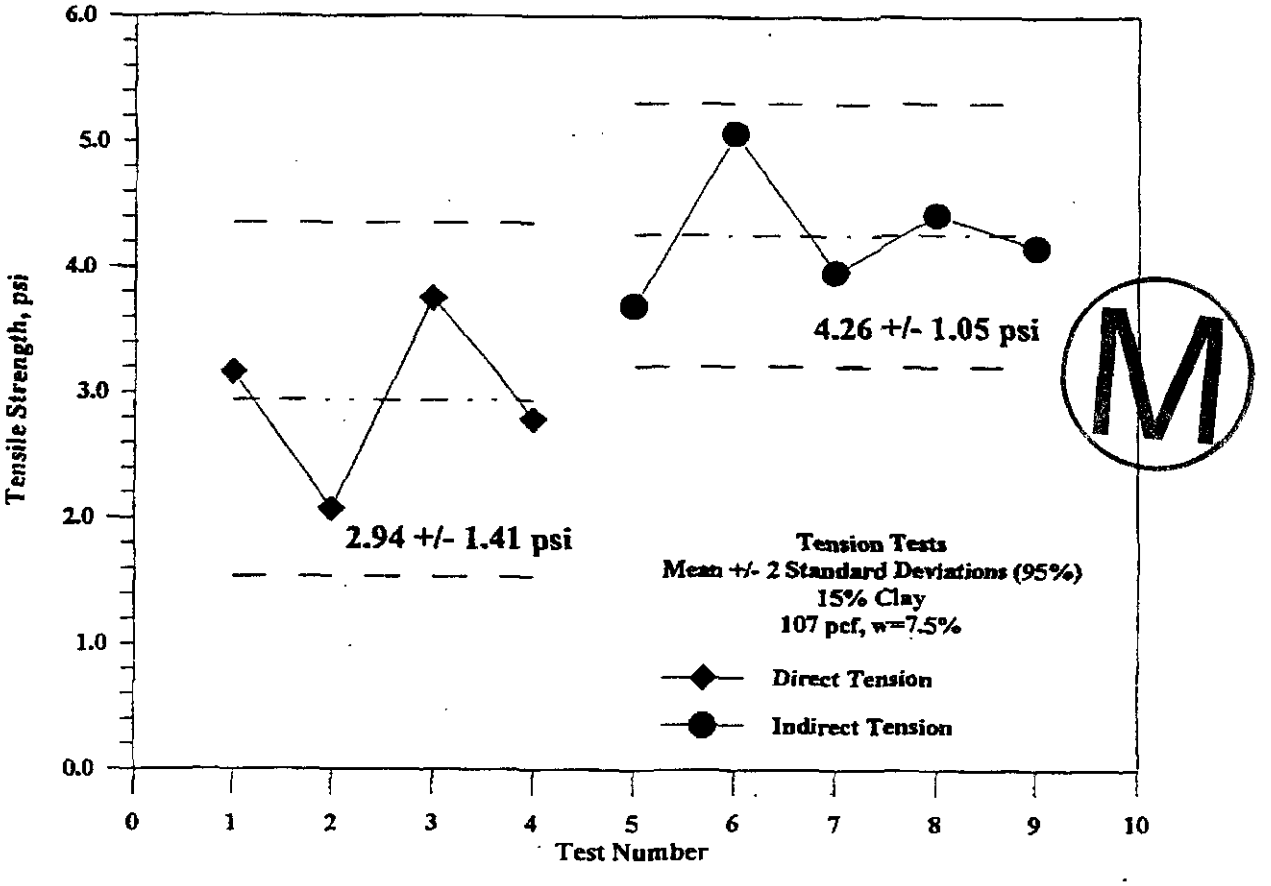
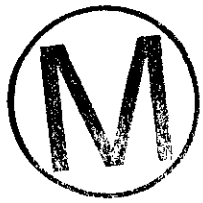


Figure 2- 10. Tension Test Results.

Bertram-Howery, S.G., and Hunter, R.L., eds. 1989. Preliminary Plan for Disposal-System Characterization and Long-term Performance Evaluation of the Waste Isolation Pilot Plant. SAND89-0178. Sandia National Laboritories, Albuquerque, NM. WPO 24103.

ABSTRACT;
" The U. S. Department of Energy is planning to dispose of transuranic wastes at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Sandia National Laboratories is responsible for evaluating the compliance of the WIPP with the Environmental Protection Agency's Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR 191, Subpart B). This plan has been developed to present the issues that will be addressed before compliance can be evaluated. These issues examine the procedural requirements for evaluating compliance, which follow from the procedural nature of the Standard, and the technical requirements for further characterizing the behavior of the disposal system, including uncertainties, to support the compliance assessment. The plan briefly describes the activities that will be conducted prior to 1993 by Sandia to characterize the WIPP disposal system's behavior and predict its performance."



Bertram-Howery, S.G., and Swift, P.N., 1990. Status Report: Potential for Long-Term Isolation by the Waste Isolation Pilot Plant Disposal System. SAND90-0616. Sandia National Laboratories, Albuquerque, NM. WPO 23865.

ABSTRACT, p. 1, para. 1;

" This report summarizes the early-1990 status of the WIPP performance-assessment work to evaluate compliance with EPA regulation 40 CFR Part 191, Subpart B, which sets environmental standards for radioactive waste disposal (Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes). The report reviews the qualitative and quantitative requirements for compliance, and identifies issues where unknowns complicate evaluating compliance. It discusses in relatively non-technical terms the approaches to resolving those issues, and concludes that compliance is achievable. The report is not an evaluation of compliance: available data are insufficient to make evaluations; and 40 CFR Part 191 has not been reissued following remand.

Work to date indicates a high degree of confidence that, as currently designed, the WIPP will comply with the Individual Protection Requirements of Subpart B, applicable to the undisturbed performance of the Repository. Compliance with the Ground Water Protection Requirements of Subpart B does not apply to the WIPP: no "special source of ground water," as defined in Subpart B, exists at the repository.

Compliance with the Containment Requirements of Subpart B appears uncertain for present design only in the event of inadvertent human intrusion into the repository prior to 10,000 years after decommissioning. Preliminary calculations show excessive radionuclide releases possibly could occur following intrusion given a coincidence of unfavorable conditions. The DOE is investigating two options to assure compliance. One reduces the probability of future intrusion through a passive marker system. The second redesigns the repository to achieve compliance by lessening the removal of radionuclides following intrusion. Numerous modifications that could assure compliance are technically feasible: testing will verify effectiveness, and modifications will be made if performance assessments indicate they will be needed. Benefits of modifications must be balanced against questions of safety, cost, regulatory constraints, and public acceptance. The DOE is confident compliance with the Containment Requirements can be achieved through these options."

Bethke, C.M., 1994. "The Geochemist's Workbench - Version 2.0 - A User's Guide to Rxn, Act2, Tact, React, Gtplot." Unpublished code. University of Illinois at Champaign-Urbana, Hydrogeology Program, Urbana, IL.

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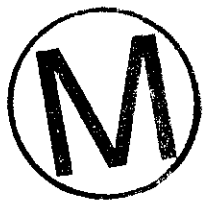


Borns, D.J., 1985. Marker Bed 139: A Study of Drillcore from a Systematic Array, SAND85-0023, Sandia National Laboratories, Albuquerque, NM. WPO 24529.

ABSTRACT, p 3;

" In southeastern New Mexico, Marker Bed 139 (referred to in this report as MB139) is one of 45 numbered siliceous or sulfatic units within the Salado Formation of the northern Delaware Basin. MB139 is divided into five zones. Zones I and V are the upper and lower contact zones, respectively. Zone II is a syndepositionally deformed subunit of polyhalitic anhydrite. Zone III is mixed anhydrite and polyhalitic anhydrite, a distinctive pale-green and pink, with subhorizontal fractures. Zone IV consists of interlayered halite and anhydrite without the overprint of polyhalite.

This sequence was transitional between submarine and subaerial. The anhydritic units of MB139 formed in salt-pan or mudflat environments or both. Undulations observed along the upper contact of MB139 are interpreted to result from traction deposits or from reworking of the upper portion of the marker bed during the transition from anhydrite to halite deposition. Zones II and III exhibit soft-sediment deformation and later traces of dewatering; e.g., formation of stylolites. Such deformation is not observed in the halite above MB139 or in Zone V and the halite units below MB139.

A distinctive set of subhorizontal fractures occurs in MB139 in mid-Zone III and, to some extent, in Zone IV. These fractures are partially infilled with halite and polyhalite. Brine occurrences at the mined facility horizon at the Waste Isolation Pilot Plant may be related to these fractures. The fractures formed either in response to stress cycles that were functions of sedimentation and erosion, or in response to deformation in the underlying Castile Formation. The subhorizontal orientation, dominant in the sampling to date, is more consistent with the interplay between stress and sedimentation cycles."

Borns, D.J. 1987. *Rates of Evaporite Deformation: The Role of Pressure Solution.* SAND85-1599. Sandia National Laboratories, Albuquerque, NM. WPO 27640.

Rates of Evaporite Deformation: The Role of Pressure Solution, p. 1;

" Evaporite sequences have been intensely studies for hazardous waste disposal and hydrocarbon development and storage. Rates of deformation are important in evaluating the long-term performance of different evaporites. Reported naturally occurring strain rates ($\dot{\xi}$) are: $5 \times 10^{-11}\ s^{-1}$ for a salt glacier; 10^{-11} for mine closure; 3×10^{-14}, 10^{-15}, and 10^{-16} for salt domes; 3×10^{-16} for bedded salt. Rates are controlled by temperature, differential stress, and active mechanism of deformation for each specific type of evaporite and setting.

Strain rates are estimated through in-situ measurements and the integration of geometric strain analysis and stratigraphic arguments for the time required for the observed deformation to occur. An inherent problem in such calculations is the large extrapolation of rates through time. Another approach for rate estimation is to calculate ξ directly, using the constitutive models for different deformation mechanisms that may be dominant. Specific mechanisms can be determined from petrofabric study, as at the WIPP site, SE New Mexico, where textures indicating that pressure solution was active are observed. Calculations based on experimental data are limited by the relatively poor data on diffusion in intergranular fluids. A variety of grain boundary diffusion models have been used. Some models (e.g., cubic approximation of the grain shape) leave gradients undefined at the grain edge.

Fore gravity-driven deformation near the WIPP site, geometric-stratigraphic integration predicts a $\dot{\xi}$ of $10^{-14}\ s^{-1}$ to $10^{-16}\ s^{-1}$ are predicted using models for dislocation creep and pressure solution. The rates using two approaches, geometric-stratigraphic and constitutive, are basically in agreement. These rates for the gravity-driven flow structures near WIPP reflect lower temperatures and stresses than salt domes. At the temperatures and stresses estimated for the WIPP flow structures, pressure solution is probably the dominant mechanism, rather than dislocation creep. It remains to be determined where in the transition from transient to steady-state response to an underground excavation in rock-salt pressure solution becomes a major mechanism."

Brausch, L.M., Kuhn, A.K. and Register, J.K. 1982. Natural Resources Study, Waste Isolation Pilot Plant (WIPP) Project, Southeastern, New Mexico. TME 3156, U.S. Department of Energy, Waste Isolation Pilot Plant, Albuquerque, NM. WPO 39094.

1.1.1 Description of the WIPP Site; p. 2, para. 2;

" The land area presently being considered for the WIPP project is about 18, 960 acres, an area approximately six miles in diameter, of which nearly 17,000 acres will be used to provide buffer zones around the underground facility. The site is divided into four control zones as follows (Figure 2):

- Control Zone I at the site center will contain nearly all of the surface facilities and occupy about 100 acres.
- Control Zone II, an area of about 1,800 acres, overlies the area of maximum potential underground development.
- Control Zone III occupies an area of about 6,200 acres. This zone provides a one-mile buffer strip around the area of maximum potential underground development.
- Control Zone IV, a second one-mile-wide buffer zone, contains an area of about 11,000 acres."

5.0 SUMMARY AND CONCLUSIONS; p. 64, para. 1;

" Studies have been conducted to evaluate the potential effects of developing the mineral and energy resources underlying or accessible from within (and outside of) Control Zone IV at the WIPP site. These assessments serve as input to the DOE decision-making process and reevaluation regarding the interim policy for resource recovery at the WIPP site. During the study, it was assumed that resource recovery was not allowed in Control Zones I, II, and III.

The methodology used in developing this evaluation can be summarized as follows:

- Determine the extraction technologies/activities that are applicable to the potash and hydrocarbon resources present at the WIPP site.
- Evaluate the type, extent, and degree of disturbance of the rock strata in the vicinity of the WIPP facility induced by these extraction activities.
- Assess whether such disturbance would affect the radiation dose consequences previously reported in the WIPP SAR long-term waste isolation assessment.

The conclusion of this study is that activities related to potash and hydrocarbon resource extraction and solution mining from within (and outside of) Control Zone IV, using currently available and applicable technology, will not compromise the integrity of the WIPP waste emplacement facility and increase the likelihood of a breaching event."

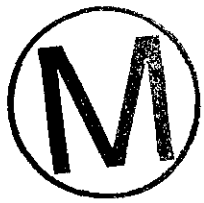
Brodsky, N.S. 1994. Hydrostatic and Shear Consolidation Tests With Permeability Measurements on Waste Isolation Pilot Plant Crushed Salt. SAND93-7058. Sandia National Laboratories, Albuquerque, NM. WPO 10087.

Pg. 66 Para. 1

" **ABSTRACT.** Sandia National Laboratories (SNL) has been pursuing a laboratory program designed to quantify its consolidation properties and permeability. Experimental results presented in this report complement existing studies and work in progress conducted by SNL. The experiments described in this report were designed to 1) measure permeabilities of consolidated specimens of crushed salt, 2) determine the influence of brine saturation on consolidation under hydrostatic loads, and 3) measure the effects of small applied shear stresses on consolidation properties."

Pg. 67 Para. 4

" To obtain the highest permeabilities (and therefore the worst case scenario from the standpoint of repository performance), the data were replotted in Figure 5-20 using only the initial slopes for tests in which flow rates slowed substantially."



Brush, L.H., 1990. Test Plan for Laboratory and Modeling Studies of Repository and Radionuclide Chemistry for the Waste Isolation Pilot Plant. SAND90-0266, Sandia National Laboratories, Albuquerque, NM. WPO 26015.

1.10.1 Temperature; p. 8, para. 2;

" The WIPP repository horizon is 655 m below the surface. The temperature of the Salado Fm. at this depth, beyond the annular volume affected by ventilation of the mine, is 28°C (Munson et al., 1987).

The CH TRU waste to be emplaced in drums and boxes in WIPP disposal rooms will produce essentially no heat.

The RH TRU waste to be emplaced in canisters in the ribs will produce some heat, but will probably not increase the temperature within WIPP disposal rooms significantly."

In lieu of modeling studies of the thermal response of the contents of WIPP disposal rooms to RH TRU waste, Brush specified a temperature of 30°C for the laboratory and modeling studies described herein. Most investigators are carrying out their experiments at this temperature. However, in some cases they conduct experiments at 25°C or at ambient laboratory temperatures."

2.3.1.3 PRELIMINARY DEFINITION OF A STANDARD SALADO-FM. BRINE COMPOSITION; p. 17, para. 5;

" Molecke (1990a) is planning bin-scale tests with CH TRU waste. The volume of brine required for these tests is too large to collect from the WIPP underground workings. Brush therefore defined a preliminary, standard composition for brine from the Salado Fm. and is developing a formulation for this brine (a description of this formulation will appear elsewhere). The composition of this or any other "average" Salado-Fm. brine depends on the data used to compute its composition and how those data are weighted. Because he cannot yet explain the chemical variations described in 2.3.1.1, these choices are arbitrary. The composition of this Salado-Fm. brine is subject to revision as he quantifies the causes of these chemical variations."

2.3.2 Castile-Fm. Brines; p. 21, para. 2;

" Popielak et al. (1983) investigated the occurrence of brine reservoirs in the Castile Fm. in the vicinity of the WIPP site and analyzed numerous samples of these brines from three drillholes. Because the WIPP project has not studies the chemistry of these fluids since the investigation of Popielak et al. (1983), Brush will use the results of their chemical analyses to define a standard Castile-Fm. brine for studies of repository and radionuclide chemistry."

2.3.3 Fluids from Overlying Formation; p. 23, para. 1;

" Two groups are studying the chemistry of fluids from the Rustler Fm. and the Rustler/Salado contact zone in the vicinity of the WIPP site. For results from the Water Quality Sampling Program, see: Uhland and Randall, 1986; Uhland, Randall, and Carrasco,

1987; Randall, Crawley, and Lyon, 1988. See Robinson (1988) and Lappin et al. (1989) for results from SNL. These groups participate in an interlaboratory comparison study comparable to that under way for analyses of brines from the Salado Fm. (2.4.3).

Brush is evaluating these previously published results to select chemical analyses of fluids that could seep down the shafts, along the drifts, and around or through the seals to WIPP disposal rooms. Brush is currently using five of these fluids (Table 2.4) for his study of reactions between fluids from overlying formations and Salado-Fm. brines and minerals (2.4.6)."

2.4 DESCRIPTIONS OF LABORATORY, MODELING, AND FIELD STUDIES; p. 23, para. 4;

" The objectives of these studies are to: (1) quantify the causes of chemical variations in brines from the Salado Fm. (2.4.1); (2) quantify any spatial or stratigraphic variations in Salado-Fm. brines (2.4.2); (3) quantify the variations caused by differences in the analytical techniques used by the three laboratories analyzing Salado-Fm. brines (2.4.3); (4) quantify the effects of sampling artifacts described in 2.3.1.1 on variations in Salado-Fm. brines (2.4.4); (5) simulate reactions between fluids from the Castile Fm. or overlying formations, and Salado-Fm. brines and minerals (2.4.5 and 2.4.6)."

p. 67, para. 3;

" Studies reviewed by Spinks and Woods (1976) imply that the range of α particles in plastics is generally a few tens of microns. This is less than their range in air (a few centimeters) and similar to their range in aqueous solutions. These estimates all assume energies of a few MeV for α particles. The altered zone will actually extend beyond 10 μm due to secondary electrons and γ rays generated by interactions between the α particles and the polymer matrix. The thickness of the plastics used in the studies described in 5.5.1 is probably greater than the range of α particles in these materials. Irradiation damage will fall off sharply as a function of depth; therefore, the plastics will be inhomogeneously irradiated. Because a relatively small volume of the samples may be affected, it may be difficult to detect microbial activity even if irradiation actually increases the biodegradability of these plastics. The limited range of α particles in plastics might also limit the extent to which radiolysis increases their biodegradability in WIPP disposal rooms."

7.4 ESTIMATES OF LIGAND CONCENTRATIONS IN WIPP BRINES; p. 87, para. 3;

" Estimates of the likely concentrations of organic and inorganic ligands in any brine present in WIPP disposal rooms are necessary to design realistic laboratory speciation and solubility studies, as well as other laboratory studies of radionuclide chemistry. Brush and Anderson (1988b) estimated the concentrations of the organic ligands citrate, EDTA, oxine, and TTA in three quantities of brine that could eventually resaturate WIPP disposal rooms for Choppin's (1988a) estimates of radionuclide solubilities (7.1 and Table 7.1).

Subsequently, Drez and James-Lipponer (1989) revised previous estimates of the quantities of citrate and oxine in the WIPP inventory and made new estimates for eight

additional organic and inorganic ligands not considered previously. The estimates of the quantities of EDTA and TTA in the WIPP inventory that Brush and Anderson (1988b) used (7.1) are still the best estimates available. Furthermore, Brush revised his estimates of the quantities of brine that could eventually resaturate WIPP disposal rooms.

During the Preparation of their preliminary inventory of the nonradioactive constituents of the CH TRU waste to be emplaced in the WIPP, Drez and James-Lipponer (1989) identified numerous, additional organic compounds (Table 7.2) that might form complexes with Pu, Am, Th, and U in any brine present in WIPP disposal rooms and increase their solubilities. Based on his review of this list, Choppin (1988b) concluded that if present at high enough concentrations, ten of the 60 compounds listed in Table 7.2 could increase radionuclide solubilities. These ten compounds are soluble in aqueous solutions, at least under some conditions. They are acetamide, acetic acid, ammonium thiocyanate, ascorbic acid, citric acid, di(20ethylhexyl)-phosphoric acid (DHP), α-hydroxy isobutyric acid, lactic acid, oxalic acid, and 1,10-phenanthroline. Choppin (1988b) also concluded that dihexyl-n, n-diethylcarbamoyl methyl phosphonate (DHDECMP), TBP, and TOPO could also increase radionuclide solubilities, but only in organic solvents. Unlike the ten compounds listed above, DHDECMP, TBP and TOPO are insoluble in aqueous solution under any condition."

