EPA Comment
G-1 Fluid Injection

The number of active injection and salt-water disposal wells near WIPP has increased from 27 to 39 as of September 30, 2002, an increase of 12 injection-type wells. The CRA also noted that in the feature, event, and process (FEP) determination, DOE continued to screen out fluid injection but changed the screening justification for this FEP from a regulatory basis to a consequence basis. Please describe and provide the analysis used to support this modification.

During the review for EPA's initial WIPP certification decision, DOE performed an analysis that evaluated the potential impact of fluid injection near the WIPP site. DOE must update the original evaluation using the new well information and parameter estimates, such as injection volumes and flow rates of injection fluid. As with the original analysis, the update should identify whether the amount, if any, of potential brine inflow is captured within the current performance assessment.

DOE Response

1 Background

In 1996 for the Compliance Certification Application (CCA), the DOE screened fluid injection from performance assessment calculations based on the regulatory exclusion provided in 40 CFR § 194.33(d), which states,

> *"With respect to future drilling events, performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of the borehole."*

Therefore in the CCA, the use of future boreholes for activities such as liquid waste disposal, enhanced oil and gas production, and hydrocarbon storage was eliminated from performance assessment calculations on regulatory grounds (see CCA Appendix SCR, Section 3.3.1.3).

However, during their review of the CCA, the EPA requested additional analyses relating to fluid injection in their March 19, 1996 letter where they state:

> *"Therefore, EPA requires either additional substantiation to support the elimination of fluid injection scenarios from performance assessment calculations, or revision of the performance assessment to include appropriate fluid injection scenarios."*

Based on this request, the DOE assumed that the EPA was disallowing a regulatory screening in spite of the provisions of § 194.33(d). Therefore a consequence analysis (Stoelzel and Swift 1997) was conducted and submitted to EPA June 16, 1997. This analysis demonstrated that even with very conservative assumptions, fluid injection practices in the future will not affect the WIPP repository. EPA concurred with this analysis and stated in their Technical Support Document (TSD) for Section 194.32: Fluid Injection Analysis that:

> *Based on these two analyses* (Stoelzel and O'Brien [1996], Stoelzel and Swift [1997]) *and the independent analyses performed by EPA, the Agency concludes that fluid injection scenarios have been appropriately screened out from consideration in the performance assessment of the WIPP repository* ***due to a lack of consequence*** [emphasis added]. (TSD for 194.32,114 Section 5.1)

Therefore, for the Compliance Recertification Application (CRA), the screening of these events and processes was changed from a regulatory screening to a screening based on no consequence, as it is believed that the EPA effectively changed the screening basis in their final certification documentation.

For the purposes of recertification, all changes since the initial certification must be re-evaluated. It is therefore appropriate to evaluate any changes in fluid injection practices near the WIPP and determine if these changes affect the assumptions, analyses, or conclusions of the consequence analysis conducted in support of the CCA.

This evaluation can be summarized into two parts: 1) an evaluation of the changes in injection practices in the area surrounding the WIPP; and 2) an evaluation of affected modeling assumptions and parameters that would be used to re-evaluate the original consequence analysis, if necessary.

2 Changes in Injection Practices Since the CCA

2.1 Number of Injection Wells

The DOE presented updated injection well data in Attachment A to Appendix Data of the CRA. As noted by the EPA in their comment above, injection wells (both salt water disposal [SWD] and waterflood) within the vicinity have increased from 27 (DOE 1997) to 39. As part of the screening discussion in Attachment SCR of Appendix PA, a report titled "Water Injection in WIPP Vicinity: Current Practices, Failure Rates and Future Operations" (Hall et al. 2003) is referenced and provides additional information regarding failures in injection wells in the vicinity of the WIPP. Hall et al. notes that salt water disposal is the primary source of injection, and that injected volumes in the area near WIPP very closely parallel produced water volumes. Therefore, as water production increases, so does produced water disposal (injection). Fluctuation of produced water volumes over the life of the oil reservoirs near WIPP will cause similar increases and decreases in injected volumes, as well as active injection wells.

Changes in the number of active injection wells were anticipated by the EPA, as noted in the Technical Support Document for 194.32, Fluid Injection Analysis:

> *"…At any given time, it is likely that the number of active injection wells will change as oilfield activity continues. Some currently active injectors are likely to be plugged as other wells are put into active injection service…"*

As the EPA notes above, it is expected that the number of injection wells will fluctuate over time, depending on a number of production factors in the area. The current amount of produced water, the distance to the nearest disposal well, and availability of dry holes and/or depleted wells will play a role in the number of active disposal wells at any given time. So, while the number of injection wells has increased for the CRA, this increase is not unexpected.