Brush, L.H., 1995. "Systems Prioritization Method - Iteration 2 Baseline Position Paper: Gas Generation in the Waste Isolation Pilot Plant." Sandia National Laboratories, Albuquerque, NM. WPO 28740.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Budavari, S., O'Neil, M.J., Smith, A., and Heckelman, P.E. eds. 1989. The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals. 11th ed. Merck & Co., Rathway, New Jersey.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Budescu, D.V., and Wallsten, T.S. 1987. "Subjective Estimation of Precise and Vague Uncertainties," Judgmental Forecasting. eds. G. Wright and P. Ayton. John Wiley & Sons, Chichester, New York. p. 63. WPO 39635.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Butcher, B.M. 1994. "A Model for Cuttings Release Waste Properties." Memorandum, January 6, 1994. Sandia National Laboratories, Albuquerque, NM.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Butcher, B.M., Thompson, T.W., VanBuskirk, R.G., and Patti, N.C. 1991. Mechanical Compaction of Waste Isolation Pilot Plant Simulated Waste. SAND90-1206. Sandia National Laboratories, Albuquerque, NM. WPO 23968.

1.0 INTRODUCTION; p. 1, para. 1;

" A fundamental issue in evaluating performance of the Waste Isolation Pilot Plant (WIPP) facility near Carlsbad, NM, is the migration of fluids through the storage areas and the potential for dispersing radioactive materials in the event of human intrusion. The radioactive wastes to be stores in the WIPP consist of a variety of materials, including metals, combustibles (plastics and fibers), and "sludge." Unprocessed waste will be contained in 55-gallon drums (DOT-17C) or other containers such as standard waste boxes.

Most of the waste materials will initially have high porosities (or void volumes) and hence will be highly permeable if the waste remains unprocessed. However, over time the drums may be expected to collapse due to the closure of the rooms and the consequent loading of the containers. Under these conditions the contained materials will compact and cause a reduction in porosity and permeability (Butcher, 1989). These changes need to be defined as a function of time to evaluate the performance of the repository. For example, estimation of the change in density of the waste with time is required to predict what the final density of the waste will be and how soon states approaching this condition will occur. Information about the compaction characteristics of the waste must be obtained to make these predictions.

This report summarizes the results of a series of experiments and analyses performed to investigate the compaction of the waste materials and the collapse of waste filled drums.[1] Two phases of testing have been performed:

Part I: Determined the stress-density consolidation curves of various mixtures of solid materials to provide a preliminary characterization of this behavior and to select a suitable description for the waste.

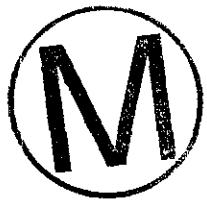
Part II: Determined the collapse behavior of actual drums filled with a variety of materials."

Bynum, R.V., 1996. Memo to M.S. Tierney and C. Stockman. "Update of Uncertainty Range and Distribution for Actinide Solubilities to be Used in CCA NUTS Calculation." WPO 38535.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Callahan, G.D. 1993. "Further Discussion of the TRU Waste Model," A Summary of the Models Used for the Mechanical Response of Disposal Rooms in the Waste Isolation Pilot Plant with Regard to Compliance with 40 CFR 191, Subpart B. SAND92-0427. B.M. Butcher and F.T. Mendenhall. Sandia National Laboratories, Albuquerque, NM. pp. A-27 through A-30. In Appendix A of WPO 23356.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.



Chaturvedi, L., ed. 1987. The Rustler Formation at the WIPP Site, Report of a Workshop on the Geology and Hydrology of the Rustler Formation as it Relates to the WIPP Project. EEG-34. Environmental Evaluation Group, Santa Fe, NM.

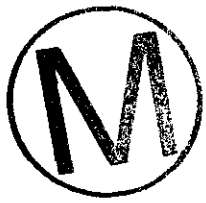
INTRODUCTION, p. 1;

" A workshop on 'The Rustler Formation at the WIPP Site' was organized by the Environmental Evaluation Group on March 7, 1985. The workshop was held at a time when a new series of studies on the Rustler Formation was starting. It provided the scientists from Sandia National Laboratories, the U.S. Geological Survey, IT Corporation, the Department of Energy and the Environmental Evaluation Group, an opportunity to exchange and discuss the up-to-date information on the geological and hydrological characteristics of the Rustler Formation. The papers and the summaries that follow reflect the status of knowledge at the time of the workshop (March, 1985). The decision to publish the proceedings was not made until after all the papers were received by the end of 1986.

Eight papers were presented at the workshop and much of the time was spent in discussing the relevance and significance of results obtained thus far and the need for further work. Following is a brief description of each of the papers presented and a summary of the discussions."

Christ, C.L., and Hostetler, P.B. 1970. "Studies in the System $MgO-SiO_2-CO_2-H_2O$.II. Activity-Product Constant of Magnesite." American Journel of Science. Vol 268, no. 4, pp. 439-453.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.



DOE (U.S. Department of Energy), 1979. Draft Environmental Impact Statement Waste Isolation Pilot Plant DOE/EIS-0026-D. U.S. Department of Energy, Washington, D.C.

Foreword; p. iii, para. 1;

" In furtherance of its responsibilities to develop and implement methods for the safe and environmentally acceptable management of radioactive wastes, the U. S. Department of Energy (DOE) is considering five major decisions:

1. Whether to pursue the construction of the proposed Waste Isolation Pilot Plant (WIPP), a mined repository for the disposal of transuranic wastes, with an initial period of retrievable emplacement
2. Whether the WIPP should include an intermediate-scale facility in which up to 1000 assemblies of spent fuel from commercial electricity-generating reactors would be disposed of, with an initial period of retrievable emplacement
3. Whether the WIPP should include a research-and-development facility in which experiments with all types of nuclear waste, including high-level waste, can be performed
4. What the timing and location of the WIPP should be
5. Whether to commit land now for a potential repository site in Eddy County, New Mexico

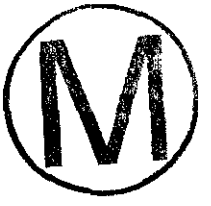
Pursuant to its responsibilities under the National Environmental Policy Act of 1969 (42 U. S. C. 4321 et seq.), the DOE has prepared this document as environmental input for the foregoing decisions. It also may be used as input for subsequent decisions by the DOE and other Federal agencies with respect to the site of the proposed facility."

p. iv, para. 2;

" This document is concerned only with decisions concerning a transuranic-waste repository, an intermediate-scale facility, and associated experiments. To provide a sufficient basis for these decisions, it also analyzes the radiological consequences of waste transportation and processing. Nevertheless, it is not intended to provide an environmental analysis to support decision on actual routes or methods for transporting material to the repository or to support decision on the construction of facilities for processing waste destined for the repository. The environmental implications of these decisions will be addressed in subsequent documents.

This environmental impact statement is arranged in the following manner: Chapter 1 is an overall summary of the analysis contained in the document. Chapters 2 through 4 set forth the policy objectives of the national waste management program and analyze the full spectrum of reasonable alternatives for meeting these objectives, including the WIPP. Chapter 5 presents the interim waste-acceptance criteria and waste-form alternatives for the WIPP. Chapters 6 through 13 provide a detailed description and environmental analysis of the WIPP repository and its proposed site. Chapter 14 describes the interactions that have taken place with Federal, State, and local authorities and with the general public in connection with the repository. The appendices contain data and discussions in support of

the material in the text."



DOE (U.S. Department of Energy), 1980a. Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE-EIS-0026, U.S. Department of Energy, Assistant Secretary for Defense Programs, Washington, D.C. WPO 38835, WPO 38838 - WPO 38839.

p 1-2, Section 1.2.1 1980 WIPP FEIS

" The 1980 WIPP Final Environmental Impact statement (FEIS) and the associated public review and comment period provided environmental input for the DOE's initial decision to proceed with the WIPP (DOE, 1980). The significance of impacts associated with the various alternatives was assessed. For the selected alternative, a two-phased approach to development was proposed: 1) a site and preliminary design validation (SPDV) program, as discussed in Subsection 8.2.1 of the FEIS, and 2) full construction, as discussed in FEIS Subsection 8.2.2. The durations of key WIPP activities are shown in Figure 1.1.

The 1980 FEIS presented an analysis of the environmental impacts of a number of alternatives for demonstrating the safe disposal of TRU waste. The alternatives considered include:

- Alternative 1. No action. A research and development facility to demonstrate safe disposal of TRU waste would not be developed and post-1970 TRU waste would continue to be retrievably stored.
- Alternative 2. Developing the WIPP at the Los Medanos site in southeastern New Mexico.
- Alternative 3. Disposing of stored TRU waste in the first available repository for high-level radioactive waste.
- Alternative 4. Delaying a decision on the site for a WIPP until at least 1984 to allow for investigation of alternative sites.

Alternative methods and geologic media for TRU waste disposal were also considered but rejected in the FEIS. The alternative methods included burial in deep ocean sediments, emplacement in deep drillholes, transmutation, and ejection into space. The alternative geologic media included igneous, volcanic, and argillaceous rocks.

The DOE's Record of Decision, published January 28, 1981 (46 FR 9162), announced the DOE's selection of Alternative 2: to proceed with the phased development of the WIPP at the Los Medanos site in southeastern New Mexico. . . ."

DOE (U.S. Department of Energy), 1980b. WIPP SAR: Waste Isolation Pilot Plant Safety Analysis Report, U.S. Department of Energy, Washington, D.C.

INTRODUCTION, p. 1.1-1;

" This Safety Analysis Report (SAR) has been prepared by the U.S. department of Energy (DOE) to support construction and operation of the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico. The WIPP facility is designed to receive, inspect, emplace, and store unclassified defense-generated transuranic wastes in a retrievable fashion in an underground salt medium and to conduct studies and perform experiments in salt with high-level wastes. Upon the successful completion of these studies and experiments, WIPP is designed to serve as a permanent facility.

The first chapter of this report provides a summary of the location and major design features of WIPP. Chapters 2 through 5 describe the site characteristics, design criteria, and design bases used in the design of the plant and plant operations. Chapter 6 discusses radiation protection; Chapters 7 and 8 present an accident analysis of the plant and an assessment of the long-term waste isolation at WIPP. The conduct of operations and operating controls and limits are discussed in Chapters 9 and 10. The quality assurance programs are described in Chapter 11."

DOE (U.S. Department of Energy). 1989. Draft Supplement Environmental Impact Statement, Waste Isolation Pilot Plant. DOE/EIS-0026-DS, U.S. Department of Energy, Washington, D.C.

ABSTRACT, p iii;

" IN 1980, the DOE published the Final Environmental Impact Statement (FEIS) for the WIPP. This FEIS analyzed and compared the environmental impacts of various alternatives for demonstrating the safe disposal of transuranic (TRU) radioactive wastes resulting from DOE national defense related activities. Based on the environmental analyses in the FEIS, the DOE published a Record of decision in 1981 to proceed with the phased development of the WIPP in southeastern New Mexico as authorized by the Congress in Public Law 96-164.

Since publication of the FEIS, new geological and hydrological information has led to changes in the understanding of the hydrogeological characteristics of the WIPP site as they relate to the long-term performance of the underground waste repository. In addition, there have been changes in the information and assumptions used to analyze the environmental impacts in the FEIS. These changes include: 1) analyses of certain additional DOE generator and/or storage sites as potential contributors to the WIPP waste inventory, 2) changes in the composition of the TRU waste inventory, 3) consideration of the hazardous chemical constituents in TRU wastes, 4) modification and refinement of the system for the transportation of TRU wastes to the WIPP, and 5) addition of the Test Phase.

The purpose of this SEIS is to update the environmental record established in 1980 by evaluating the environmental impacts associated with new information, new circumstances, and proposal modifications. This SEIS evaluates and compares the proposed action and two alternatives for demonstrating the safe disposal of TRU wastes:

The proposed action is to operate the WIPP under a 'Test Phase' for approximately five years during which time certain tests and operational demonstration would be carried out. The tests would be conducted to reduce uncertainties associated with the prediction of natural processes that might affect long-term performance of the underground waste repository. Results of these tests would be used to assess the ability of the WIPP to meet applicable federal standards for the long-term protection of the public and the environment. The operational demonstrations would be conducted to show the ability of the TRU waste management system to certify, package, transport, and emplace TRU wastes in the WIPP safely and efficiently. Upon completion of the Test Phase, the DOE would determine, based on a performance assessment, whether the WIPP would comply with U.S. Environmental Protection Agency (EPA) standards for the long-term disposal of TRU wastes (i.e., 40 CFR Part 191, Subpart B). If there is a determination of compliance, the WIPP would enter a permanent disposal phase of approximately 20 years to demonstrate the safe disposal of TRU wastes. After completion of waste emplacement, the surface facilities would be decommissioned, and the WIPP underground facilities would serve as a permanent radioactive waste repository.

The first alternative, no action, is similar to the no action alternative discussed in the 1980 FEIS. Under this alternative, TRU wastes would continue to be stored at the various

generator and storage sites, while the WIPP facility would be decommissioned and potentially put to other uses.

The second alternative to the proposed action is to delay emplacement of TRU wastes in the WIPP underground until a determination has been made of compliance with EPA standards for TRU waste disposal (i.e., 40 CFR Part 191, Subpart B). The DOE has determined that bin-scale tests could be conducted outside the WIPP underground facilities in a specially designed aboveground facility. This alternative has many implications including delays in both the operational demonstrations and room-scale tests, and the lack of room-scale test data for the compliance demonstration, a temporary mothballing of the WIPP facilities. This is true in any case. The specialized facility for aboveground bin-scale tests could be constructed at any one of several DOE sites. In order to analyze the environmental impacts of this alternative in the SEIS, the DOE has evaluated the Idaho National Engineering Laboratory in Idaho as a representative site for the aboveground bin-scale tests."

DOE (U.S. Department of Energy), 1991. Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives: Final Report of the Engineered Alternatives Task Force, DOE/WIPP 91-007, Revision 0, Waste Isolation Pilot Plant, Carlsbad, NM.

EXECUTIVE SUMMARY, p ES-i;

" The Engineered Alternatives Task Force (EATF) was established by the United States Department of Energy (DOE) WIPP Project Office (WPO) in September, 1989 (Hunt, A., 1990), to evaluate the relative effectiveness and feasibility of implementation of selected design enhancements (referred to as 'engineered alternatives') for the Waste Isolation Pilot Plant (WIPP). These enhancements consist of modifications of existing waste forms and/or the WIPP facility, and other design variations such as passive marker systems. The purpose of this report is to summarize the methodologies and results of evaluation of the effectiveness of selected engineered alternatives relative to the existing repository design, and to discuss the feasibility of implementing these alternatives with respect to availability of technology, cost, schedule, and regulatory concerns.

Preliminary analyses of the long-term performance of the WIPP disposal system performed by Sandia National Laboratories (SNL) (referred to as 'performance assessment') have identified two potential problems in demonstrating compliance with the applicable regulation 40 CFR Part 191 (EPA, 1985) that governs the disposal of transuranic radioactive waste. The first potential problem relates to gas generation. Lappin et al. (1989) discuss the possibility that up to 1,500 moles of gas can be generated per drum (or drum equivalent) of waste from anoxic corrosion, microbial degradation, and radiolysis, at rates that may be as high as 2.55 moles/drum/year. Although processes exist to dissipate excess gas pressure, these processes are currently believed to be slow relative to the current estimates of gas generation rates, resulting in gas pressures in storage rooms that may temporarily exceed lithostatic pressure. The consequences of exceeding lithostatic pressure are currently being evaluated by SNL (Lappin et al., 1989). Unless these evaluations demonstrate that either excess pressures will not occur, or that excess pressures will not degrade the performance of the disposal system, some type of waste form or facility modification may be required to either eliminate gas generation or reduce the rate of gas generation. For example, if the organics in the waste are incinerated and vitrified, then microbial gas generation can be eliminated.

A second potential problem in demonstrating compliance with 40 CFR Part 191 relates to the consequences predicted from future inadvertent human intrusion events. Preliminary evaluations of compliance with the containment requirement of 40 CFR Part 191 performed by SNL suggest that some of the current waste forms (under current interpretations of human intrusion provisions) may eventually be found to be unacceptable for disposal at the WIPP (Marietta et al., 1989). This may be due to uncertainties in key performance parameters of the waste forms. Key parameters that control the release of radionuclides during human intrusion scenarios are permeability of the waste storage rooms, radionuclide solubilities, and the availability of brine. Permeability of the storage rooms can

be effectively reduced by the use of a grout backfill and/or shredding and cementation of the waste. Solubilities can be reduced by the use of grout backfill or the addition of lime to raise the pH of any brine that may come in contact with the waste."

DOE (U.S. Department of Energy). 1995c. Waste Isolation Pilot Plant Safety Analysis Report. DOE/WIPP-95-2065, Rev. 0, Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM. NTIS Order # DE9006847.

5.4 Long-Term Waste Isolation Assessment; p. 5-71, para. 1;

" Applicable regulations require the DOE to assess the capability of the WIPP repository to isolate TRU & TRU mixed wastes for a 10,000-year period (40 CFR 191[1], 40 CFR 268.6[2]). The DOE is required to demonstrate, through this long-term assessment, that the repository can reasonably be expected to contain the wastes such that established quantitative release limits for both radionuclides and hazardous constituents are not exceeded for the 10,000-year performance period. The DOE's Performance Assessment (PA) is a probabilistic risk assessment tool designed to evaluate the long-term performance of the repository.

The PA process requires three (3) general types of information. These include: 1) those future events and processes that could occur, 2) the relative probabilities that such events and processes will occur, and 3) the consequences of such events and processes, should they occur.

Once a comprehensive set of such Features, Events and Processes (FEPs) are identified, a screening process is initiated. FEPs that are specifically excluded by regulation, are determined physically not reasonable, are of low probability, or are of low consequence are screened from the PA analysis. All FEPs that remain are treated in the PA through either incorporation in the modeling system or through modeling assumptions.

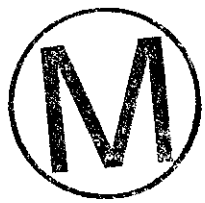
Consequence analyses are conducted using the applicable quantitative measures of performance from the driving regulations. The results are used to develop probabilistic distributions of calculated releases. These distributions will be used to display results in the form of a Complimentary Cumulative Distribution Function (CCDF). This CCDF will allow direct measure of calculated performance to the applicable release limits.

Uncertainty and sensitivity analyses will be conducted as appropriate. These efforts will differ in that the compliance assessment for hazardous chemicals will be deterministic in nature. Uncertainty analysis for this assessment will consist of a qualitative pre-modeling process where reasonable, discreet values are estimated for parametric input in instances where variables are imprecisely known. The compliance assessment for radionuclides is probabilistic in that imprecisely known variables are expressed in terms of ranges for parametric input and are randomly sampled across the range during the modeling process. The uncertainty analyses will be performed as a post-modeling process and will be both qualitative and quantitative.

Sensitivity analysis will identify those portions of the disposal system that drive the largest change in calculated result with their variation. Results of sensitivity analysis will be important for such activities as developing long-term monitoring concepts and other qualitative assurances, which will complement the expected performance of the natural disposal system.

Applicable regulatory agencies will determine the DOE's compliance with the

regulations. The PA analysis will be presented in the Compliance Certification Application (40 CFR 191[1]) and the No-Migration Variance Petition (40 CFR 268.6[2])."



DOE (U.S. Department of Energy). 1995d. Waste Isolation Pilot Plant Seal System Design Report, DOE/WIPP-95-3117. Waste Isolation Pilot Plant, Carlsbad, NM. WPO 29062.

ABSTRACT, p. iii;

" This report documents the Waste Isolation Pilot Plant shaft sealing system design. The seals are designed to limit the release of radionuclides and hazardous constituents from an underground nuclear waste repository in salt. Design concepts documents in this report will form the basis for no-migration variance petition modeling. In addition, these concepts are the basis for detailed sealing system design development and evaluations that will be completed in 1996 in support of the planned Compliance Certification Application. The report describes the geologic and hydrologic setting for the seals, presents qualitative and quantitative design guidance, describes the design, documents the sealing materials and their properties, and discusses evaluations of sealing system performance. The design uses a variety of common materials that have very low permeability, demonstrated technologies for construction processes, multiple components to perform each intended function, and the entire length of the shafts to effect a seal system that will meet the performance requirements. For the permanent or long-term seal that resists both gas and brine flow, more than 500 ft of highly compacted crushed salt is used in series with more than 400 ft of clay barriers. The design retards gas flow in the short term using a combination or a rigid concrete barrier (enhanced by an asphalt waterstop) and a compacted clay barrier approximately 100 ft high. Short-term brine flow down the shaft is limited by a clay barrier within the overlying formation and by a combination of more than 500 ft of asphalt, clay, and concrete barriers within the salt."

6.0 CONCLUSIONS, p. 53;

" The WIPP shaft sealing system design documented in this report is an effective implementable design concept. The design concepts were developed through an interactive process involving technical specialists in the design and construction of underground facilities, materials behavior, rock mechanics analysis, and fluid flow analysis. The design uses (1) a variety of common materials that have very low permeability, (2) demonstrated technologies for construction processes, (3) multiple components to perform each intended function, and (4) the entire length of the shafts to effect a sealing system. In addition, the design incorporates recent developments related to:

- successful demonstrations of compactions technology for salt compaction;
- Attainment of high densities and accompanying low permeabilities in consolidating crushed salt;
- Development of a constitutive model for crushed salt consolidation;
- Design guidance that better quantify performance goals for, and the importance of, seal permeability;
- design guidance on functional requirements for seal components;
- development of improved capabilities for simulating WIPP salt creep behavior and potential DRZ development and healing;

- successful retesting (~10 years after emplacement) of WIPP small-scale concrete seal performance, which shows permeability $\sim 10^{-20} m^2$; and
- additional information from WIPP studies, international studies, and construction experience related to the very low permeabilities of salt-saturated concrete, asphalt, and clay.

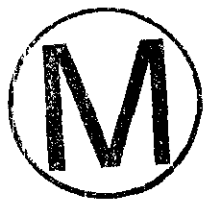
The designers have provided a shaft sealing system that is an effective barrier to brine and gas flow. For the permanent or long-term seal that resists both gas and brine flow, robustness is achieved by providing more than 500 ft of a highly-compacted crushed salt barrier in series with more than 400 ft of clay barriers. The design retards gas flow in the short-term using a redundant combination of a rigid concrete barrier (enhanced by an asphalt waterstop included as an additional DRZ barrier) and a compacted clay barrier approximately 100 ft in length. Finally, short-term brine flow down the shaft is limited by a clay barrier within the Rustler Formation and by a combined length of mare than 500 ft of asphalt, clay, and concrete barriers within the Salado Formation. These design concepts form the basis for No-Migration Variance Petition modeling, initiation of the detailed design development, and evaluations that will be completed in 1996 for incorporation, as appropriate, into the Compliance Certification Application."

DOE (U.S. Department of Energy). 1996a. CAO Management Plan, Peer Review. CAO-96-1187, Carlsbad Area Office, Carlsbad, NM.

Introduction, p.1;
" This Peer Review Management Plan (PRMP) describes the management processes which the U. S. Department of Energy (DOE), Carlsbad Area Office (CAO) will use to control the planning, implementation, and documentation of peer reviews (PR) to be conducted by the CAO-Office of Regulatory Compliance (ORC), as prescribed in 40 CFR Part 194, and as deemed necessary by the ORC to meet the criteria described in this rule. These PRs include conceptual models, waste characterization sensitivity analyses [as prescribed in 40 CFR Part 194 section 27(a)(1&2)], qualification of existing data [as prescribed in 40 CFR Part 194 section 22(b)], and confirmation of the Passive Institutional Controls (PICs) analyses and design document (40 CFR Part 194 section 43)."

Purpose, p. 1;
" The purpose of this PRMP is to identify and initiate activities necessary to determine if (Rev. 1) data and other WIPP-related information not obtained in accordance with an appropriate quality assurance program are qualified to be used to demonstrate compliance with 40 CFR Part 191 and 40 CFR Part 194 (Rev. 1). The requirement for conducting PRs is specified in the CAO Quality Assurance Program Description (QAPD). The purpose of the PRs conducted by ORC is to meet the requirements of 40 CFR Part 194 section 27(a)(1) and (2), to qualify existing unqualified data [as prescribed in section 22(b)], and to confirm the results of the Passive Institutional Controls design analyses and report according to 40 CFR Part 194 section 43.

A PR is a documented, critical review performed by peers who are independent of the work being reviewed. The peers' independence from the work being reviewed means that the peer: a) was not involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed; and b) to the extent practical, has sufficient freedom from funding considerations to assure the work is impartially reviewed."



DOE (U.S. Department of Energy). 1996b. "CAO Team Procedure." TP 10.5, Rev. 0, Carlsbad Area Office, Carlsbad, NM.

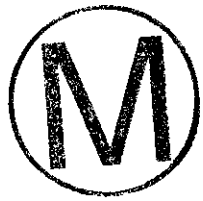
NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

DOE (U.S. Department of Energy). 1996d. Waste Isolation Pilot Plant Disposal Phase Supplemental Environmental Impact Statement: Implementation Plan. DOE/EIS-0026-S-2-IP, REV. 0, United States Department of Energy, Carlsbad Area Office, Carlsbad, NM.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

DOI (U.S. Department of the Interior), Bureau of Mines. 1976. Mineral Facts and Problems, 1975 Edition. U.S. Bureau of Mines Bulletin 667 (BUMINES-B-667). Bureau of Mines, Washington, D.C. Abvailable from NTIS as PB-266 089/2.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.



Drez. P. 1991. "Preliminary Nonradionuclide Inventory of CH-TRU Waste," Preliminary Comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1991. Volume 3: Reference Data. WIPP Performance Assessment Division, Eds. R.P. Rechard, A.C. Peterson, J.D. Schreiber, H.J. Iuzzolino, M.S. Tierney, and J.S. Sandha. SAND91-0893/3. Sandia National Laboratories, Albuquerque, NM. pp. A-43 through A-53. In Appendix A of WPO 26015.

Preliminary Nonradionuclide Inventory of CH-TRU Waste; p. A-45, para. 1;

" May 9. 1989

Dear Dr. Brush:

Attached is a preliminary report on the status of the Nonradionuclide Inventory Database and detailed tabulations of waste materials as requested in the last amendment to the IT Sandia Support contract. I am sorry for the slight delay in completing the report, but the CH-TRU generator/storage sites were late in their responses and the process of tabulating the appropriate data proved to be a difficult task. Part of the difficulty has to do with the slight variations in the way the sites report data.

Listed below is the information contained in this package:

- Report entitled: "Preliminary Nonradionuclide Inventory for CH-TRU Waste." The report includes a description of how the data was collected from the CH-TRU waste generator/storage sites, a description of the database used to compile the data, and examples of how the calculations were made including any limitations (Item 7 in Statement of Work).
- Table 3-5 in the report summarizes the total quantity of combustible materials in the waste, including cellulosics, plastics and other combustibles (Item 3 in Statement of Work).

  Although only total cellulosics were requested, data on plastics and other combustibles were also tabulated, anticipating their eventual need to support the Performance Assessment program.
- Table 3-5 in the report estimates the quantity of various types of cellulosic materials in the total cellulosic inventory (Item 4 in Statement of Work).

  A breakdown of the various types of plastic and rubber materials has also been provided in Table 3-5. Caution is advised in the interpretation of the plastics in the tables, since two sites choose to report the weight of plastic bagging and rigid liners as part of the waste totals.
- Table 3-6 in the report estimates the total quantity of metals in the CH-TRU waste and also provides a breakdown of the various types of metals in the waste (Item 5 in Statement of Work).

  Caution is advised in the interpretation of this table, since two sites choose to report the amount of metal in the waste packaging as part of the waste contents in this table. I have no way of separating out the weight of the waste cannister from the database at this time.

  In an attempt to provide a complete inventory (including waste packaging), Table 3-8

provides a preliminary estimate of the amount of plastic and other internal packaging in addition to an estimate of the metal included in the waste. Variations in the method of packaging from site to site have been accounted for in the tabulation of the data.

- Table 3-7 in the report estimates the total quantity of nitrates and total inorganic carbon (TIC) in the waste (Items 2 and 6 in Statement of Work). Graphite or charcoal is not considered part of this summary, only inorganic carbonate.
- Printouts for each generator/storage site that represent complete data dumps of the Nonradionuclide Inventory Database (Item 7 of Statement of Work).
- Floppy disks containing all the dBASE files for the database. An explanation of the files is provided in Appendix 2.0 of the report (Item 7 of Statement of Work)."

Dunham C.W., 1966, The Theory and Practice of Reinforced Concrete. 4th ed. McGraw-Hill, New York, p 36.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Earth Technology Corporation. 1988. Final Report for Time Domain Electromagnetic (TDEM) Surveys at the WIPP Site, SAND87-7144, The Earth Technology Corporation, Golden, CO; Sandia National Laboratories, Albuquerque, NM. WPO 25668.

EXECUTIVE SUMMARY, p ii;

The Earth Technology Corporation was contracted by Sandia National Laboratories to perform a time domain electromagnetic (TDEM) survey at the WIPP site for the purpose of mapping the depth of occurrence of brine pockets and layers. The impetus for the geophysical survey was that pressurized brine had been encountered in drill holes in the Castile Formation immediately underlying the bedded salts of the Salado Formation in which the waste storage panels are mined. TDEM is a geophysical technique that determines layering in the subsurface from surface resistivity measurements. Because brine layers and pockets have low resistivities compared to the bedded salts of the host rock, they are good targets for electrical exploration.

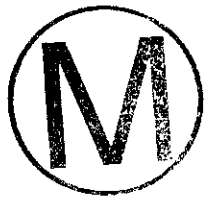
Most of the measurements (36 out of 38) were located in a 1.5 by 1 km grid directly over the waste storage panels. Two measurements were made next to drill holes WIPP #12 and DOE #1 to validate the interpretation of the geophysical survey. Also, one drill hole (ERDA #9) at the northern boundary of the survey grid was used for calibration.

The results of the survey can be summarized as follows:

- The geoelectric sections derived from the TDEM measurements compare well with geologic and geophysical data of the three drill holes. At WIPP #12 the occurrence of brine at a depth of about 800m (2600 ft.) is clearly seen in the TDEM data.

- The results of the TDEM survey over the waste storage panels show the first occurrence of brine at depths corresponding to the Castile Formation in portions of the area and to the Bell Canyon Formation in the rest of the area, some 400 to 600 m below the mined depth of the waste storage panels in the Salado formation. There is no evidence in the data for brine pockets in the Salado or other formations over the waste storage panels.

Only one sounding was made near drill hole WIPP #12 for the purpose of calibration. Since the center loop TDEM surveys conducted correlate well with drill holes and other geologic data, it is recommended that the areal extent of the brine pocket encountered at WIPP #12 be mapped by surveying a grid centered on WIPP #12."



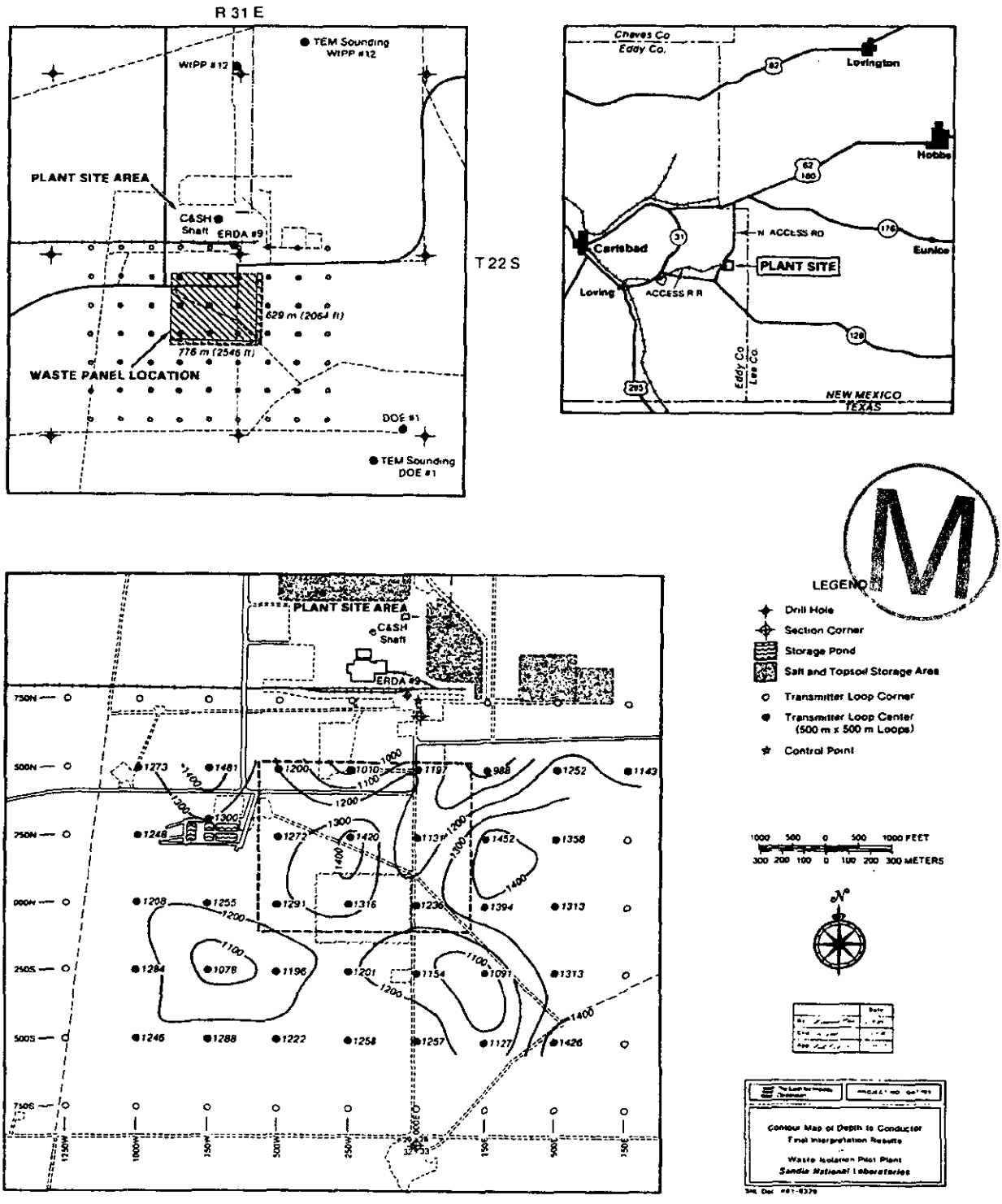


Figure 1-1. TEM Sounding Locations and Waste Panel Location

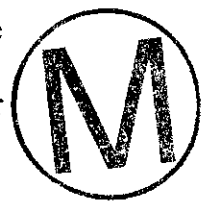
EPA (U.S. Environmental Protection Agency), 1985. "40 CFR Part 191: Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule," Federal Register, Volume 50, no. 182, pp. 38066-38089. WPO 39132.

SUMMARY, p. 38066, col. 1;

" The Environmental Protection Agency (EPA) is promulgating generally applicable environmental standards for the management and disposal of spent nuclear fuel and high-level and transuranic wastes. The standards apply to management and disposal of such materials generated by activities regulated by the Nuclear Regulatory Commission (NRC) and to disposal of similar materials generated by atomic energy defense activities under the jurisdiction of the Department of Energy (DOE). These standards have been developed pursuant to the Agency's authorities and responsibilities under the Atomic Energy Act of 1954, as amended; Reorganization Plan No. 3 of 1970; and the Nuclear Waste Policy Act of 1982.

Subpart A of these standards limits the radiation exposure of members of the public from the management and storage of spent fuel or high-level or transuranic wastes prior to disposal at waste management and disposal facilities regulated by the NRC. Subpart A also limits the radiation exposures to members of the public from waste emplacement and storage operations at DOE disposal facilities that are not regulated by the NRC.

Subpart B establishes several different types of requirements for disposal of these materials. The primary standards for disposal are long-term containment requirements that limit projected releases of radioactivity to the accessible environment for 10,000 years after disposal. These release limits should insure that risks to future generations from disposal of these wastes will be no greater than the risks that would have existed if the uranium ore used to create the wastes had not been mined to begin with. A set of six qualitative assurance requirements is an equally important element of Subpart B designed to provide adequate confidence that all containment requirements will be met. The third set of requirements are limitations on exposures to individual members of the public for 1,000 years after disposal. Finally, a set of ground water protection requirements limits radionuclide concentrations for 1,000 years after disposal in water withdrawn from most Class I ground waters to the concentrations allowed by the Agency's interim drinking water standards (unless concentrations in the Class I ground waters already exceed limits in 40 CFR Part 141, in which case this set of requirements would limit the increases in the radionuclide concentrations to those specified in 40 CFR Part 141). Subpart B also contains informational guidance for implementation of the disposal standards to clarify the Agency's intended application of these standards, which address a time frame without precedent in environmental regulations. Although disposal of these materials in mined geologic repositories has received the most attention, the disposal standards apply to disposal by any method, except disposal directly into the oceans or ocean sediments.



This notice describes the final rule that the Agency developed after considering the public comments received on the proposed rule published on December 29, 1982, and the

recommendations of a technical review conducted by the Agency's Science Advisory Board (SAB). The major comments received on the proposed standards are summarized together with the Agency's responses to them. Detailed responses to all the comments received are discussed in the Response to Comments Document prepared for this final rule.
DATE: These standards shall be promulgated for purposes of judicial review at 1:00 p.m. eastern time on October 3, 1985. These standards shall become effective on November 18, 1985."

EPA (U.S. Environmental Protection Agency), 1993. "40 CFR Part 191: Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule," Federal Register, Vol. 58, no. 242, pp. 66398-66416. WPO 39133.

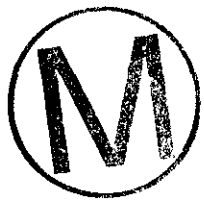
PREAMBLE: SUMMARY;

" The U.S. Environmental Protection Agency (EPA) is promulgating amendments to the environmental standards for the disposal of spent nuclear fuel, high-level and transuranic wastes (40 CFR 191.15 and Subpart C).

EPA originally promulgated these standards in 1985 pursuant to the Agency's authorities and responsibilities under the Nuclear Waste Policy Act of 1982, as amended, the Atomic Energy Act of 1954, as amended, and §2(a)(6) of Reorganization Plan No. 3 of 1970 (5 USC app. 1). In 1987, following a legal challenge, the U.S. Court of Appeals for the First Circuit (hereinafter referred to as 'the First Circuit' or ' the court') remanded subpart B of the 1985 standards to the Agency for further consideration. *Natural Resources Defense Council, Inc. v. United States Environmental Protection Agency*, 824 F.2d 1258 (1st Cir. 1987). Recently enacted legislation, (Pub. L. 102-579) known as the Waste Isolation Pilot Plant Land Withdrawal Act (WIPP LWA), however, reinstates the 1985 disposal standards except 'the 3 aspects of §§191.15 and 191.16 of such [standards] that were subject of the remand ordered' by the First Circuit. The WIPP LWA directs EPA to expedite issuance of final disposal standards and specifies that such regulations shall not be applicable to the characterization, licensing, construction, operation, or closure of any site required to be characterized under §113(a) of Public Law 97-425, the Nuclear Waste Policy Act of 1982.

Today's action represents the Agency's response to this legislation and to the issues raised by the court pertaining to individual and ground-water protection requirements. After considering the relevant comments received on the February 10, 1993 proposed rulemaking, the Agency has taken this final action in the form of amendments to parts 191 of title 40 of the Code of Federal Regulations. In so doing, EPA has not revised any of the regulations reinstated by the WIPP LWA.

DATES: These amendments will become effective on January 19, 1994. These amendments will be promulgated for purposes of judicial review at 1 p.m. eastern standard time on December 20, 1993."



EPA (U.S. Environmental Protection Agency), 1996a. "40 CFR Part 194: Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations; Final Rule," Federal Register, Vol. 61, no. 28, pp. 5224-5245.