2.2 Injection Well Failures (Test Failures)

Kirkes and Evans (1997) identified injection well "failures" for the period leading up to the certification of the WIPP. These failures were not instances in which fluid was migrating from the target zone, but rather represent the failure of required annual tests, based on New Mexico Oil Conservation Division (NMOCD) regulations. These failures usually represent leaking tubing, packer, or casing. Regulations require that any wells failing a test must be repaired prior to being returned to injection. Prior to the certification of WIPP, Kirkes and Evans (1997) documented a failure rate of 0.028 for the nine-township area surrounding the WIPP[1]. Since WIPP Certification, Hall et al. (2003) identifies six additional failed tests. In addition, WRES (2004) conducted its own independent search for injection failures and also identifies six failures. These failures represent a cumulative failure rate of 0.032 for the same area surrounding the WIPP[2].

As will be discussed later, it is only through simultaneous hardware failures where a potential leak pathway is created that could allow injected fluid to migrate out of the target zone. Hall et al. states,

> *"The prior report [Kirkes and Evans 1997] found 'given the infrequency of tubing and packer leaks…, and the infrequency of casing leaks, the probability of these two leaks is very, very low.' This conclusion remains valid, based on recent failure data. Furthermore, these failures are readily detected and repaired. Therefore these failures do not impact the WIPP site since any injected fluids are contained within the downhole tubulars and do not migrate out of the desired injection interval."*

2.3 Changes in Injection Volumes

Hall et al. notes that total injection volumes for the WIPP vicinity have increased as a result in the increase in injection wells. Average daily injection for the area is currently

[1] The failure rate of .028 is based on 3 identified failures in 106 years of regulated operation.
[2] The failure rate of .032 is based on 9 identified failures in 278 years of regulated operation (includes pre-1997 failures).

approximately 44,000 barrels of water injected per day (BWIPD), or approximately 1,250 BWIPD per well.[3] This compares to average daily injection of 32,500 BWIPD at the end of 1997, or 1,250 BWIPD per well.[4] So, while total daily injection volumes have increased, the volume injected per well has stayed fairly stable at 1,250 BWIPD. Hall et al. also notes that while volumes have increased, the Delaware Mountain Group reservoirs are underpressurized. This is because cumulative petroleum withdraws to date are significantly greater than cumulative injection volume. This underpressurized condition is expected to continue because withdraws continue to outpace injection.

2.4 Changes in Injection Pressures

The NMOCD does not allow injection pressures to exceed 0.2 psia per foot of depth to the top of the perforations. This guideline results in maximum sand face pressures that are significantly below the fracture pressure for the target horizons near WIPP. In a few exceptions, a step-rate test may be performed to allow injection above the 0.2 psia per foot rule. In 1997, Kirkes and Evans identified one well in the vicinity of the WIPP that had undergone a step-rate test and was subsequently allowed to inject at above the 0.2 psia per foot rule. Since then, three of the 39 injection wells have had step-rate tests and currently inject above the 0.2 psia guideline. WRES (2003) shows the maximum injection pressure permitted via step-rate test to be the Getty "24" Federal No. 5 at 0.39 psia per foot[5]. Kirkes and Evans (1997) and Hall et al. indicate that due to the low viscosity and high leak-off properties of salt water, the creation of a vertical fracture is highly improbable at the injection rates currently seen in the vicinity of the WIPP.

3 Analysis if Related Modeling Assumptions and Parameters

Stoelzel and Swift (1997) conducted a conservative analysis that used the BRAGFLO code (modified from that used in the CCA), to specifically evaluate the effects of a leaking injection well at the WIPP boundary. Their analysis used bounding conservative assumptions for many of the key functions and characteristics of a typical injection well.

The following sections will address the current applicability of the modeling conducted by Stoelzel and Swift (1997). Relevant modeling assumptions, parametric values, and code that are affected by changes made in the CRA are identified and evaluated for impact, if any.