SUMMARY, p. 5224, col. 1;

" The Environmental Protection Agency (EPA) is promulgating criteria for determining if the Waste Isolation Pilot Plant (WIPP) will comply with EPA's environmental radiation protection standards for the disposal of radioactive waste. If the Administrator of the EPA determines that the WIPP will comply with the standards for disposal, then the Administrator will issue to the Secretary of Energy a certification of compliance which will allow the emplacement of transuranic waste in the WIPP to begin, provided that all other statutory requirements have been met. If a certification is issued, EPA will also use this final rule to determine if the WIPP has remained in compliance with EPA's environmental radiation protection standards, once every five years after the initial receipt of waste for disposal at the WIPP. This rulemaking was mandated by the WIPP Land Withdrawal Act of 1992. EFFECTIVE DATE: These regulations are effective April 9, 1996."

§194.27 Peer review; p. 5241, col. 3, para. 10;

" (a) Any compliance application shall include documentation of peer review that has been conducted, in a manner required by this section, for:

(1) Conceptual models selected and developed by the Department;

(2) Waste characterization analyses as required in §194.24(b)/ and

(3) Engineered barrier evaluation as required in §194.44.

(b) Peer review processes required in paragraph (a) of this section, and conducted subsequent to the promulgation of this part, shall be conducted in a manner that is compatible with NUREG-1297, "Peer Review for High-Level Nuclear Waste Repositories," published February 1988. (Incorporation by reference as specified in §194.5.)

(c) Any compliance application shall:

(1) Include information that demonstrates that peer review processes required in paragraph (a) of this section, and conducted prior to the implementation of the promulgation of this part, were conducted in accordance with an alternate process substantially equivalent in effect to NUREG-1297 and approved by the Administrator or the Administrator's authorized representative; and

(2) Document any peer review processes conducted in addition to those required pursuant to paragraph (a) of this section. Such documentation shall include formal requests, from the Department to outside review groups or individuals, to review or comment on any information used to support compliance applications, and the responses from such groups or individuals."

EPA (U.S. Environmental Protection Agency), 1996b. 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. EPA 402-R-96-002. U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

1. Introduction; p. 1-1, para. 1;

" The Environmental Protection Agency's (EPA) regulation, 40 CFR part 194, sets forth criteria for determining if the Waste Isolation Pilot Plant (WIPP) will comply with EPA's environmental radiation protection standards for the disposal of radioactive waste, found at 40 CFR part 191 subparts B and C. If the Administrator of EPA determines that the WIPP will comply with the standards for disposal, then the Administrator will issue to the Secretary of Energy a certification of compliance which will allow the emplacement of transuranic waste in the WIPP to begin, provided that all other statutory requirements have been met. If a certification is issued, EPA will also use 40 CFR part 194 to determine if the WIPP has remained in compliance with EPA's environmental radiation protection standards, once every five years after the initial receipt of waste for disposal at the WIPP. The final preamble and regulation to 40 CFR part 194, as they appear in the Federal Register, take precedence over any descriptions or interpretations of the final rule that appear in this document.

This document provides much of the necessary background information and technical analyses which the Agency used during the development of 40 CFR part 194. The document explicates fourteen issues considered by EPA in establishing the individual criteria contained in 40 CFR part 194."

7.1.1 Background

The 40 CFR part 194 compliance criteria for the WIPP provide the following requirements for peer review, at §194.27 of the final rule:

(a) Any compliance application shall include documentation of peer review that has been conducted for, in a manner required by this section, for:
(1) Conceptual models selected and developed by the Department;
(2) Waste characterization analysis as required in §194.24(b); and
(3) Engineered barrier evaluation as required in §194.44.

(b) Peer review processes required in paragraph (a) of this section, and conducted subsequent to the promulgation of this part, shall be conducted in a manner that is compatible with NUREG-1297 "Peer Review for High-Level Nuclear Waste Repositories."

(c) Any compliance application shall:
(1) Include information that demonstrates that peer review process required in paragraph (a), and conducted prior to the implementation of the promulgation of this part, were conducted in accordance with an alternate process substantially equivalent in effect to NUREG-1297 and approved by the

Administrator or the Administrator's authorized representative; and
(2) Document any peer review processes conducted in addition to those required pursuant to paragraph (a) of this section. Such documentation shall include formal requests, from the Department to outside review groups or individuals, to review or comment on any information used to support compliance applications, and the responses from such groups or individuals.

The EPA must be satisfied that peer review processes at the WIPP are sufficient to assess the scientific premises properly on which the performance assessments are based."

EPA (U.S. Environmental Protection Agency) 1996c. Compliance Application Guidance for 40 CFR Part 194. EPA 402-R-95-014. United States Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C. WPO 39159.

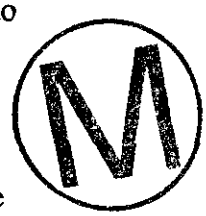
p. 60, para. 7;

" (c) *The Administrator may allow the Department to assume passive institutional control credit, in the form of reduced likelihood of human intrusion, if the Department demonstrates in the compliance application that such credit is justified because the passive institutional controls are expected to endure and be understood by potential intruders for the time period approved by the Administrator. Such credit, or a smaller credit as determined by the Administrator, cannot be used for more than several hundred years and may decrease over time. In no case, however, shall passive institutional controls be assumed to eliminate the likelihood of human intrusion entirely.*

EPA may allow up to approximately 700 years of credit for passive institutional controls in performance assessments. If DOE proposes a credit, EPA expects that DOE's implementation plan for such controls will clearly articulate why credit is warranted for the proposed time frame. For example, if DOE assumes credit for as long as 700 years after disposal, the information provided in the compliance application relative to PICs is expected to support that assumption. Under no circumstance may passive controls be assumed to eliminate human intrusion entirely.

If DOE assumes credit for passive controls, EPA expects any compliance application to identify:

- the estimated effectiveness of passive controls over time, in terms of reducing the likelihood of potential human intrusion; for example, a graphic representation illustrating how credit will diminish over time;
- the methodology employed to estimate the effectiveness of passive controls; and
- justification for the proposed credit, based on how well the controls are expected to endure and be understood.



If any credit is assumed for passive controls, credit should begin at the time of disposal (i.e., when the shafts of the disposal system are backfilled and sealed), although some of the credit may not be needed in light of credit for active institutional controls.

EPA will make its determination regarding credit for passive controls based on the two aspects of PICs identified in §194.43(c): that they are expected to endure for the proposed period, and that they are expected to be understood by potential intruders for the proposed period. EPA expects that DOE's justification of the proposed credit will clearly address these two aspects. The first aspect, the period of time for which the markers "are expected to endure," is likely to require a deterministic analysis, based on scientific data, that takes into account assumptions like those outlined in the CAG for §194.43(a)(1).

The second aspect, the period of time for which the markers will "be understood by potential intruders," is likely to require qualitative analysis and discussion. EPA expects that DOE will establish a framework of assumptions for PICs that is a prudent extrapolation of the future state assumptions established in §194.25. For example, §194.25 may allow DOE

to assume, for the purpose of developing the performance assessment models, that particular governmental regulations will remain in force. Such an assumption would be inappropriate, however, in the justification of credit for PICs. Instead, DOE may choose to assume that while some form of governmental regulation exists, the exact form and content of any regulation cannot be identified with certainty. In other words, DOE may not a priori rely on the future states assumption in this context. Rather, DOE must demonstrate--based on the particular measures at issue and documented, reasoned justification--why any assumptions made in these circumstances are sound.

EPA believes that there are certain societal 'common denominators,' such as the existence of some form of government and some level or regulatory control over the exploration for and some level of regulatory control over the exploration for and development of resources, that could be considered in the discussion of the PICs. These common denominators are patterns of human behavior that may be detected throughout history and around the world. The degree to which the PICs implemented at the WIPP rely on common denominators will determine the degree to which the PICs are effective at being understood by potential intruders in the future. Other examples of common denominators (but by no means a comprehensive list) are: the ability of pictures to convey meaning, the curiosity of humans, the expectation that some people will avoid, ignore or be ignorant of government controls, the use of the written word to transmit information and concepts, and story-telling or the generational 'passing down' of history.

Explicit application of future state assumptions to passive controls--i.e., the assumption that all present-day societal and demographic factors will remain constant--will not be considered by EPA to justify adequately the design of PICs or the estimation of credit."

Felmy, A.R., and Weare, J.H. 1986. "The Prediction of Borate Mineral Equilibria in Natural Waters: Application to Searles Lake, California," Geochimica et Cosmochimica Acta. Vol. 50, no. 12, pp. 2771-2783. WPO 30421.

ABSTRACT, p. 2771;

" The chemical equilibrium model of HARVIE et al, (1984) has been extended to include borate species. The model is based upon the semi-empirical equations of PITZER (1973) and is valid to high ionic strength ($\approx$14 m) and high borate concentration. Excellent agreement with the existing emf, isopiestic, and solubility data in the system (Na-K-Ca-Mg-H-Cl-SO_4-CO_2-$B(OH)_4$-H_2O) is obtained. Calculated mineral solubilities are in general within 10% of their experimental values, even at high ionic strengths.

The model was applied to the multicomponent, high ionic strength ($\approx$10) and high borate concentration (B_T ~o.5m) Searles Lake evaporite deposit. Utilizing the chemical composition of the interstitial brine, the model predicts equilibrium between the brine and only those minerals which are known to be in contact with the brine. These calculations clearly demonstrate the applicability of the model to high ionic strength, high borate concentration natural waters.

The model was also utilized to calculate the mineral sequences which should result from evaporation of the major source of water for Searles Lake, the Owens River. The geochemical conditions necessary for the formation of the most recent mud and saline units are examined. The final results indicate that the mineral sequences found in the most recent saline unit in Searles Lake can be produced by evaporation of a water close in composition to present Owens River water, provided primary dolomite formation is delayed and back reaction between the Parting Mud and the Upper Salt is inhibited."

Finley, R.E. 1996. "Tensile Strength of Consolidated Crushed Salt," Memorandum to D.R. Anderson and M.S.Y. Chu, May 3, 1996. Sandia National Laboratories, Albuquerque, NM.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Friend, D.G., and Huber, M.L.. 1994. "Thermophysical Property Standard Reference Data from NIST," International Journal of Thermophysics. Vol. 15, no. 6, pp. 1279-1288.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Gonzalez, D.D. 1983. Groundwater Flow in the Rustler Formation, Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico (SENM): Interim Report. SAND82-1012. Sandia National Laboratories, Albuquerque, NM. WPO 27528.

ABSTRACT, p. 2;

" The Culebra Dolomite of the Rustler Formation is the dominant aquifer near the WIPP. If this artesian aquifer became contaminated as a result of the most probable release scenario, radionuclides could be transported to the biosphere through the groundwater. Five sites have been selected for intensive geohydrologic investigations to determine the hydraulic parameters needed to describe the flow and solute transport characteristics of the Culebra Dolomite. Tracer tests at two locations have determined an effective porosity of 0.7% in the principle direction of flow northwest of the proposed facility and near Nash Draw, and 18% at a site 1-1/4 miles southwest; dispersivity was 100 and 17 ft, respectively. Anisotropy has been evaluated at three locations where the ratio of the principle to minor transmissivity tensor has been found to range from 2.1:1 to 2.7:1, despite a variation of three orders of magnitude in transmissivity. The principle transmissivity component is about northwest by southeast for those locations. Aquifer head potentials for the Culebra Dolomite indicate that flow patterns are southeast over most of the designated WIPP area, based on the anisotropy at three locations and potentials in fresh-water equivalant (sic) head throughout."

Graf, D.L., Eardley, A.J., and Shimp, S.F. 1961. "A Preliminary Report on Magnesium Carbonate Formation in Glacial Lake Bonneville," Journal of Geology. Vol. 69, no. 2, pp. 219-223.

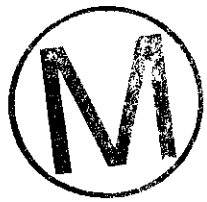
NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Hansen, F.D. 1996. "Review Plan: Shaft Seal System Design for the Waste Isolation Pilot Plant." Sandia National Laboratories, Albuquerque, NM. Attachment in WPO 36546.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Hansen, F.D. and Ahrens, E.H. 1996. "Large-Scale Dynamic Compaction of Natural Salt," 4th International Conference on the Mechanical Behavior of Salt, Montreal, Canada, June 17-18, 1996. SAND96-0792C. Sandia National Laboratories, Albuquerque, NM. WPO 39544.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.



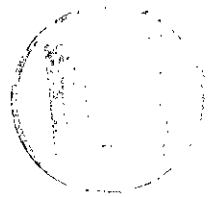
Harvie, C.E., Møller, N., and Weare, J.H. 1980. "The Prediction of Mineral Solubilities in Natural Waters: The Na-K-Mg-Ca-SO_4-H_2O System from Zero to High Concentration at 25°C, Geochemica et Cosmochimica Acta., Vol. 44, no. 7, pp. 981-999. WPO 30423.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Harvie, C.E., N. Møller, and J.H. Weare. 1984. "The Prediction of Mineral Solubilities in Natural Waters: The Na-K-Mg-Ca-H-Cl-SO_4-OH-HCO_3-CO_3-CO_2-H_2O System to High Ionic Strengths at 25°C," Geochimica et Cosmochimica Acta. Vol. 48, no. 4, pp. 723-751. WPO 30422.

ABSTRACT, p 723;

" The mineral solubility model of HARVIE and WEARE (1980) is extended to the eight component system, Na-K-Mg-Ca-H-Cl-SO_4-OH-HCO_3-CO_3-CO_2-H_2O to high concentrations. The model is based on the semi-empirical equations of PITZER (1973) and co-workers for the thermodynamics of aqueous electrolyte solutions. The model is parameterized using many of the available isoplastic, electromotive force, and solubility data available for many of the subsystems. The predictive abilities of the model are demonstrated by comparison to experimental data in systems more complex than those used in parameterization. The essential features of a chemical model for aqueous electrolyte solutions and the relationship between pH and the equilibrium properties of a solution are discussed."



Haug, A., Kelley, V.A., LaVenue, A.M., and Pickens, J.F. 1987. Modeling of Ground-Water Flow in the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site: Interim Report, SAND86-7167, Sandia National Laboratories, Albuquerque, NM. WPO 28486.

INTRODUCTION, p. 1-1;

" The modeling studies of ground-water flow in the Culebra Dolomite Member of the Rustler Formation reported here have been performed as part of the regional hydrologic characterization studies for the Waste Isolation Pilot Plant (WIPP) site in southeastern New Mexico (Figure 1.1). The site characterization studies are being conducted in accordance with the Consultation and Cooperation Agreement between the U.S. Department of Energy and the State of New Mexico as part of the evaluation of the suitability of bedded salt of the Salado Formation for isolation of defense transuranic waste. The regional hydrologic characterization studies are being conducted by Sandia National Laboratories on behalf of the Department of Energy."

Holcomb, D.J., and Shields, M. 1987. Hydrostatic Creep Consolidation of Crushed Salt with Added Water. SAND87-1990. Sandia National Laboratories, Albuquerque, NM. WPO 26778.

Background, p 6;

" A facility for the disposal of radioactive waste has been constructed near Carlsbad, New Mexico in bedded salt of the Salado formation. Beginning in 1988, the Waste Isolation Pilot Plant (WIPP) is scheduled to accept waste generated by defense programs. In order to show the long-term safety of the facility; it is necessary to demonstrate that the system of sealing the rooms and drifts will be effective for times on the order of 10,000 years. Only one sealing material can be guaranteed to be compatible with the unmined salt for that length of time: salt. If it could be shown that the mined salt could be reemplaced ("backfilled") and reconsolidated by the creep closure of the drifts and rooms to a sufficiently low permeability in a reasonable time, then the security of the seals would be assured. For this reason, a program to determine the long-term mechanical and hydrological properties of the crushed salt under various conditions has been carried out. A number of studies have been done on the consolidation of granulated salt. Studies were carried out by Stinebaugh[1] and Holcomb and Hannum[2] on the rapid (quasistatic) compression of granulated salt, where pressure up to 20 MPa were applied and removed over the span of about ten minutes. Results for quasistatic compression indicated that even at a pressure of 20 MPa, crushed salt would not consolidate to a fractional density of more than about .8, where fractional density is defined as the actual density divided by the intact density. At this density, permeability is in the darcy range ($10^{-12}m^2$) [3] as compared to 50 nanodarcies for the intact, healed salt [4].

Clearly, is reconsolidated salt is to play any role in sealing, the permeability must be reduced to near that of the formation. Because salt is known to creep relatively rapidly it was expected that consolidation would also be a time-dependent process. One of the earliest studies of the time-dependent consolidation of granulated salt is that of Shor, Baes and Canonico [5]. Using pure salt with grain sizes in the range of 100 micrometers they investigated the effects of various pore fluids, from air to saturated brine, on the consolidation rate under uniaxial strain conditions. From this work they developed a model which included a strong third-power dependence on the particle size. By extrapolation, they predicted that in NaCl brine, particle sizes of 1 centimetre would require about 30,000 years to consolidate to a point where permeability was in the microdarcy range. If the salt particle size was reduced to 1 millimetre, then the time would scale to about 30 years. As might be expected, the consolidation rates were much higher for salt grains in brine than for salt grains in air. A suprising result was that if dodecane, an organic solvent which is insoluble in water, was used as a pore fluid, then consolidation rates were actually higher than that of the brine-saturated sample, but only if the salt was not carefully dried. When dried salt was used, the consolidation rates were less than when air was used as the pore fluid. This is the first indication that even trace amounts of water are sufficient to greatly accelerate the consolidation process of salt.

Several studies have been done on . . ."

Holt, R.M., and Powers, D.W. 1984. Geotechnical Activities in the Waste Handling Shaft, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico. WTSD-TME-038. U.S. Department of Energy, Waste Isolation Pilot Plant, Carlsbad, NM.

ABSTRACT, p. v;

" The Waste handling shaft (waste shaft) at the Waste Isolation Pilot Plant (WIPP) site is an enlargement of the drilled, Site and Preliminary Design Validation (SPDV) ventilation shaft. Geotechnical activities in the waste shaft were designed to confirm the SPDV ventilation shaft mapping results and to provide additional information about identified zones of interest. The activities included identification of instrument locations, geologic inspections of the exposed shaft surface during sinking operations, reconnaissance geologic mapping of the waste shaft sump, and detailed geologic mapping in identified zones of interest. These activities were carried out concurrently with construction.

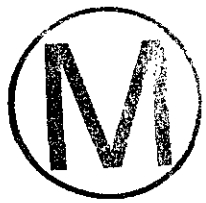
The results of the geologic inspections in the waste shaft and the reconnaissance geologic mapping in the waste shaft sump correlate well with previous characterizations. However, the detailed 360° geologic mapping performed in several zones of interest did not reveal post-depositional dissolution features, thought to occur at several stratigraphic horizons in the Rustler Formation at the WIPP site. At the waste shaft, zones previously identified as dissolution residues in nearby boreholes contained pronounced primary sedimentary features."

1.0 INTRODUCTION; p. 27, para. 1;

" The Permian Rustler Formation was recently examined in detail in two shafts at the WIPP site: the waste handling shaft (waste shaft) and the exhaust shaft. The examination of the Rustler in the shafts has provided unique data previously unavailable from any other source. Fresh exposures of the Rustler in the shafts exhibited abundant primary sedimentary structures. Though some evidence of these features has been reported in outcrop and core descriptions, the abundance of primary sedimentary structures observed in the shafts is unequaled in previously described sections. These data are reported here in their stratigraphic context as an initial basis for evaluation of depositional environments of the Rustler and reevaluating the role of dissolution in the formation of the Rustler."

Holt, R., and Powers, D. 1987. "Rustler Formation in the Waste Handling and Exhaust Shafts, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico," The Rustler Formation at the WIPP Site, Report of a Workshop on the Geology and Hydrology of the Rustler Formation as it Relates to the WIPP Project. EEG-34. Environmental Evaluation Group, Santa Fe, NM.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.



Hunter, R.L., 1985. A Regional Water Balance for the Waste Isolation Pilot Plant (WIPP) Site and Surrounding Area. SAND84-2233, Sandia National Laboratories, Albuquerque, NM. WPO 27628.

ABSTRACT, p. 3;

" The WIPP water-balance study area defined here comprises ~2000 mi^2 in Eddy and Lea Counties, southeastern New Mexico. Inflows to the study area are precipitation (roughly 1.47 x 10^6 ac-ft/yr), surface water (roughly 1.1 x 10^5 ac-ft/yr), water imported by municipalities and industries (roughly 3 x 10^4 ac-ft/yr), and ground water (volume not estimated). Outflows from the area are evapotranspiration (roughly 1.5 x 10^6 ac-ft/yr), surface water (roughly 1.2 x 10^5 ac-ft/yr), and possibly some ground water. The volume of surface and ground water in storage in Nash Draw has increased since the beginning of potash refining. Regional ground water flow in aquifers above the Salado Formation is from the northeast to the southwest, although this pattern is interrupted by Clayton Basin, Nash Draw, and San Simon Swale. The Pecos River is the only important perennial stream. Most of the area has no integrated surface-water drainage.

The available data suggest that ~1600 mi^2 of the study area are hydrologically separate from Nash Draw and the WIPP site. Ground water north of Highway 180 apparently discharges into Clayton Basin and evaporates. Water in San Simon Swale apparently percolates downward and flows to the southeast. Data are inadequate to create a water budget for the Nash Draw-WIPP site hydrologic system alone, although an attempt to do so can provide guidance for further study."

Jaeger, J.C. and Cook, N.G.W. 1979. Fundamentals of Rock Mechanics, 2nd ed. Chapman and Hall, London; Halsted Press, New York, NY.

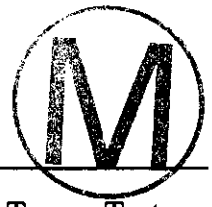
NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Jones, T.L., Kelley, V.A., Pickens, J.F., Upton, D.T., Beauheim, R.L., and Davies, P.B. 1992. Integration of Interpretation Results of Tracer Tests Performed in the Culebra Dolomite at the Waste Isolation Pilot Plant Site. SAND92-1579. Sandia National Laboratories, Albuquerque, NM. WPO 23504.

ABSTRACT, p i;

" Conservative tracer tests have been conducted within the Culebra Dolomite Member of the Rustler Formation at the H-2, H-3, H-4, H-6, and H-11 hydropads for transport scales ranging from approximately 20 to 40 m. Convergent-flow and two-well recirculating tracer tests provide data that is used to quantitatively characterize flow and transport processes. The observed long time period required for initial (detectable) tracer breakthrough (74 to 316 days) in the H-2 and H-4 tracer tests suggest the prevalence of single-porosity, matrix-only transport at these locations. Hydraulic-test responses at these two hydropads also indicate single-porosity, matrix-only conditions. The relatively poor quality of data defining the breakthrough curves from the H-2 and H-4 tracer tests precluded a detailed, quantitative analysis of transport parameter values from these tests. Interpretations of pumping tests and tracer tests at the H-3, H-6, and H-11 hydropads indicated that the Culebra dolomite behaves as a double-porosity (fracture-plus-matrix) medium at these locations. Both the H-3 and H-11 hydropads are located along the offsite transport pathways southeast of the Waste Isolation Pilot Plant waste-panel area. Significant fracture participation in transport is evidenced by rapid initial tracer breakthrough (1 to 21 hrs) on one travel path at each of these hydropads. The H-3, H-6 , and H-11 convergent-flow tracer tests were analyzed using the SWIFT II model with the Culebra fracture/matrix system idealized as three, orthogonal, intersecting fracture sets equally spaced in all three directions. Input values and ranges for the assigned transport parameters (effective thickness, well spacing, pumping rate, free-water diffusion coefficient, longitudinal dispersivity, and matrix porosity) were specified based on field measurements, laboratory measurements on Culebra core, and scientific judgement. Measurement and/or calculated uncertainties were also defined for the assigned parameters. Two approaches were used to model double-porosity transport. The first approach assumed that differences in tracer breakthrough behavior at a single hydropad were caused by differences (heterogeneity) in matrix-block length (fracture spacing) between different travel paths. The second approach assumed that differences in tracer breakthrough behavior were caused by horizontal anisotropy in the flow field. Interpretations based on the heterogeneous-analysis approach yielded matrix-block lengths ranging from 0.11 to 1.23 m and fracture porosities ranging from 5.0×10^{-4} to 1.0×10^{-3}. Interpretations based on the anisotropic-analysis approach yielded matrix-block lengths ranging from 0.15 to 0.48 m, fracture porosities ranging from 1.0×10^{-3} to 3.0×10^{-3}, and anisotropy ratios ranging from 3:1 to 7:1. Sensitivity analyses were conducted to provide insight into the relative impact of varying individual transport parameters and to provide estimates of fitted-parameter uncertainty. These analyses yielded minimum and maximum matrix-block lengths for all hydropads that ranged from 0.02 to 3.22 m. Sensitivity analyses also showed that neither single-porosity, fracture-only transport nor single-porosity, matrix-only transport can

reproduce the observed transport behavior at the H-3, H-6, and H-11 hydropads."



Kelley, V.A., and Pickens, J.F. 1986. Interpretation of the Convergent-Flow Tracer Tests Conducted in the Culebra Dolomite at the H-3 and H-4 Hydropads at the Waste Isolation Pilot Plant (WIPP) Site. SAND86-7161. Sandia National Laboratories, Albuquerque, NM. WPO 27674.

ABSTRACT, p. ii;

" Tracer tests utilizing conservative organic tracers have been conducted in the Culebra Dolomite Member of the Rustler Formation at the locations of the H-2, H-3, H-4, and H-6 hydropads. The objective of this report is to present a quantitative evaluation of the physical solute-transport parameters of the Culebra dolomite at the H-3 and H-4 hydropad locations from interpretation of the tracer-test data. The tracer-test configurations consisted of a pumping well and two tracer-addition wells arranged in approximate equilateral triangles with 30-m sides. The transport of organic tracers from the tracer-addition wells to the pumping wells was analyzed using the finite-difference model SWIFT II, which is capable of simulating single- and double-porosity flow and transport.

The interpretive approach for analyzing the tracer-breakthrough curves at the pumping well first consisted of estimating the appropriate governing processes using the information base for each specific hydropad. For the H-3 hydropad, the test data indicated that a double-porosity interpretation approach was the most appropriate. In this conceptualization, the fractures represented the principle transport medium and the matrix provided the bulk of the solute-storage capability. The simulation model accounted for advective-dispersive transport in the fractures and diffusive transport in the matrix. Calibration of the tracer-breakthrough curves included conducting a parameter sensitivity analysis on longitudinal dispersivity, tortuosity, matrix porosity, fracture porosity, effective matrix block size, pumping rate, initial tracer-input distribution, and distance between pumping and tracer-addition wells. Calibration of the tracer-breakthrough curves for the H-3 tracer test resulted in longitudinal dispersivities from 5 to 10% of the flow path (well-separation distance), a fracture porosity of 1.9×10^{-3}, and effective matrix block sizes of 0.25 to 2.1 m.

There is uncertainty in the assumed or calibrated values for tortuosity, fracture porosity, matrix porosity, and matrix block size which were used to describe solute transport in the Culebra at the H-3 hydropad. Reduction in this uncertainty would require additional laboratory and field testing (e.g., additional drilling and coring, additional matrix porosity determinations on core, diffusion experiments, and additional on-site tracer testing). The results obtained from the conservative-tracer test suggest that fracture flow and matrix diffusion dominate solute transport in the Culebra at the H-3 hydropad. Further, the parameters derived to fit the tracer-breakthrough curves are thought to be consistent with the physical conceptualization of the Culebra at the H-3 hydropad.

The interpretation of the H-4 hydropad tracer test has not provided quantitative estimates of the physical solute-transport parameters for the Culebra. Qualitatively, the observed tracer-breakthrough curves could be simulated by representing the Culebra with a layered system of higher- and lower-permeability units. In this system, transport would be dominated by the higher-permeability zones with diffusive interaction with the lower-

permeability zones. No evidence was obtained to indicate that transport of the tracers had occurred through fractures; however, considering the fractured nature of the Culebra at the H-3 and H-6 hydropads and other locations at the WIPP site, the existence of fractures in the Culebra at the H-4 hydropad should still be considered a possibility. However, if present, these fractures do not appear to have had a significant effect on solute transport on paths examined in the H-4 tracer test."

Labreche, D.A., Callahan, G.D., DeVries, K.L., and Osnes, J.D. 1993. Comparison of Two Geomechanical Analysis Codes for WIPP Disposal Room Modeling: Sancho and Spectrom-12. Topical Report RSI-0461, Albuquerque, NM; RE/SPEC Inc., Rapid City, SD. WPO 36821.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Lambert, S.J., 1983. Dissolution of Evaporites in and Around the Delaware Basin, Southeastern New Mexico and West Texas. SAND82-0461. Sandia National Laboratories, Albuquerque, NM. WPO 27520.

ABSTRACT, p 3;

" Permian evaporites in the Ochoan Castile, Salado, and Rustler Formations in the Delaware Basin of southeastern New Mexico and west Texas have been subjected to various degrees of dissolution (notably of halite and gypsum) through geologic time. Eastward tilting of the Delaware Basin has resulted in the exhumation and erosion of Ochoan rocks in the western part of the basin. Waters in the Capitan, Rustler, Castile, and Bell Canyon Formations have previously been proposed as agents or consequences of evaporite dissolution according to four principle models; solution-and-fill, phreatic dissolution, brine density flow, and stratabound dissolution (along bedding planes). Several geomorphological features of positive and negative relief have previously been cited as indicators of evaporite dissolution. Brine density flow has been used to explain the selective dissolution of certain evaporite horizons during the late Cenozoic. A review of available geological data has revealed that

- Halite deposition was probably not so extensive as formerly believed
- Waters with potential to dissolve evaporites are in the Rustler and Capitan, but not in the Bell Canyon, Salado mine seeps, or the Castile brine reservoirs
- Brine density flow has not been active in removing most of the 'missing' halite, nor are 'point-source' dissolution features likely to have their roots at the Bell Canyon
- Major evaporite dissolution has not been confined to the late Cenozoic, but much of it took place during the Permian, Triassic, Jurassic, and Tertiary periods
- The Bell Canyon Formation has not been a sink for dissolution-derived brine

Stratabound dissolution is an efficient process for the removal of evaporites and is well exemplified in Nash Draw. This process entails downdip migration of meteoric water within beds of competent fractured rock, with upward and downward excursions of the water into adjacent halite-bearing beds. The chief weakness in the stratabound model for dissolution is the as-yet-unidentified sink for dissolution brine. If the stratabound model of dissolution is active in removal of lower Salado halite, the threat of dissolution to the WIPP in the next 250,000 yr is comparable to the threat to the same area posed by the growth of Nash Draw during the past 600,000 yr. The regional geological history showed the past threat to be negligible."

Lambert, S.J. 1987. Feasibility Study: Applicability of Geochronologic Methods Involving Radiocarbon and Other Nuclides to the Groundwater Hydrology of the Rustler Formation, Southeastern New Mexico. SAND86-1054. Sandia National Laboratories, Albuquerque, NM. WPO 24475.

ABSTRACT, p. i;

" Radiocarbon, tritium, and ^{36}Cl were measured in groundwaters from the dolomite aquifers of the Rustler Formation in the northern Delaware Basin of southeastern New Mexico to determine the feasibility of using these nuclides in dating the groundwater at and near the Waste Isolation Pilot Plant, a facility for geological disposal of radioactive waste. No measurable ^{36}Cl was found in any of these groundwaters, which derive their dissolved chloride from Permian evaporites. Demonstrably uncontaminated groundwaters contained no significant amounts of tritium (<0.2 TU). Percent modern carbon (PMC) correlates linearly and directly with bicarbonate concentration, indicating mixing of a high-PMC/high-bicarbonate reservoir with a low-PMC/low-bicarbonate reservoir. This relationship, together with the history of development of the wells sampling the groundwaters, indicates contamination by anthropogenic modern carbon rather than simple dilution by dissolving rock carbonate. $\delta^{13}C$ does not linearly correlate with bicarbonate, indicating no single source of contaminant radiocarbon. Values of PMC and $\delta^{13}C$ for groundwaters were used to calculate apparent radiocarbon ages according to an interpretive model that accounts for water/rock interactions in carbonate aquifers. All but six pairs of values gave significant negative ages (-1,000 to -7,000 years). This suggests that in contaminated samples the model over-adjusts (based on $\delta^{13}C$) for radiocarbon loss due to dilution and isotopic exchange with the rock. Four groundwater samples (3 from the Rustler and 1 from the overlying Dewey Lake Red Beds) gave apparent radiocarbon ages $>$ 10,000 a, and their carbon-isotope systematics suggest that their apparent ages are all the result of a single evolutionary trend of rock/water interaction involving carbon isotope exchange, with a probable recharge age of 13,000 a b. p. This time of isolation from the atmosphere, which is unrelated to travel time within the Rustler, is consistent with paleoclimatic evidence of wetter conditions more conducive to recharge in the Late Pleistocene than at present."

Lambert, S.J., and Carter, J.A. 1984. Uranium-Isotope Disequilibrium in Brine Reservoirs of the Castile Formation, Northern Delaware Basin, Southeastern New Mexico. I: Principles and Methods. SAND83-0144. Sandia National Laboratories, Albuquerque, NM. WPO 28341.

ABSTRACT, p 3;

" We evaluated uranium isotope activity ratios with respect to models for the origin of the brines in two brine reservoirs in the Castile Formation (ERDA No. 6 and WIPP No. 12). In Castile anhydrite, a completely closed water system that was continuously leaching Th-recoil-produced ^{234}U from freshly exposed surfaces of fractured host rock would give rise to uranium 234/238 isotope activity ratio (α) values significantly higher than observed values. Therefore, the brine occurrences are not the result of continuous deformation. Similarly, a model assuming movement of intergranular Permian seawater into fractures was found inconsistent with observed uranium isotope systematics. The observed α-values (95% confidence limits) of ERDA No. 6 (1.34 to 1.58) and WIPP No. 12 (1.74 to 2.54), used in conjunction with an inferred initial α_0 higher than observed values, allows calculation of reasonable finite minimum ages, involving no preferential leaching of ^{234}U in the host rock. If the brine occurrences are inferred to have been connected at one time with a more extensive nearby hydrologic system, the Capitan limestone (α_0 = 5.1), calculated minimum ages of isolation from that system are 700 000 to 880 000 yr for ERDA No. 6 and 360 000 to 610 000 yr for WIPP No. 12. These ranges in ages are the 95% confidence limits based on experimental determination of α-values. The ages thus derived may reflect an episode of structural deformation in the Pleistocene that allowed water to enter the resulting fractures."

Lambert, S.J., and Carter, J.A. 1987. Uranium-Isotope Systematics in Groundwaters of the Rustler Formation, Northern Delaware Basin, Southeastern New Mexico, I: Principles and Preliminary Results. SAND87-0388. Sandia National Laboratories, Albuquerque, NM. WPO 24453.

ABSTRACT, p i;

" Values for uranium concentration ([U]) and $^{234}U/^{238}U$ activity ratio (A.R.), have been determined for groundwaters and host rocks from the Rustler Formation near the Waste Isolation Pilot Plant (WIPP) site in the northern Delaware Basin of southeastern New Mexico. [U] varies from about 0.02 to 40 x 10^{-9} g/g, increasing westward across the WIPP site to Nash Draw, a dissolution valley underlain by outcrops of Rustler Formation evaporites. Large deviations from secular equilibrium (A.R. $\approx$ 1) in the groundwaters increase eastward from about 2 to 3 in Nash Draw to almost 12 in the eastern part of the WIPP site. [U] and A.R. variations cannot be completely explained by simple mixing due to congruent dissolution of uranium from rock (without isotopic fractionation). A.R. values typically increase along the flow path in a reducing environment, and the observed eastward increase in A.R. suggests a relict flow system whose dominant flow direction (eastward) was at high angles to that now observed. A westward decrease in A.R., coupled with a steady increase in [U] indicates not only that there was a change in flow direction since recharge, but that Rustler groundwater is now draining from areas of high potentiometric level and low permeability near the WIPP site, without appreciable recharge. The maximum time required for this westward drainage is about 200,000 a. The minimum time required to achieve the highest observed A.R.s during the earlier episode of eastward flow from recharge in the west is 10,000 to 30,000 a. Radiocarbon and stable-isotope studies of the Rustler Formation near the WIPP indicate that the modern Rustler flow system is not at steady state, recharge being dominated by wetter climatic conditions in the Pleistocene. Uranium-isotope studies are consistent with these results, and further suggest that present flow directions are qualitatively different from those existing at the time of recharge."

Lambert, S.J., and Harvey, D.M. 1987. Stable-Isotope Geochemistry of Groundwaters In the Delaware Basin of Southeastern New Mexico. SAND87-0138. Sandia National Laboratories, Albuquerque, NM. WPO 24150.

ABSTRACT, p i;

" $^{18}O/^{16}O$ and D/H ratio measurements have been made on groundwaters sampled from the Rustler Formation (Ochoan, Permian) and related rocks in the northern Delaware Basin of southeastern New Mexico. Most confined Rustler waters at the Waste Isolation Pilot Plant (WIPP) site and to the west in Nash Draw and confined waters from the Capitan limestone constitute one population in $\delta D/\delta^{18}O$ space, while unconfined groundwaters inferred to originate as modern surface recharge to alluvium, sandstones in the Ogallala Formation, the near-surface Rustler in southwestern Nash Draw, and the Capitan vadose zone in the Guadalupe Mountains (Carlsbad caverns) constitute a distinctly different population; the two do not overlap. A likely explanation for this distinction is that meteoric recharge to most of the Rustler and Capitan took place in the geologic past under climatic conditions significantly different from the present. Available tritium and radiocarbon data are consistent with this hypothesis, and the apparent age of confined groundwaters is in excess of 12,000 radiocarbon years, suggesting that recharge took place under wetter conditions in the late Pleistocene. Processes governing recharge in the Delaware basin are significantly different from those in the nearby Roswell Artesian Basin, but may be similar to those previously described for the Albuquerque (New Mexico) and Murray (South Australia) Basins. Rustler water from the WIPP site and east-central Nash Draw is not discharging from springs in southwestern Nash Draw; the discharge there is part of a local shallow groundwater system associated with surficial gypsum karst and discharge from nearby potash refining. Water at the Rustler/Salado contact at the WIPP site is of meteoric origin, but has experienced isotope shift that increases with decreasing permeability, and is part of the same isotopic trend as the ERDA 6 brine occurrence and fluid inclusions from Salado Formation halite core. Radiometric ages of secondary Salado minerals are not consistent with vertical mixing between deep brines and meteoric waters to form the fluid inclusions. Mine seeps and WIPP fluid inclusions have similar isotopic compositions, perhaps related to syndepositional mixing of evaporite brines and rainwaters. Rustler dolomites have not recrystallized in isotopic equilibrium with Rustler water, but much of the gypsum in the Ochoan section has done so. The absence of modern meteoric recharge to the Rustler at and near the WIPP site indicates that the hydrologic system there is not at steady state. Instead, the system is responding to the cessation of local recharge, this cessation occurring some 10,000 to 30,000 years ago."

Lappin, A.R., 1988. Summary of Site-Characterization Studies Conducted From 1983 Through 1987 at the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico. SAND 88-0157. Sandia National Laboratories, Albuquerque, NM. WPO 24945.

" SUMMARY

The Waste Isolation Pilot Plant (WIPP), which is designed for receipt, handling, storage, and permanent isolation of defense-generated transuranic wastes, is being excavated at a depth of approximately 655 m in bedded halites of the Permian Solado Formation of southeastern New mexico. Site-characterization activities at the present WIPP site began in 1976. Full construction of the facility began in 1983, after completion of "Site and Preliminary Design validation" (SPDV) activities and reporting. Site-characterization activities since 1983 have had the objectives of updating or refining the overall conceptual model of the geologic, hydrologic, and structural behavior of the WIPP site and providing data adequate for use in WIPP performance assessment.

This report has four main objectives:

1. Summarize the results of WIPP site-characterization studies carried out since the spring of 1983 as a result of specific agreements between the U. S., Department of Energy and the state of new mexico.

2. Summarize the results and status of site-characterization and facility-characterization studies carried out since 1983, but not specifically included in mandated agreements.

3. Compile the results of WIPP site-characterization studies into an internally consistent conceptual model for the geologic, hydrologic, geochemical, and structural behavior of the WIPP site. This model includes some consideration of the effects of the WIPP facility and shafts on the local characteristics of the Solado and Rustler Formations.