3.1 Changes Affecting Assumptions

3.1.1 Conceptual Leak Pathways

Stoelzel and Swift (1997) assumed that the worst-case failure of injection well hardware is when casing failures coincide with tubing or packer failures. Either failure by itself

[3] This value is based on 36 active injection wells at the time of Hall et al. (2003).
[4] This value is based on 26 active injection wells at the time of Kirkes and Evans (1997).
[5] This well is permitted at a maximum injection pressure of 1,780 psi (0.39 psi per foot), although records show the well operates at 1191 psi (0.26 psi per foot).

presents no direct pathway to other units. Pathways out-of-zone only occur when a casing failure is coincident with a tubing/packer failure. Stoelzel and Swift (1997) use observed failure rates for well casing and then conservatively assume a tubing/packer failure occurs at the same time. Without this conservative assumption, there would be no realistic pathway for injection fluid to migrate out of the target horizon. New failure rates provided by WRES (2004) (see Section 2.2 above) are very similar to those reported in 1997. The new rates do not invalidate any of the assumptions related to hardware failure, as Stoelzel and Swift (1997) conservatively assume that the hypothetical injection well at the WIPP boundary fails (has a failure rate of 1.0).

3.1.2 Injection Pressures

Injection pressures modeled by Stoelzel and Swift (1997) conservatively exceed allowable permitted pressures. As mentioned above, the NMOCD requires the surface pressure not to exceed 0.2 psia per foot of depth to the top of the perforations, unless a "step-rate" test is performed. Stoelzel and Swift (1997) used a very conservative injection pressure of 1.0 psia per foot. This value is far greater than any of the operating injection wells in the vicinity of the WIPP.[6] Therefore, the injection pressures used in the Stoelzel and Swift (1997) analysis continue to be a very conservative upper bound for injection wells in the vicinity of the WIPP.

3.1.3 Injection Volumes

Injected volumes used by Stoelzel and Swift (1997) greatly exceed known fields in the area. This overestimation is explained by Stoelzel and Swift (1997) (section 4.2.1) but nonetheless exceeds any actual injection project by many times. For example, injected volumes seen in Stoelzel and Swift's model ranged from 30.8 x 10^6 cubic meters to 647.4 x 10^6 cubic meters. This compares to the David Ross AIT Federal Number 1 which has one of the largest cumulative injection volumes at 1.3 x 10^6 cubic meters. In fact, Hall et al. (2003) reports the cumulative injection volume for the entire nine township to be 10.1 x 10^6 cubic meters.

Based on data presented in Hall et al. (2003) and the Delaware Basin Drilling Surveillance Program (DBDSP) (WRES 2004), there have been no observed occurrences or practices that invalidate any of the assumptions or the conceptual model used in the Stoelzel and Swift (1997) analysis. Were this modeling analysis to be conducted again, the same injection volumes used by Stoelzel and Swift (1997) would remain valid and conservative.

3.2 Changes Affecting Parameters

The analysis by Stoelzel and Swift (1997) used parameters that were used directly from the CCA performance assessment or were based on such parameters. Specifically, they used three permeability parameters to represent three possible conditions in an injection

[6] As stated in Section 2.4, the highest permitted injection pressure in the vicinity of the WIPP is 1,780 psia, or 0.39 psia per foot depth.

borehole: (1) a non-degraded cement sheath (properly operating injection borehole), (2) partially degraded cement sheath, and (3) fully degraded cement sheath. All three of these parameters are affected by changes that have been made since the CCA. In addition, the Stoelzel and Swift (1997) analysis used a permeability of the Culebra that was current at the time of the CCA. This parameter was changed slightly for the CRA performance assessment to reflect new transmissivity fields. These parameter changes are discussed below.

3.2.1 Log permeability of non-degraded cement (CONC_PLG: PRMY_LOG)

This parameter was used to define the permeability of the *non-degraded* cement sheath in the Stoelzel and Swift (1997) analysis. As indicated below, this parameter was changed for the PAVT (and adopted for the CRA) from a constant to a uniform distribution in which all values are lower than the constant CCA value. Since lower permeability of the cement sheath leads to less leakage, this change can only result in less brine leaking from a properly functioning injection borehole. Therefore the use of the CCA value is conservative relative to the updated CRA distribution.

Stoelzel and Swift (CCA):	Constant:	-1.6301000e+001 (equal to 5×10^{-17} m^2)
CRA:	Uniform:	min = -19, max = -17 (equal to 10^{-19} to 10^{-17} m^2)

3.2.2 Log permeability of a partially degraded cement sheath

This parameter was used to define the permeability of a *partially* degraded cement sheath in the Stoelzel and Swift (1997) analysis. This parameter was calculated as the median of a uniform distribution between the log permeability values for non-degraded cement (described above) and fully degraded cement (described below). Because both the upper and lower bounds describing this distribution have been decreased for the PAVT (and adopted for the CRA), the median value will decrease and therefore the original value used in the Stoelzel and Swift (1997) analysis remains conservative relative to the updated CRA values.