4. Discuss the present limitations and/or uncertainties in the conceptual geologic model of the WIPP site and facility."

Lappin, A.R., Hunter, R.L., Garber, D.P., and Davies, P.B. eds. 1989. Systems Analysis, Long-Term Radionuclide Transport, and Dose Assessments, Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico; March 1989. SAND89-0462. Sandia National Laboratories, Albuquerque, NM. WPO 24125.

EXECUTIVE SUMMARY, p iii;

" This report summarizes the current understanding of the expected long-term behavior of the Waste Isolation Pilot Plant (WIPP) repository and estimates long-term radionuclide doses in a series of six analyses investigating both undisturbed repository performance (Case I) and performance in response to a relatively high-consequence human Intrusion (Case II). It is the result of an intensive effort over a short time. The U. S. Department of Energy (DOE) decided to have Sandia National Laboratories prepare this report as a result of a meeting held January 5, 1989. The conceptual model of the expected long-term behavior of the WIPP repository used in this report was formulated in early to mid January 1989, drawing on information and understanding developed over the past decade. Numerical modeling of ground-water flow, radionuclide transport, and doses to humans began January 20, 1989 and was completed March 20, 1989.

The report has several objectives:

1. To briefly summarize Sandia's current technical understanding of the major components of long-term performance of the WIPP repository. The following areas are specifically addressed:

. . . .

f. radionuclide-transport mechanisms and properties of the Culebra Dolomite, the major pathway for ground-water transport of radionuclides from the WIPP to the biosphere.

. . . .

4. To describe, document, and interpret six sets of calculations estimating the potential health effects to individuals resulting from emplacement of CH-TRU wastes in the WIPP, hydrologic saturation of the repository as a result of either natural processes or human intrusion, direct and indirect exposure during and after drilling (where appropriate), and ground-water transport of radionuclides to a hypothetical stock well south of the WIPP site.

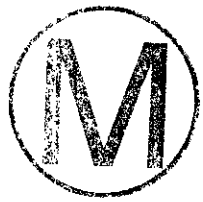
The calculations presented here investigate radionuclide transport and resulting health effects both during undisturbed performance of the WIPP repository and in response to a relatively high-consequence human intrusion into the repository. The human intrusion considered is drilling that results in a long-term interconnection of the repository, an underlying brine reservoir in the Castile Fm., and the overlying Culebra Dolomite. The Culebra Dolomite provides a relatively permeable pathway for ground-water transport of radionuclides to the hypothetical stock well."

LaVenue, A.M., Haug, A., and Kelley, V.A. 1988. Numerical Simulation of Ground-Water Flow in the Culebra Dolomite at the Waste Isolation Pilot Plant WIPP Site: Second Interim Report. SAND88-7002. Sandia National Laboratories, Albuquerque, NM. WPO 28558.

EXECUTIVE SUMMARY, p ii;

" This hydrologic modeling study has been performed as part of the regional hydrologic characterization of the Waste Isolation Pilot Plant (WIPP) Site in southeastern New Mexico. The study resulted in an estimation of the transmissivity distribution, hydraulic potentials, flow field, and fluid densities in the Culebra Dolomite Member of the Permian Rustler Formation at the WIPP site.

The three-dimensional finite-difference code SWIFT-II . . ."



Lenke, L.R., Berglund, J.W., and Cole, R.A. 1996. "Blowout Experiments Using Fine Grained Silica Sands in an Axisymmetric Geometry." NMERI 1996/7/32250. New Mexico Engineering Research Institute, University of New Mexico, Albuquerque, NM.

1. INTRODUCTION; p. 1, para. 1;

" The Waste Isolation Pilot Plant (WIPP) located in southern New Mexico is the first planned, mined geologic repository for transuranic wastes generated by U. S. defense programs. WIPP is currently being evaluated to assess compliance with the requirements of EPA 40 CFR 191 Subpart B (US EPA, 1985). Briefly, this requirement, promulgated by the Environmental Protection Agency, limits the amount of radioactive material that can be released to the accessible environment over a 10000 year regulatory period.

This report addresses an experimental laboratory program developed to model sudden solids release during outgassing and resultant blowout from a waste repository breached by a rotary drilling bit. An axisymmetric geometry was employed. These experiments were conducted on uniform sized, cohesionless silica sands in a partially saturated condition. Pressures within the experimental model were monitored and release volumes as a function of these pressures were measured.

The release volumes were compared with a mathematical model developed by the authors which is described in a subsequent section of this report. This model assumes that the sole source of strength within the partially saturated granular media is caused by capillary surface tension between particles. The transport mechanism for subsequent mass removal is based on the terminal velocity of individual particles.

1.1 Background

Of the possible pathways for release to the accessible environment during the 10000 year regulatory period, one of the most important is that caused by the inadvertent penetration of a waste storage room by an exploratory drillbit. Assuming that current, standard drilling practices for gas and oil are used, solid radioactive waste can be released to the ground surface by three mechanisms; namely, cuttings, cavings and spallings. The last mechanism includes the borehole spall caused by the flow of waste generated gas to the borehole and resultant blowout to the ground surface. The volume associated with such a blowout is difficult to assess.

The waste in its unmodified form will consist of a mixture of contaminated organic (e.g., cloth, wood, rubber, plastics) and inorganic (e.g., metal, glass) materials and sludges. After placement in the mined (salt) repository the waste will be compressed by the creep closure of the surrounding salt and in addition may become exposed to brine. The exposure of the metallic waste to brine is expected to cause corrosion of the metals and as a byproduct will generate hydrogen gas (H_2). Additional gas will be generated by the biodegradation of the organics in the waste inventory. The gas volumes generated by corrosion and biodegradation are expected to rise continuously for 400 to 600 years until they reach and possibly exceed the lithostatic overburden stress which at the repository horizon is estimated to be 14.8 MPa. If a waste room is penetrated by a drillbit when the pressure is high, the gas will escape to the lower pressure borehole, and may initiate spalling of the borehole wall

and blowout to the ground surface. The waste will then be transported to the ground surface in the drilling mud and/or in the flowing gas.

Cuttings, cavings, and spallings have been identified as potentially important direct release processes affecting the long term compliance requirements of 40 CFR 191. The computational model for cuttings and cavings is complete and except for values of the effective shear resistance to erosion the data are adequate. No experimental data for waste shear resistance to erosion are available and, consequently, values typical for sea bed erosion have been used for performance assessment computations. These values are probably conservative and generate releases greater than for partially decomposed unmodified waste."

2. MATHEMATICAL MODEL; p. 4, para. 1;

" The CUTTING_S User's Manual (1995). discusses the physical processes that are assumed to influence the quantity of waste brought to the ground surface as the result of the inadvertent penetration of the repository by an exploratory drill bit. The range of activity of these release processes based on waste permeability and pore pressure are depicted graphically in Figure 2-1. Above a repository gas pressure of 8 MPa waste is forced toward the lower pressure borehole (spalling) and some of the waste i s transported to the surface. In this section of the report a mathematical model is developed that addresses the solid waste release caused only by blowout as depicted in Figure 2-1.

The results from steady state flow experiments conducted on a partially saturated granular media (glass spheres) in an axisymmetric cylindrical geometry indicate that a porous pattern of channels is formed adjacent to the "borehole" (Lenke and Berglund, 1995). As a consequence of these experiments, the following conceptual model is developed which more closely corresponds to the physical processes observed in the experiments. The basis of this conceptual model is described in the remainder of this section."

Marietta, M.G., Bertram-Howery, S.G., Anderson, D.R., Brinster, K.F., Guzowski, R.V., Iuzzolino, H., and Rechard, R.P. 1989. Performance Assessment Methodology Demonstration: Methodology Development for Evaluating Compliance With EPA 40 CFR Part 191, Subpart B, for the Waste Isolation Pilot Plant. SAND89-2027. Sandia National Laboratories, Albuquerque, NM. WPO 25952.

ABSTRACT;

" This report describes a demonstration of the performance assessment methodology for the Waste Isolation Pilot Plant (WIPP) to be used in assessing compliance with the Environmental Protection Agency's Standard, *Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes* (40 CFR Part 191, Subpart B). This demonstration incorporates development and screening of potentially disruptive scenarios. A preliminary analysis of the WIPP disposal system's response to human intrusion scenarios produces preliminary complementary cumulative distribution functions (CCDFs) similar to those that will ultimately be used to assess the compliance of the WIPP with the Containment Requirements of the Standard. Preliminary estimates of scenario probabilities are used to construct two demonstration CCDFs. The conceptual model of the disposal system consists of geologic,, hydrologic, and disposal system subsystems along with the physical and chemical processes associated with these subsystems. Parameter values defining the systems contain uncertainties and modeling approximations of such a disposal system contributes to those uncertainties. The WIPP compliance assessment methodology consists of a system of techniques and computer codes that estimate releases of radionuclides from the disposal system, incorporating analysis of the parameter uncertainties in the estimates. Demonstration CCDFs are presented, but are not yet credible enough to judge the probability of compliance of the WIPP with the EPA Standard. One CCDF, based primarily on conservative reference data and conservative conceptual models, exceeds EPA limits, and another CCDF that represents effects of possible engineered alternatives does not exceed EPA limits."

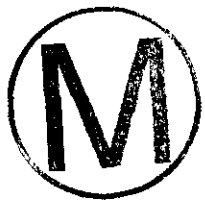
Martell, A.E., and Smith, R.M., 1977. Critical Stability Constants. Vol. 3: Other Organic Ligands. Plenum Publishing Corp, New York, NY.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Matalucci, R.V. 1982. Simulated-Waste Experiments Planned for the Waste Isolation Pilot Plant (WIPP). SAND82-0547. Sandia National Laboratories, Albuquerque, NM. WPO 24689..

ABSTRACT, p. 3-4;

" The US Department of Energy manages an R&D Program to provide a technical basis for systems design and safety and environmental assessments for future repositories of radioactive wastes resulting from US defense activities. The Waste Isolation Pilot Plant (WIPP) is southeast New Mexico is being developed within that Program as an R&D facility to demonstrate the safe disposal of such wastes in bedded salt. The Simulated-Waste Experiments (SWEs) refer to the in situ tests (without radioactivity) in the WIPP R&D Program that address the technical issues of isolating radioactive wastes in bedded salt. The SWEs include tests that concern the program areas of repository development and interactions of the waste package with the host rock. Data obtained from these tests will be used in evaluating performance assessment models and in developing a technical basis for future repository design and operations."



Mavor, M.J., and Logan, T.L. 1994. "Recent Advances in Coal Gas-Well Openhole Well Completion Technology," JPT, Journal of Petroleum Technology, Vol. 46, no. 7, pp. 587-593.

Summary, p. 587, col 1;
" This paper reviews the current applications of openhole techniques in the San Juan basin. Examples of recent advances and details for the use of the technology are documented in many of the references. The range of reservoir properties required for successful implementation of the technology is included. Hypotheses proposed to explain the success of the openhole wells are presented. The paper concludes with a discussion on future advances required to improve current completion procedures and the potential applicability of the process to other reservoir rock types."

Molecke, M.A., 1979. Gas Generation from Transuranic Waste Degradation: Data Summary and Interpretation. SAND79-1245. Sandia National Laboratories, Albuquerque, NM. WPO 26715.

1.0 INTRODUCTION, p 1, para 1;
" The generation of gases from the degradation of existing and potential forms of defense-related transuranic wastes has been the subject of extensive experimental investigations (1,2,3,4,5,6) over the past two to four years."

p. 1, para. 2;
" This paper summarizes and provides interpretation of all applicable waste degradation-gas generation data. This is an updated and significantly expanded review of an interim assessment document presented in January, 1979 (7). For completeness, data presented earlier (7) will be included along with the significant body of new data gathered in the last six months. This review and assessment has been compiled to assist the Department of Energy Waste Acceptance Criteria Steering Committee (WACSC) on their deliberations of acceptable TRU waste forms, whether existing in temporary storage or in laboratory development, for safe isolation in the WIPP.

This comprehensive review includes data and gas generation rates from several common TRU waste forms, various degradation mechanisms, synergism between mechanisms, resultant gas compositions, methods for reducing gas production rates, and comparisons between generation modes. Many of the experimental investigations to be described are still in progress; some of the data are preliminary and may be subsequently refined."

NIST (National Institute of Science and Technology). 1996. NIST Standard Reference Materials Catalog, 1995-1996. Standards Reference Materials Program, National Insititute of Standards and Technology, Washington, D.C.

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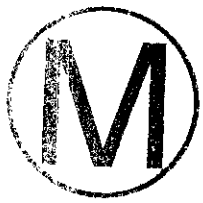

Novak, C.F. 1995. "The Waste Isolation Pilot Plant (WIPP) Actinide Source Term: Test Plan for the Conceptual Model and the Dissolved Concentration Submodel." SAND95-1895 (September 21, 1995 revision). Sandia National Laboratories, Albuquerque, NM. WPO 27860.

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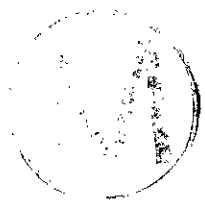

Novak, C.F., Moore, R.C., and Vann Bynum, R. 1996. "Prediction of Dissolved Concentrations for $^{+}$III, $^{+}$IV, $^{+}$V, and $^{+}$VI Actinides in Salado and Castile Brine." Memorandum. Sandia National Laboratories, Albuquerque, NM.

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Papenguth, H.W., and Behl, Y.K. 1996. Test Plan for Evaluation of Colloid-Facilitated Actinide Transport at the Waste Isolation Pilot Plant. TP 96-01. Sandia National Laboratories, Albuquerque, NM. WPO 31337.

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Perry, R.H., and Clinton, C.H. 1973. Chemical Engineers" Handbook, 5th ed. McGraw-Hill Book Company, New York, NY.

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Pitzer, K.S. 1991. "Ion Interaction Approach: Theory and Data." Activity Cooefficients in Electrolyte Solutions. 2nd ed. Ed. K.S. Pitzer. CRC Press, Boca Raton, FL. pp. 75-154.

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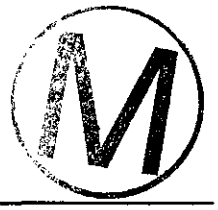

Popielak, R.S., Beauheim, R.L., Black, S.R., Coons, W.E., Ellingson, C.T., and Olsen, R.L. 1983. Brine Reservoirs in the Castile Formation, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico, TME 3153, U.S. Department of Energy, Waste Isolation Pilot Plant, Albuquerque, NM. (Available from NTIS as DE86004341/XAB.)

EXECUTIVE SUMMARY, p 1;

" The Waste Isolation Pilot Plant (WIPP) project is a U. S. Department of Energy (DOE) research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States. This demonstration consists of two parts. First, about six million cubic feet of TRU waste will be emplaced in the thick bedded-salt deposits of the Salado Formation in southeastern New Mexico at a depth of about 2150 feet. Second, the WIPP will provide for research relative to the interactions of defense high-level waste with bedded salt, though all high-level waste will be removed prior to facility decommissioning.

A potential location was selected for the WIPP in the northern Delaware Basin of New Mexico, and three exploratory core holes were drilled (AEC-7, AEC-8, and ERDA-6; Figure 1). While drilling the third such hole (ERDA-6), substantial geologic structural deformation was noted, and brine and gas sufficiently pressurized to flow to the surface were encountered. The unpredictability of the geology led to relocation of the site to its present location in 1974 (Figure 1). Since relocation, an extensive site characterization program has been conducted, and the adequacy of the site has generally been demonstrated.

In 1981, an agreement was signed between the State of New Mexico, the DOE, and others which included several studies intended to address the State's concerns relative to the suitability of the proposed WIPP site. Some of these studies addressed an area of geologic interest north of the proposed site, and pressurized brine reservoirs in the Delaware Basin. The work was begun in October 1981 and included the reopening and testing of ERDA-6, and the deepening and testing of WIPP-12, an exploration borehole which also encountered pressurized brine and gas. This report provides an account of these studies.

These studies and preparation of the brine reservoir report were performed by the WIPP Technical Support Contractor (TSC), primarily by D'Appolonia Consulting Engineers, Inc. (a member of the WIPP-TSC) under subcontract to the Westinghouse Electric Corporation (the TSC prime contractor). Sandia National Laboratories, Albuquerque, N.M., provided critical review of the studies and report; the U. S. Geological Survey also made comments.

The occurrence of pressurized brine reservoirs in the Castile Formation (underlying the Salado Formation) of the Delaware Basin has been documented over the past 40 years by reports of reservoir encounters by hydrocarbon exploration drilling. In general, these reservoirs were known to be contained in fractured anhydrite with associated hydrogen sulfide gas and were thought to be related to antiforms in the Castile.

Various theories were advanced to explain the origin of reservoirs, which include dissolution of evaporites by recent ground waters, dehydration of gypsum to form anhydrite, entrapment of ancient seawater during evaporite deposition, and ancient dissolution and

reprecipitation of evaporite minerals. Should certain of these theories be correct, the suitability of the WIPP site could be in question. Thus, the purpose of this study was to determine the characteristics and origin of these reservoirs and evaluate their potential impact on the integrity and stability of the WIPP site.

Data used in the performance of this study were obtained from drilling and hydrological testing in boreholes ERDA-6" and WIPP-12 and from chemical analyses of samples of reservoir brine and gas collected at these two wells. Information was also obtained from a review of published and unpublished literature on the geology and hydrology of the basin. The principle data reviewed and analyzed in this report are contained in "Data File report - ERDA-6 and WIPP-12 Testing" (D'Appolonia, 1982, 1983)."

Quality Assurance Department. 1995. "Verification of Design Adequacy." Waste Isolation Pilot Plant Quality Assurance Procedure QAP 3-2, Revision 1 (July 31, 1995). Sandia National Laboratories, Albuquerque, NM. Filed in records package WPO 37178.

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Reeves, M., Kelley, V.A., and Pickens, J.F. 1987. Regional Double-Porosity Solute Transport in the Culebra Dolomite: An Analysis of Parameter Sensitivity and Importance at the Wste Isolation Pilot Plant (WIPP) Site. SAND87-7105. Sandia National Laboratories, Albuquerque, NM. WPO 25714.

ABSTRACT, p. ii;

" A high-transmissivity fracture-controlled path is assumed, for modeling purposes, to provide the means for transport of infinitely long-lived radionuclides through the Culebra dolomite to the accessible environment at the Waste Isolation Pilot Plant (WIPP) site, following a breach which does not disturb the existing head potentials within the unit. Both matrix diffusion and sorption retard the transport. Parameter ranges and base-case values depict the uncertain properties of the Culebra while simulations with SWIFT II exhibit the corresponding ranges in travel time, the performance measure adopted for this report. Consistent with the paucity of the double-porosity data base, model assumptions are kept simple and parameter ranges relatively large. Thus, computed travel times may be unrealistic and should not be quoted apart from the model assumptions. Computed parameter sensitivities and estimated parameter importance, however, should provide valuable guidance to the current site-characterization program at the WIPP site. The report demonstrates the importance of the rate of fluid flow within the fractures and the relative capacity of the rock matrix for the retention of radioactive contaminants. It also demonstrates the relative unimportance of some of the matrix kinetic parameters which relate to the matrix-diffusion time. The report underscores the importance of hydraulic and tracer tests, particularly in the southeast sector of the WIPP site. Such tests would further confirm the flow and transport conceptualization, determine the extent of site heterogeneity, and reduce uncertainty in the transport properties."

Sax, N.I., and Lewis, R.J. 1987. Hawley's Condensed Chemical Dictionary, 11th ed. Van Nostrand Reinhold, New York, NY.

INTRODUCTION, P. ix;

" The first edition of the Condensed Chemical Dictionary appeared in 1919, when the chemical industry in the United States was entering a huge expansion program as a result of World War I. The urgent need for such a reference book became apparent to Francis M. Turner, President of the Chemical Catalog Company, predecessor of the Reinhold Publishing Corporation. Under his supervision a succession of Editors developed and expanded the Condensed Chemical Dictionary to meet the growing needs of the chemical industries. Since his death this development has continued, with the result that the work has achieved worldwide recognition in its field.

The Condensed Chemical Dictionary is a unique publication. It is not a dictionary in the usual sense of a compilation of brief definitions, but rather a compendium of technical data and descriptive information covering many thousand chemicals and chemical phenomena, organized in such a way as to meet the needs of those who have only minutes to devote to any given substance or topic.

Three distinct types of information are presented: (1) descriptions of chemicals, raw materials, processes and equipment; (2) expanded definitions of chemical entities, phenomena, and terminology; and (3) description or identification of a wide range of trademarked products used in the chemical industries. Supplementing these are listings of accepted chemical abbreviations used in the literature, short biographies of chemists of historic importance, and descriptions or notations of the nature and location of many American technical societies and trade associations. In special cases editorial notes have been supplied where it was felt necessary to clarify or amplify a definition or description. A few entries written by specialists are acknowledged by use of the author's name.

In a work of this nature, selection of topics for inclusion can hardly fail to be influenced by current interests and developing concerns within the topic area. The growing importance to chemists, and to the general public as well, of environmental and health hazards, which came to the forefront so quickly in the 1960s was reflected in the Eighth Edition, which greatly increased its coverage of this aspect of chemistry. After that, the magnitude of the energy problem became uppermost in the thinking of a broad spectrum of engineers, chemists, and physicists, since it has certainly become one of the most important technical problems confronting this country. Both the Ninth and Tenth Editions, while retaining emphasis on environmental considerations, were expanded in the area of energy and its sources, as far as permitted by available information. The effort in the eleventh edition has been to provide condensed, authoritative, factually oriented statements and descriptions, and to resist prognostications as to the future potential of any particular energy source. At the same time, continuing attention has been devoted to common hazards, such as flammable and explosive materials, poisons, pesticides, carcinogens, corrosive agents, radioactive wastes, etc., in line with the increasing public concern over these matters.

In connection with certain classifications of substances, particularly pesticides and

carcinogens, which have occasioned the most controversy, the statement "Use may be restricted" indicates that a state or local regulation may exist even though the product has not been officially banned, or that a definitive ruling on its use is pending. When a product has been banned outright, the statement "Use has been prohibited" is used. A number of disputed cases have arisen in recent years; though some have been definitely settled, others are still being evaluated or are in the process of litigation, for example, saccharin.

In such a work as this, in view of the many materials in various stages of evaluative testing, court procedures, appeals, hearings, etc., it is impossible to keep abreast of every development. The user should check the current status of any questionable products before making decisions that involve them (see also paragraph on Hazards, below)."

Sayles, F.L., and Fyfe, W.S. 1973. "The Crystallization of Magnesite from Aqueous Solution," Geochimica et Cosmochimica Acta. Vol 37, no. 1, pp 87-99.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Snyder, R.P., Gard, L.M., Jr., and Mercer, J.W. 1982. Evaluation of Breccia Pipes In Southeastern New Mexico and Their Relation to the Waste Isolation Pilot Plant (WIPP) Site, With Section on Drill-Stem Tests, WIPP-31. Open-File Report 82-968, U.S. Geological Survey for the U.S. Department of Energy, Albuquerque Operations Office, Denver, CO.

INTRODUCTION, p. 1;

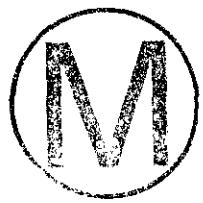
" The Waste Isolation Pilot Plant (WIPP) site is located about 40 km (25 mi) east of Carlsbad, N. Mex. (fig. 1). The site geography has been described in detail by Powers and others (1978) and U.S. Department of Energy (1980, 1981). Site selection was based principally on the existence of a thick section of Permian evaporites, mainly halite. The purpose of establishing this site is to demonstrate whether or not an evaporite environment is acceptable for the disposal of trans-uranic waste generated by the Nation's defense programs.

The primary concern regarding safe disposal of nuclear waste is to isolate the waste from the biosphere until it is no longer a danger to mankind. One of the most probable methods of accidental release of radiation from nuclear waste isolated in a geologic medium is leaching and transport of the waste by moving ground water. It is therefore of primary importance to identify any potential channelways that might allow water to enter a repository site located on bedded salt of the Salado Formation of southeastern New Mexico. The presence of the thick Permian (225 m.y.) rocks attests to the fact that major dissolution of the halite by unsaturated ground water has not occurred at the WIPP site.

Focus of Current Study

This report describes several dissolution features in the Delaware Basin and elsewhere that have been referred to as breccia pipes. Breccia pipes (also called breccia chimneys) as they occur in evaporites are vertical cylindrical pipes or chimneys that may or may not involve more than one geologic formation. The chimneys are filled with downward-displaced brecciated rock. In this context, the rock is brecciated by having collapsed into a void at depth that was probably created by ground-water solution and removal of deep-lying evaporite or carbonate rocks in an underlying aquifer system (Anderson and Kirkland, 1980; Bachman, 1980). Such features have been described in evaporite deposits in many areas of the world.

The current study was done for the U.S. Department of Energy (DOE) in response to a suggestion that because breccia pipes are thought to be the result of deep dissolution, they may represent channelways for future ingress of ground water, and that they should be considered in risk assessment programs for the evaluation of proposed waste repositories in bedded evaporite rocks. To this end, features referred to as breccia pipes in southeastern New Mexico have been assessed in relation to the integrity of the WIPP site. Reports by Anderson (1978), Bachman (1980), and Vine (1960) described dissolution and karst features in the Pecos region of southeastern New Mexico and discussed the origin and history of breccia pipes. The present report is intended to supplement these studies and provide detail that was not available to them at the time their reports were written.



Using the data from exploratory work, answers may be found to the following

questions concerning breccia pipes:

1. Do breccia pipes penetrate through the evaporite section?
2. What is the physical description of a pipe?
3. How are they formed?
4. How deep do they go?
5. When are they formed, and are they forming at present?
6. Are they permeable?
7. Where are they formed, can they form at the WIPP site?
8. Do they represent a threat to the WIPP site?"

Stein, C.L. 1985. Mineralogy in the Waste Isolation Pilot Plant (WIPP) Facility Stratigraphic Horizon. SAND85-0321. Sandia National Laboratories, Albuquerque, NM. WPO 27631.

ABSTRACT; p. 3, para. 1;

" Forty-six samples were selected for this study from two cores, one extending 50 ft up through the roof of the WIPP facility and the other penetrating 50 ft below the facility floor. These samples, selected from approximately every other foot of core length, represent the major lithologies present in the immediate vicinity of the WIPP facility horizon: "clean" halite, polyhalitic halite, argillaceous halite, and mixed polyhalitic-argillaceous halite. Samples were analyzed for not NaCl mineralogy by determining weight percents of water- and EDTA-insoluble residues, which were then identified by x-ray diffraction. In general, WIPP halite contains at most 5 wt% non-NaCl residue. The major mineral constituents are quartz, magnesite, anhydrite, gypsum, polyhalite, and clays. Results of this study confirm that, in previous descriptions of WIPP core, trace mineral quantities have been visually overestimated by approximately an order of magnitude."

Streeter, V.L. 1958. Fluid Mechanics. 2nd ed. McGraw-Hill. New York, NY.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Stühenberg, D., and Zhang, C. 1995. "Results of Experiments on the Compaction and Permeability Behavior of Crushed Salt," Fifth International Conference on Radioactive Waste Management and Environmental Remediation -- ICEM '95: Proceedings. Volume 1:Cross-Cutting Issues and Management of High-Level Waste and Environmental Remediation, Berlin, Germany, September 3-9, 1995. Eds. S. Slate and F. Feizollahi. American Society of Mechanical Engineers, New York, NY. p. 797-801. ISBN: 0-7918-1219-7.

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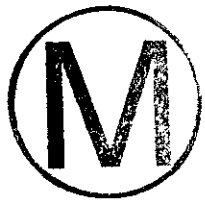

Thompson, T.W., Coons, W.E., Krumhansl, J.L., and Hansen, F.D. 1996. "Inadvertent Intrusion Borehole Permeability. Final Report." Filed as an attachment to WPO 39622, WPO 39624 and WPO 39626

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Vaughn, P.L. 1996. "Impacts of Using Only H_2 on Repository Flow and Pressure." May 21, 1996. Sandia National Laboratories, Albuquerque, NM.

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Von der Borch, C. 1965. "The Distribution and Preliminary Geochemistry of Modern Carbonate Sediments of the Coorong Area, South Australia," Geochimica et Cosmochemica Acta, vol. 29, pp. 781-799.

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Wang Y., 1996a, "Define Chemical Conditions for FMT Actinide Solubility Calculations." Memorandum to Malcolm Siegel, May 18, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 37038.

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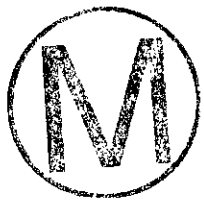

Wang, Y. 1996b. "Evaluation of the Thermal Effect of Exothermal Chemical Reactions for WIPP Performance Assessment." Memorandum to R.V. Bynum and L.H. Brush, July 19, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 39871.

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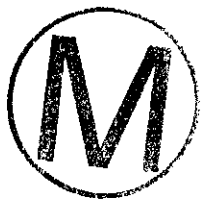

Wang, Y., and L.H. Brush. 1996a. "Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment." Memorandum to M.S. Tierney, January 26, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 31943.

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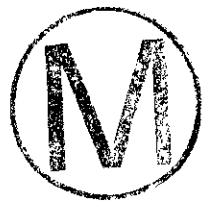

Wang, Y., and L.H. Brush. 1996b. "Modify the Stoichiometric Factor y in BRAGFLO to Inlcude the Effect MgO Added to WIPP Repository as Backfill." Memorandum to M.S. Tierney, February 23, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 32286.

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Watkins, D. 1996. "Estimate of Cement Content in TRU Solidified Waste Forms Scheduled for Disposal in WIPP," Memorandum to Les Shephard, April 4, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 37064.

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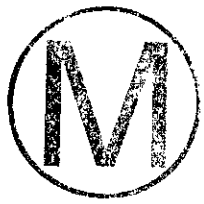

Wawersik, W.R., and Stone, C.M 1989. "A Charcertization of Pressure Records in Inelastic Rock Demonstrated by Hydraulic Fracturing Measurements in Salt," International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts. Vol. 26, no. 6, pp. 613-627. (This document was also released as SAND87-2569J, which is filed in the SWCF as WPO 24523.)

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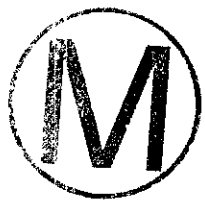

Weatherby, J.R., Brown, W.T., and Butcher, B.M. 1991. "The Closure of WIPP Disposal Rooms Filled with Various Waste and Backfill Combinations," Rock Mechanics as a Multidisciplinary Science, Proceedings of the 32nd U.S. Symposium on Rock Mechanics, Norman, OK, July 10-12, 1991. Ed. J-C. Roegiers. A.A. Balkema, Brookfield, VT. pp. 919-928. (This document was also released as SAND90-2399C, which is filed in the SWCF as WPO 28617.)

ABSTRACT p. 1;
" Two-dimensional finite element analyses were used to investigate the closure of WIPP disposal rooms filled with backfill and rooms filled with a combination of waste and backfill. Two different backfill materials were considered. The analyses provide estimates of the porosity in the disposal room as a function of time. These results have been used to help evaluate the suitability of the backfill materials for use in the repository."

p 4, para 4;
" The stress-strain behavior of the waste was represented by a volumetric plasticity model with a piecewise linear function defining the relationship between the mean stress p and the volumetric strain e_v. Compaction experiments on simulated waste were used to develop this relationship. Table 2 lists the ordered pairs that define the piecewise linear relationship between p and e_v in the two analyses that include waste."

Table 2: Assumed relationship between the mean stress and the volume strain for the CH-TRU waste.

Mean Stress, p (MPa)	Volume Strain, e_v ($\log(\rho/\rho_0)$)
0.028	0.032
0.733	0.741
1.133	0.898
1.667	1.029
2.800	1.180
10.17	1.536

Weiner, R.F. 1996. "Dissolved Ligand Concentrations." Memorandum to C.F. Novak, March 27, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 36163.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

WIPP PA (Performance Assessment). 1991-1992. Preliminary Comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1991. SAND91-0893. Sandia National Laboratories, Albuquerque, NM. Vols. 1-4.

ABSTRACT, p i;

" Before disposing of transuranic wastes at the Waste Isolation Pilot Plant (WIPP), the United States Department of Energy must have a reasonable expectation that the WIPP will comply with the quantitative requirements of Subpart B of the United States Environmental Protection Agency's (EPA) Standard, *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*. Sandia National Laboratories, through iterative performance assessments of the WIPP disposal system, is conducting an evaluation of the long-term performance of the WIPP that includes analyses for the Containment Requirements and the Individual Protection Requirements of Subpart B of the Standard. Recognizing that unequivocal proof of compliance with the Standard is not possible because of the substantial uncertainties in predicting future human actions or natural events, the EPA expects compliance to be determined on the basis of specified quantitative analyses and informed, qualitative judgment. Performance assessments of the WIPP will provide as detailed and thorough a basis as practical for the quantitative aspects of that decision.

PREFACE; p. vii, para. 1;

" The Waste Isolation Pilot Plant (WIPP) is planned as the first mined geologic repository for transuranic (TRU) wastes generated by defense programs of the United States Department of Energy (DOE). Assessing compliance with the long-term performance criteria of Subpart B of the United States Environmental Protection Agency's (EPA) Standard, Environmental Radiation Protection Standards for the Management and Disposal of Spend Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR Part 191), is a cornerstone for the DOE's successful implementation of a TRU-waste disposal system.

This report (the 1991 Preliminary Comparison) is a preliminary version of the planned document, Comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plane (the Comparison). The 1991 Preliminary Comparison is the second in a series of annual "Performance Analysis and DOE Documentation" reports shown in the timing for performance assessment in the 1991 DOE report Strategy for the Waste Isolation Pilot Plant Test Phase (DOE/EM/48063-2). The Test Phase schedule and projected budget may change; if so, the schedule for the performance-assessment reports will also change. Where data and models are available, the text is a preview of the final report scheduled for 1996 (DOE/EM/48063-2). This report is a preview of the final Comparison only to the extent that the Standard, when repromulgated, is the same as the vacated 1985 Standard. This report treats the vacated Subpart B of the Standard as if it were still effective, because the DOE and the State of New Mexico have agreed that compliance evaluation will continue on that basis until a new Subpart B is promulgated. The approach to the Standard and the resultant methodology reported here do not reflect the EPA's efforts to develop a new Subpart B.

The 1991 Preliminary Comparison is based on last year's reports: the Preliminary Comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1990 (SAND90-2347), Data Used in Preliminary Performance Assessment of the Waste Isolation Pilot Plant (1990) (SAND89-2408), and Sensitivity Analysis Techniques and Results for Performance Assessment at the Waste Isolation Pilot Plant (SAND90-7103). The 1991 Preliminary Comparison consists of four volumes. Volumes 2 (Probability and Consequence Modeling) and 3 (Reference Data) will be published in December 1991 with this volume (Methodology and Results). Volume 4 (Uncertainty and Sensitivity Analyses) will be published in March 1992.

Performance assessment is a dynamic process that relies on iterative simulations using techniques developed and data collected as work progresses. Neither the data base nor the models are fixed at this stage, and all aspects of the compliance-assessment system are subject to review as new information becomes available. Much of the modeling system described in this report will not change as the work progresses. Some of it will change, however, as problems are resolved and new models and data are incorporated into the system for use in subsequent simulations.

Vertical change bars in the right margins of Volume 1 of the 1991 Preliminary Comparison indicate changes from the text published in the single-volume 1990 Preliminary Comparison. Chapters 3 through 7 and Chapters 10 and 11 of the 1991 report, however, have been substantially revised or rewritten since the 1990 version and do not contain change bars. Chapters 3, 4, and 5 have been revised to reflect additions to the methodology and data used in evaluating the WIPP. Chapters 6 and 7 contain the results of the 1991 preliminary performance-assessment calculations. Chapters 10 and 11 discuss the 1991 results and summarize the status of the work to be completed to develop an adequate basis for evaluating compliance with Subpart B of the Standard.

Volumes 2, 3, and 4 do not contain change bars. Volume 2 is a compilation of essentially new material or material that was presented in a briefer form in 1990. Volume 3 is based on Data Used in Preliminary Performance Assessment of the Waste Isolation Pilot Plant (1990), SAND89-2408, but contains numerous additions and refinements to the reference data base. Volume 4 reports the results of the uncertainty and sensitivity analyses for the 1991 calculations. Sensitivity analyses identify aspects of the modeling system that have the greatest potential to affect performance, thereby helping guide ongoing research. Because new data or new interpretations of existing data may change the conceptual models and/or the ranges and distributions of parameters throughout the life of the WIPP Project, sensitivity analyses are also iterative. Volume 4 is substantially revised and rewritten compared to the previous year's report, Sensitivity Analysis Techniques and Results for Performance Assessment at the Waste Isolation Pilot Plant, SAND90-7103."

APPENDIX B: RESPONSE TO REVIEW COMMENTS; p. b-3, para. 1;

" Comments in this appendix relate to SAND90-2347, Preliminary Comparison with CFR Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1990. Responses relate to SAND91-0893, the 1991 version of SAND90-2347."

WIPP PA (Performance Assessment) 1992-1993. Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992. SAND92-0700. Sandia National Laboratories, Albuquerque, NM. Vols. 1-5.

1. INTRODUCTION; p. 1-1, para. 1;

" The Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, is a research and development project of the United States Department of Energy (DOE). The WIPP is authorized by Congress (Public Law 96-164, 1979) and is designed as a full-scale, mined geologic repository to demonstrate the safe management, storage, and disposal of transuranic (TRU) radioactive wastes generated by DOE defense programs since 1970. In addition to TRU radionuclides, the wastes may contain hazardous (nonradioactive) constituents. Before permanently disposing of radioactive wastes in the WIPP, the DOE must evaluate the repository based on various regulatory criteria for disposal of all the waste components, and the United States Environmental Protection Agency (EPA) must certify that compliance has been satisfactorily demonstrated.

Performance assessments will form the basis for evaluations of compliance with applicable long-term regulations of the EPA, including regulations pertaining to both radioactive and hazardous wastes (see Section 1.2 for a discussion of applicable regulations). This volume provides an overview of WIPP performance assessment and summarizes the December 1992 preliminary comparison with 40 CFR Part 191, Subpart B, which contains the long-term requirements of the Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (US EPA, 1985). Results presented here are preliminary and are not suitable for final comparison with 40 CFR 191, Subpart B. Portions of the modeling system remain incomplete, and the level of confidence in the performance estimates is not sufficient for a defensible compliance evaluation. Results are suitable for providing interim guidance to the WIPP Project as it prepares for a final compliance evaluation.

Several DOE documents explain the relationship between long-term regulatory information needs and the experimental programs that will fill those needs. The WIPP Test Phase Plan (US DOE, 1990a, currently in revision) contains descriptions of experimental programs related to disposal room and drift systems (see also Section 2.4 of this volume and Volumes 2 and 3 of this report), TRU-waste experiments, sealing systems and rock mechanics, hydrology of the transport within the host rock for the WIPP, and flow and transport in rock layers surrounding the WIPP. For each experimental program, the document describes the relevant information needs identified by performance assessments (defined in Section 3.3.1 of this volume) and indicates how the program has been designed to fill those needs.

The technical needs for laboratory and field experiments involving TRU and TRU-mixed waste and simulated waste have been assessed (US DOE, 1992a). These tests are designed to provide information on two topics identified as important for evaluating regulatory compliance: generation of gas from degradation of TRU wastes (defined in Section 2.5.1 of this volume), and the concentration of radionuclides and hazardous

constituents within disposal-room brine, both as dissolved species and as colloids.

Extensive laboratory and field studies conducted during the Site Characterization Phase for the WIPP have provided information used to date in performance assessments of the WIPP. References for these studies and discussion of how their results are used in performance assessments are provided in WIPP Test Phase Activities in Support of Critical Performance Assessment (40 CFR 191 B) Information Needs (US DOE, 1992b), which is a document prepared by the DOE for the National Academy of Sciences (NAS) WIPP Panel (referred to in Section 1.1.1 of this volume), and in other reports (Tyler et al., 1988; Lappin et al., 1989; US DOE, 1990a).