Stoelzel and Swift (CCA):	Constant	-1.365000e+001 (equal to 2.24×10^{-14} m^2)
CRA:	NA	Not used in CRA

3.2.3 Log permeability of fully degraded cement sheath

This parameter was used to define the permeability of a *fully* degraded cement sheath in the Stoelzel and Swift (1997) analysis. It was set equal to the median log permeability assigned to an abandoned borehole in the CCA (BH_SAND:PRMX_LOG). This parameter distribution (and median value) was changed for the PAVT (and adopted for the CRA). The original median value was –12.5 (equal to 3.16 x 10^{-13} m^2) and was changed for the PAVT (and adopted for the CRA) to –13.65 (equal to 2.24 x 10^{-14} m^2). Since the updated median value is lower than the value used in the original Stoelzel and Swift (1997) analysis, the original analysis remains conservative relative to the updated CRA values.

3.2.4 Log permeability of the Culebra

The log permeability of the Culebra (CULEBRA:PRMX_LOG) was changed from –13.3678 (equal to 4.29 x 10^{-14} m^2) in the CCA (and PAVT) to –13.3112 (equal to 4.88 x 10^{-14} m^2) for the CRA to reflect the changes to the transmissivity fields made for the CRA. The change results in the permeability of the Culebra increasing slightly (about 14%). This change is so small, especially considering the inherent uncertainties in estimates of permeability, that it will not have any significant impact on the model results presented by Stoelzel and Swift (1997) and is only mentioned here for completeness.

3.3 Other parameter changes made for the CRA

A number of other parameters were changed for the CRA relating to features within and near the repository such as, the Option D panel closures, disturbed rock zone permeability, and the inventory of biodegradable material. In relation to the Stoelzel and Swift (1997) analysis, all these changes would only impact the dynamic conditions near the repository as represented in the cross-section model, as described in the original report. This cross-section model employed a specialized BRAGFLO grid that represented an injection borehole, a simplified repository intersected by a borehole, and an oil production borehole. Stoelzel and Swift (1997) ran the model once to validate the results of the radial model, which included only the injection borehole and intervening geologic layers. Therefore, the collection of parameter changes made to features within the repository will not have any effect on the results of the radial model and would not have any significant effects on the results of the cross-section model, especially considering the potential of the much more significant parameter changes relating to the permeability of the cement sheath, which would act to decrease the amount of brine entering the formation and thus the repository as a result of brine injection activities. Furthermore, the changes made for the CRA relating to features within and near the repository (Option D panel closures, disturbed rock zone permeability, and increased biodegradable inventory, etc) result in slightly higher repository pressures when compared with the results of the CCA. Higher pressures in the repository decrease any hydraulic gradient between an injection borehole and the repository and would lead to less brine inflow than predicted by Stoelzel and Swift (1997).

4 Conclusions

In summary, the EPA presents two requests regarding fluid injection for the CRA: 1) justify the screening of "low consequence" rather than the regulatory screening as used in the CCA, and; 2) "*update the original evaluation using the new well information and parameter estimates, such as injection volumes and flow rates of injection fluid…*" and determine the impact, if any. First, the screening of fluid injection could again be justified as a regulatory screening, as was done for the CCA. However, since a reasonable and conservative consequence analysis has been conducted at the request of the EPA and continues to be valid based on all available new information, a screening on the basis of low consequence is considered appropriate.

With regard to the second request, the DOE has evaluated the model used by Stoelzel and Swift (1997) in light of changes made to the PA system for the CRA. Except for trivial differences in Culebra permeability, the values and assumptions in the Stoelzel and Swift (1997) model are at least as, or more conservative than the newer CRA values, and effectively bound any analysis that would be conducted using the CRA PA system. Therefore, the original analysis is considered to remain valid, and effectively screens fluid injection out of PA calculations on the basis of low consequence.