This report documents the third in a series of preliminary analyses of predicted long-term performance of the WIPP that Sandia National Laboratories (SNL) conducts for the DOE. Preparation for preliminary performance assessments began with the December 1989 Draft Forecast of the Final Report for the Comparison to 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant (Bertram-Howery et al., 1989 and Performance Assessment Methodology Demonstration: Methodology Development for Evaluating Compliance with EPA 40 CFR 191, Subpart B, for the Waste Isolation Pilot Plant (Marietta et al., 1989). The 1990 report (Bertram-Howery et al., 1990) and two supporting volumes (Rechard et al., 1990a; Helton et al., 1991) presented preliminary results of evaluation that addressed only the long-term performance criteria for disposal specified in the radioactive-waste disposal standards (40 CFR 191, Subpart B, US EPA, 1985; see Chapter 3 and Appendix A of this volume). The 1991 version of the report (WIPP PA Division, 1991a, b, c; Helton et al., 1992) presented preliminary evaluations for comparison with the regulatory requirements of 40 CFR 191, Subpart B. A preliminary safety assessment that evaluates possible long-term consequences to the public health as a result of radioactive waste emplaced in the WIPP is currently being prepared.

This 1992 report updates the preliminary results of the analyses included in the 1991 version of the report. Where data and models are available, the report presents preliminary results that preview a final report. With respect to the disposal of radioactive wastes, this 1992 report is a valid preview only to the extent that 40 CFR 191, Subpart B, which was promulgated by the EPA in 1985 and remanded by a U. S. Appeals Court in 1987 (NRDC v. US EPA, 1987), is the same as the vacated 1985 version. This report treats the vacated portion of 40 CFR 191 as if it were still effective because the DOE and the State of New Mexico have agreed that compliance planning will continue on that basis until a new Subpart B is promulgated (US DOE and State of New Mexico, 1981, as modified)."

APPENDIX B; p. b-3, para. 1;

" As stated in the Waste Isolation Pilot Plant Land Withdrawal Act (Public Law 102-579, 1992), performance assessment (PA) analyses shall be provided every two years "to the State [of New Mexico], the [EPA], the National Academy of Sciences, and the EEG [Environmental Evaluation Group] for their review and comment."

The inclusion of this appendix in the 1992 Preliminary Performance Assessment marks the third year that the Sandia National Laboratories' (SNL) PA Department has

published the complete text of formal comments received from these groups together with responses indicating how comments will be addressed in future PA iterations (Bertram-Howery et al., 1990; WIPP PA Division, 1991a). In previous years this appendix has included comments from the New Mexico Environment Department (1990, 1991), the EPA Office of Radiation Programs (1990), and the EEG (1990, 1991). Comments have been received in 1992 only from the EEG. These comments pertain to the 1991 preliminary PA, as published in the first four volumes of SAND91-0893 (WIPP PA Division, 1991a, b, c; Helton et al., 1992)."

Wolery, T.J. 1992. EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0). UCRL-MA-110662 Pt. 3. Lawrence Livermore National Laboratory, Livermore, CA.

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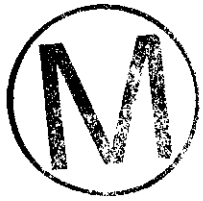

Wood, B.J., Snow, R.E., Cosler, D.J., and Haji-Djafari, S. 1982. Delaware Mountain Group (DMG) Hydrology -- Salt Removal Potential, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico. TME 3166, U.S. Department of Energy, Waste Isolation Pilot Plant, Albuquerque, NM.

INTRODUCTION AND SUMMARY, p. 1;

" This report provides an account of studies performed to evaluate the potential for salt dissolution in the Castile Formation, removal of dissolved salt by fluids in the Bell Canyon aquifer within the Delaware Mountain Group (DMG), and the potential impact of this process on the long-term integrity of the Waste Isolation Pilot Plant (WIPP) facility.

The results of this study provide responses to the stipulated agreement of July 1, 1981 with the U.S. Department of Energy (DOE) and the state of New Mexico regarding the DMG hydrologic investigation. This study was performed and this report prepared by D'Appolonia Consulting Engineers, Inc. (D'Appolonia), under Subcontract S9-CJR-45451 with Westinghouse Electric Corporation, Advanced Energy Systems Division, under Contract DE-AC04-78-ET05346 with the DOE. The Westinghouse team is serving as the Technical Support Contractors (TSC) to the DOE for the WIPP project.

This report is divided into the following six chapters:

- Introduction and Summary (1.0)
- Site Conditions (2.0)
- Salt Dissolution Features and Mechanisms (3.0)
- Evaluation of Dissolution Mechanisms in the Delaware Basin (4.0)
- Assessment of Salt Dissolution (5.0)
- Conclusions (6.0)

and supplementary appendices:

- Review of Numerical Simulation Techniques and Basic Governing Equations of Flow and Mass Transport (Appendix A)
- Sensitivity Analysis of Salt Dissolution and Transport Parameters (Appendix B)"

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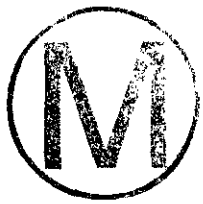
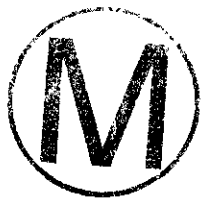


Brush, L.H., 1995. Systems Prioritization Method - Iteration 2 Baseline Position Paper: Gas Generation in the Waste Isolation Pilot Plant. Sandia National Laboratories, Albuquerque, NM.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

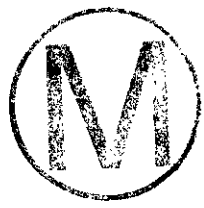


Bertram-Howery, S.G., Marietta, M.G., Rechard, R.P., Swift, P.N., Anderson, D.R., Baker, B.L., Bean, J.E., Jr., Beyeler, W., Brinster, K.F., Guzowski, R.V., Helton, J.C., McCurley, R.D., Rudeen, D.K., Schreiber, J.D., and Vaughn, P. 1990. Preliminary Comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1990. SAND90-2347. Sandia National Laboratories, Albuquerque, NM. WPO 27796.

ABSTRACT, p i;

" The Waste Isolation Pilot Plant (WIPP) is planned as the first mined geologic repository for transuranic (TRU) wastes generated by defense programs of the United States Department of Energy (DOE). Before disposing of waste at the WIPP, the DOE must evaluate compliance with the United States Environmental Protection Agency's (EPA) Standard, *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes* (40 CFR Part 1919, U. S. EPA, 1985). Sandia National Laboratories (SNL) is evaluating long-term performance against criteria in Subpart B of the Standard. 'Performance assessment' as used in this report includes analyses for the Containment Requirements (§ 191.13(a)) and the Individual Protection Requirements (§ 191.15). Because proving predictions about future human actions or natural events is not possible, the EPA expects compliance to be determined on the basis of specified quantitative analyses and informed, qualitative judgment. The goal of the WIPP performance-assessment team at SNL is to provide as detailed and thorough a basis as practical for the quantitative aspect of that decision.

This report summarizes SNL's late-1990 understanding of the WIPP Project's ability to evaluate compliance with Subpart B. This preliminary assessment cannot be defensibly compared to the requirements of the Standard to interpret whether the WIPP disposal system complies with Subpart B. Defensibility of the compliance evaluation ultimately will be determined primarily by qualitative judgment regarding 'reasonable expectations of compliance,' assuming that concept is retained by the EPA in promulgating the vacated Subpart B. Other considerations such as completeness and adequacy of the numerical simulations will also be factors in determining defensibility. Performance assessment must determine the events that can occur, the likelihood of these events, and the consequences of these events. The impacts of uncertainties must be characterized and displayed; however, no single summary measure can adequately display all the information produced in a performance assessment. Adequate documentation is an essential part of a performance assessment.



In lieu of results suitable for comparison with the Standard, this report presents results of sensitivity analyses that address specific uncertainties in the modeling system. All results are preliminary, and are conditional on assumed conceptual models and parameter value distributions. The results show the degree to which some uncertainties in the conceptual models that describe aspects of disposal-system behavior may affect predicted performance. The results also demonstrate the methodology used to assess performance. The reported complementary cumulative distribution functions (CCDF's) are statistical means of families of CCDFs. The modeling system is sensitive to changes in scenario probabilities,

and reductions in the probability of intrusion significantly reduce predicted probabilistic cumulative releases. Comparison of clay-lined-fracture and dual-porosity transport models for the dominant water-bearing unit above the repository indicate a significant increase in radionuclide retardation and a consequent reduction in predicted releases with the dual-porosity model. Simulations of a variable number of intrusions show that, for the selected probability model, multiple intrusions do not increase the largest cumulative releases. Simulations of a hypothetical waste modification suggest that for modifications to be effective, waste permeability must be reduced more than four orders of magnitude below the estimated unmodified value to restrict brine flow to an intruding borehole. Simulations of gas generation and the effects gas will have on brine flow and radionuclide transport are not sufficiently advanced to be incorporated in this year's CCDF curves, but preliminary results of one-dimensional simulations are included. Preliminary analyses for the Individual Protection Requirements suggest that no releases will occur; therefore, dose predictions are not likely to be required.

Although disposal-system characterization work has been underway for about 15 years, and much is known about the WIPP, all work necessary to support the performance assessment has not been completed. Most work currently in progress to support the performance assessment is not advanced enough to support a defensible comparison to the Standard because many important modules are in preliminary or intermediate stages of understanding or readiness. The compliance assessment system can be used for sensitivity and uncertainty analyses, and is adequate for preliminary performance studies."

DOE (U.S. Department of Energy), 1980. Waste Isolation Pilot Plant Safety Analysis Report, Washington, D.C.

Volume 1, Section, 2.4.2.2 Flood Design Consideration, p 2.4.8, para 1;
" The local drainage pattern (western slope) is such that surface runoff from areas north, south, and west of the surface facilities drains westward into the Pecos River without affecting the structures at the site. However, surface runoff generated by intense precipitation over local catchments immediately east of the surface facilities can pass through the site. Storm water runoff from areas around the surface facilities, including that on the east, are diverted by a system of peripheral interceptor drains. The site drainage system is designed so that storm runoff due to the probable maximum precipitation on the contributing drainage areas does not flood the plant. The floors of the waste handling building and other surface facilities are 0.5 feet above the grade elevation. The grade elevations of the roads, tracks, and surface facilities are designed so that storm water will drain off site under the most severe conditions (probable maximum precipitation; PMP)."

Volume 1, Section 2.4.2.3 Effects of Local Intense Precipitation, p 2.4-9, para 2, line 7;
" The WIPP is about 14 miles from the Pecos River. The general ground elevation in the vicinity of the surface facilities is about 500 feet above the riverbed and over 400 feet above the flood plain. AS discussed in sub-section 2.4.3.5 and 2.4.4, a probable maximum flood (PMF) or floods induced by potential dam failure on the Pecos River or its tributaries cannot raise the water level 500 feet to endanger the WIPP site. Therefore, as far as the potential for flooding from the Pecos River is concerned, the site is categorized as a "dry site." Since the distance between the Pecos River and the site is large and the permeability of the material separating the two is low, the response of groundwater at the site to changes in the surface level of the Pecos River is extremely slow. Therefore, it is concluded that groundwater elevation at the site are not affected by floods in the Pecos River."

Volume 1, Section 2.4.3.2 Precipitation Losses, p 2.4-11, line 20;
" The potential evaporation is much greater than the average annual precipitation of about 12 inches. In the southeastern valley, annual evaporation from a Class A pan is of the order of 110 inches. During the ward months, May through October, evaporation in the southeast portion of the state where the site is located, is about 73 inches. The monthly evaporation in the Pecos River basin is at the maximum in June and at the minimum during the months of December and January. The average annual Class A pan evaporation at Alamogordo, Avalon and Red Bluff is 109.06, 112.98 and 111.37 inches, respectively."

DOE (U.S. Department of Energy), 1990. Final Supplement Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026-FS, U.S. Department of Energy, Office of Environmental Restoration and Waste Management, Washington, D.C. Vols. 1-13.

Volume 1, Section 1.3 PURPOSE AND NEED FOR SUPPLEMENT TO FEIS, p 1-4;

" Since the publication of the FEIS in October 1980 and the subsequent Record of Decision to proceed with the phased construction and operation of the WIPP, new geologic and hydrologic information has led to changes in the understanding of the hydrogeologic characteristics of the area as they relate to the long-term performance of the WIPP. In addition, several changes have occurred in the Proposed Action and in the information and assumptions used to calculated the impacts reported in the FEIS. These include changes in the composition of the waste inventory, the transportation of waste to the WIPP, modification of the Test Phase, and the management of TRU mixed waste with hazardous chemical constituents.

This SEIS evaluates the environmental consequences of the Proposed Action as modified since 1980 in light of new information and assumptions. Modifications to the Proposed Action since 1980 that are examined in this SEIS are as follows: . . .

The new data and information and the resulting interpretations principally address the geologic and hydrologic systems at the WIPP site. They include:

- Determination of a locally lower permeability in the Salado Formation, the geologic formation in which the WIPP underground facilities are located (Subsection 4.3.2).
- Determination of a potentially higher moisture content in the Salado Formation and consequent brine inflow (Subsection 4.3.2).
- Discovery of a higher transmissivity zone in the Rustler Formation in the southeastern portion of the WIPP site (Subsection 4.3.3).
- New data leading to a conclusion that 'salt creep' (convergence) in the repository occurs faster than previously believed (Subsection 4.3.2).
- Pressurized brines within the Castile Formation which are assumed to be present beneath a portion of the WIPP waste emplacement panels (Subsection 4.3.4.2).
- Discovery of fractures in SPDV rooms (Subsection 4.3.2.4)."

DOE (U.S. Department of Energy) 1991. Resource Conservation and Recovery Act Part B Permit Application, February 1991, DOE/WIPP91-005, Prepared for the Department of Energy by Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

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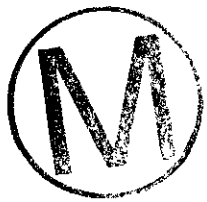

Martell, A.E., and R.M. Smith. 1982. Critical Stability Constants, Volume 5: Other Organic Ligands, Plenum Press, New York, NY.

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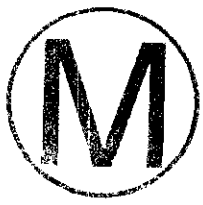
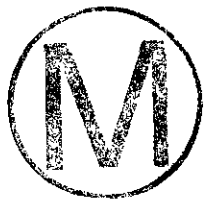


Mavor, M.J., and T.L. Logan. 1994. Recent Advances in Coal Gas-Well Openhole Well Completion Technology. JPT, July 1994. pp. 587-593.

Summary, p. 587, col 1;
" This paper reviews the current applications of openhole techniques in the San Juan basin. Examples of recent advances and details for the use of the technology are documented in many of the references. The range of reservoir properties required for successful implementation of the technology is included. Hypotheses proposed to explain the success of the openhole wells are presented. The paper concludes with a discussion on future advances required to improve current completion procedures and the potential applicability of the process to other reservoir rock types."



NMBMMR (New Mexico Bureau of Mines and Mineral Resources). 1995. Final Report Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site. March 31, 1995. New Mexico Bureau of Mines and Mineral Resources for Westinghouse Electric Corporation, Socorro, NM. WPO 39149 - WPO 39150.

EXECUTIVE SUMMARY, p E-1;

" The Waste Isolation Pilot Plant (WIPP) land withdrawal area occupies 16 mi^2, on the southeastern edge of the Known Potash Leasing Area (administered by BLM), about 30 miles southeast of Carlsbad, Eddy County, New Mexico. It is four miles on a side and is located in secs. 15 to 22 and 27 to 34 of T22S R31E. This study includes an additional study area about one mile wide surrounding and containing an additional 20 mi^2. The combined study area comprises about 36 mi^2.

The amount and value of natural resources under the WIPP land withdrawal area have not been calculated for more than ten years. This report performs this calculation using current and projected prices, production, geologic data, and conditions. The need for recalculating the volume and value of mineral resources within the boundaries of the WIPP land withdrawal area stems from the discovery of oil and associated natural gas in adjacent lease tracts during the late 1980s and 1990s, and the approach of potash mining.

During the late 1980s and early 1990s oil was discovered in the lower parts of the Delaware Mountain Group (Permian: Cherry Canyon and Brushy Canyon Formations) along the eastern, southern, and western boundaries of the land withdrawal area. In the Delaware Basin as a whole, these formations were not generally recognized as exploratory and development targets until the late 1980s. Prior to that time, they were usually bypassed during drilling with little or no thought that they might contain economically recoverable oil resources. Although these two formations had been penetrated by thousands of wells throughout the Delaware Basin, few attempts were made to adequately test them.

The main reason for bypassing these formations during drilling was a lack of understanding of their production characteristics. Water saturations calculated from analysis of electric logs were often high and did not differentiate oil-productive sandstones from sandstones that would yield mostly water upon completion. However, recent developments in log analysis (Asquith and Thomerson, 1994) have made it possible to differentiate Delaware sandstones with a high percentage of movable hydrocarbons from those with a low percentage of movable hydrocarbons. This type of analysis, in conjunction with the discovery of several commercial oil pools in the Brushy Canyon Formations, set off an oil drilling boom throughout the Delaware Basin that continues to the present. The Delaware play is currently the primary exploration and development play in the Permian Basin and is one of the most active oil plays in the United States. Of special note in the vicinity of WIPP was the discovery and development of commercial oil accumulations in the Brushy Canyon Formation at Cabin Lake; Livingston Ridge, Lost Tank, and Los Medaños pools.

During the last decade or so, potash mining has continued and the mining front is now much closer to the WIPP boundary. Mining by IMC has reached the edge of the additional study area on the southwest side of the WIPP. Future mining may occur mainly

there or on the north.

The value of potash (sylvite and langbeinite) and petroleum (oil and gas) were calculated using iterative economic models commencing in 1996 and lasting until 2031 (potash), 2026 (petroleum), and 2038 (natural gas plus associated oil). The potash and petroleum resources produced over this time frame were calculated from estimates based on drill hole data and projections of data and geology as needed. The value calculation used these resource data and projections of historical cost, price, and other economic data.

Quality Assurance Department. 1995. Verification of Design Adequacy. Quality Assurance Procedure (QAP)3-2. Rev. 1, Sandia National Laboratories, Albuquerque, NM.

1.0 Purpose, p. 3;
" The purpose of this procedure is to establish methods for verifying the adequacy of design(s) developed by Sandia National Laboratories (SNL) personnel or its contractors in support of the Waste Isolation Pilot Plant (WIPP) Project. This procedure also establishes the minimum criteria for implementing a verification method and the documentation of the method and results."

Wang, Y. 1996b. Evaluation of the Thermal Effect of Exothermal Chemical Reactions for WIPP Performance Assessment. Unpublished memorandum to R.V. Bynum and L.H. Brush, July 19, 1996. Sandia National Laboratories, Albuquerque, NM.

p.1, para. 1;
" To support your response to peer reviewer's comments, in this memo I will evaluate possible temperature increases caused by exothermal chemical reactions in the repository. The thermal effect of MgO hydration, which was evaluated previously, will be re-evaluated, based on current BRAGFLO calculations.

Assumptions:

The following exothermal chemical reactions are considered:

$MgO + H_2O \rightarrow Mg(OH)_2$ (1)

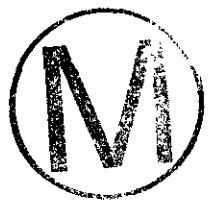
$Mg(OH)_2 + CO_2 \rightarrow MgCO_3$ (2)

$Fe + H_2O \rightarrow Fe(OH)_2 + H_2$ (3)

$C_6H_{10}O_5 + H_2O \rightarrow 3CH_4 + 3CO_2$ (4)

$Al + 3H_2O \rightarrow Al(OH)_3 + 1.5H_2$ (5)

Considering that the vertical dimension of the repository (_1 m, B. M. Butcher, personal comm.) will be much less than the horizontal extension after room closure, we assume that the heat released from the reactions will be dissipated away mainly from the ceiling and ground of the repository and the heat loss from the side walls is negligible. We also assume that all reactions will take place uniformly in a reaction region of interest. We here restrict the reaction region in a single waste panel, for the following reason: Some of the above reactions may be limited by brine inflow. BRAGFLO simulations have shown that, in the human intrusion cases, the rate of brine inflow into a borehole-penetrated waste panel will be significantly higher than that into the rest of the repository. Choosing a panel rather than the whole repository as a reaction region will make heat generation rate per unit of volume higher and the heat dissipating surface area smaller in our calculations, and therefore it is conservative. However, this choice will not affect the calculations for the reactions that are not limited by brine inflow, as you will see below."



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