Injection volumes and the number of injection wells will continue to fluctuate to meet the need to accommodate produced water volumes; these fluctuations are to be expected. However, there is no current trend or evidence that would indicate a higher probability of failures or non-compliance with maximum permitted pressures. Occurrences of malfunctioning injection wells since the CCA remain very low, and do not present a credible pathway into the repository; there have been no occurrences of the compound failure of a leaking tubing/packer concomitant with a casing leak, which are both necessary to provide a leak pathway as modeled by Stoelzel and Swift (1997). Nonetheless, should such a low probability event occur, the analysis conducted by Stoelzel and Swift (1997) continues to bound any brine that might reach the repository under very conservative conditions and assumptions.

References

Hall, R.K., Creamer, D.R., Hall, S.G. and Melzer, L.S. 2003. Water Injection Current Practices, Failure Rates and Future Operations. Westinghouse TRU Isolation Pilot Plant (WIPP) June 2003. Carlsbad, NM. ERMS # 530222.

Kirkes, G.R. and Evans, R.D. 1997. "Injection Methods: Current Practices and Failure Rates in the Delaware Basin." U.S. Department of Energy, Carlsbad Field Office. Carlsbad, New Mexico. DOE/WIPP-97-2240. EPA Docket A-93-02, Item II-G-25.

Stoelzel, D.M., and P.N. Swift. 1997. Supplementary Analyses of the Effect of Salt Water Disposal and Waterflooding on the WIPP. Sandia National Laboratories, Albuquerque, NM. ERMS # 244158 . EPA Docket A-93-02, Item II-G-25.

WRES 2004. Memorandum from S. C. Kouba to Dr. Mark Rigali."Supplemental Injection Data 1997-September, 2002." Washington Regulatory and Environmental Services. July 8, 2004.

EPA Comment
G-5 (1 and 2) PA Computer codes - SANTOS, NUMBERS and DRSPALL

We stated in our preliminary PA code review, completed in June 2003 (Docket Number: A-98-49, II-B3-70):
"After completing the Agency's review, the EPA has concluded that 36 (of the 39) computer codes and three libraries migrated to the Compaq ES45 and 8400 with OpenVMS 7.3-1 are approved for use in compliance calculations for the WIPP performance assessment. Final technical review of the remaining three codes (e.g., NUMBERS, SANTOS, DRSPALL) will be conducted separately as part of the Agency's review and evaluation of the CRA. Specifically, the EPA will ensure that:
1. DRSPALL, 1.0 is regression tested on the Compaq ES45 and 8400;
2. NUMBERS meets the QAP 19-1 requirements; and
3. SANTOS is properly evaluated for accuracy."

DOE must provide written documentation that these concerns have been adequately addressed.

DOE Response

Provided below are the SNL WIPP Record Center ERMS for the DRSPALL Version 1.00 regression testing and the Numbers, Version 1.19, NP 19-1 software qualification. The Santos accuracy evaluation will be submitted under a separate response.

1. DRSPALL regression testing completed on 4/26/04 under ERMS # 534208

2. Numbers software qualification completed:
   - Software QA Plan, ERMS# 534712
   - Requirements Document and Users Manual SAND88-0737, Numbers: A Collection of Utilities for Pre- and Postprocessing Two- and Three-Dimensional EXODUS Finite Element Models
   - Users Manual Addenda, ERMS# 535648
   - Implementation Document, ERMS # 535647
   - Verification & Validation Plan/Validation Document, ERMS # 535646 &
   - Installation & Checkout, ERMS# 535649

EPA Comment
G-6 Parameters and the Parameter Database

We stated in our parameter report, completed in March 2004 (Docket Number: A-98-49, II-B3-69):

> *"In addition, SNL provided a list of 10 additional parameters used in DRSPALL, that are not in the PAPDB (Performance Assessment Parameter Database). Essentially, these values are not in the PAPDB because they are considered by SNL to be primarily code control parameters, not material properties. In a letter dated from March 31,2004, from Dave Kessel of Sandia National Laboratories (SNL), SNL agreed to put only some of the parameters in the PAPD."*

EPA does not agree with DOE's position that these parameters are simply code control parameters and do not need to be controlled and documented in the PAPDB. DOE needs to place all of these parameters into the PA Parameter Database. The parameters in question are described below using language excerpted from the parameter report.

SPALLMOD:CHARLEN (characteristic length for tensile failure) This parameter is implemented in DRSPALL to mitigate zone-size dependence in tensile failure. The characteristic length is defined as the radial distance from the cavity wall into the solid over which the mean effective stress is evaluated. This distance must capture at least 5 computational zones. It was determined using zone size convergence studies and set at 2 cm for the CRA.

SPALLMOD:DRZTCK (DRZ thickness) The disturbed rock zone thickness in the spallings model is a constant designating the distance above the repository at which gas flow between the repository and the well bore is precluded due to effectively zero permeability. The value was set at 0.85m and the initial bit height above the repository (INITBAR-see next entry) was set at O.15m. SNL did not include this "material property" because operationally it has no impact on DRSPALL results when INITBAR = 0.15 as set for the CRA. However, this does not appear to be a run control parameter.

SPALLMOD:INlTBAR (initial height above the repository) This parameter sets the initial height of the drillbit above the top of the waste room at the start of the DRSPALL simulation. Since the rotational drilling rate is constant, this parameter sets the time from drilling start to repository penetration. It must allow enough time for startup transients in fluid pressure and velocity to stabilize before the bit penetrates the repository. Its value was established through observations of numerous test runs during code development.

SPALLMOD:EXITPLEN (exit pipe length) and EXITPDIA (exit pipe diameter) ,These parameters describe the length and diameter of the pipe that connects the well head at the top of the borehole annulus to the mud pit. The value for EXITPLEN is conservatively set to 0.00 for CRA calculations because any non-zero pipe length used would provide some resistance to mud low and raise well bottom pressure slightly which in turn would *reduce spallings. By setting EXlTPLEN to 0.00, the exit pipe functionality is not used in CRA calculations.*

SPALLMOD:GRCHBETA (Grochhceimer Beta) [7]This parameter is a constant in an empirical formula for gas flow not specific to the WET waste form and, therefore, SNL does not consider it suitable for inclusion in the PAPDB.

SPALLM0D:MAXPPRES (maximum allowed mud pump pressure) This parameter sets the maximum allowed pressure for the mud pump. A value of 27.5 Mpa was selected from literature from oilfield mud pump manufacturers. However, this parameter was not used in the CRA by the DRSPALL code because the drill pipe portion of the domain was shut off, and a constant mud flow rate condition was imposed at the bit nozzles.

SPALLMOD:REPOSTCK (repository thickness) This parameter permits the user to override the calculated repository height with an arbitrary value. It was set to 0.00 for all CRA runs, and DRSPALL calculates the height resulting from the sampled porosity (SPALLMOD:REPIPOR).

SPALLMOD:REPOTRAD (repository domain outer radius) This parameter defines the distance from the origin to the outer boundary of the repository domain. The default value is 19.2 m which is conservatively large for the spallings analyses.

SPALLMOD:STPDTIME (stop drilling time) This parameter stops the drilling at a specified time. Its default value is 1000 seconds. This value far exceeds the time necessary for the bit to pass through the repository height and thus has no effect on CRA calculations. Omitting these parameters from the PAPDB raises issues regarding parameter documentation (definition and derivation), traceability and control, and clarity in establishing precisely what values were used for each analysis supporting the CRA. These parameters were not defined nor discussed in the DRSPALL Parameter Justification Report (ERMS# 531057), leaving an apparent gap in documentation. Review of these parameters show that they are material properties and that they are appropriate for entry into the PAPDB.

DOE Response

DOE responded in detail to the itemized parameter questions raised by EPA in a recent memo to record (Lord and Rudeen, 2004). A summary table from the Lord and Rudeen (2004) memo is reproduced here as Table 1. Generally, the table provides traceability information for each of the parameters raised in G6. Parameter (property) name is given in the first column. The next column heading, “DRS File comment field” gives the exact text in the DRSPALL input control file that precedes the value declaration. The next column gives a Y (yes) or N (no) on whether the value has been added to the PA Parameter Database. Under the Traceability column, information is given on where the

[7] Note that this is a misspelling of the actual DRSPALL parameter, which is FRCHBETA (Forchheimer Beta). The current discussion was copied, as is, from the referenced memo.

value is defined within the PA framework (DRSPALL input file or PAPBD), and also where in the documentation justification is given.

Table 1. Summary Table of parameters addressed under Item G6

Property Name	DRS file[1] Comment Field	Entered into PAPDB	Traceability	
			Value defined	Justified
CHARLEN	Characteristic length	N	DRS file[1]	ERMS# 531397 ERMS# 534575 ERMS# 534287
DRZTCK	DRZ Thickness	Y	PAPDB[2]	ERMS# 533995 ERMS# 536134
INITBAR	Bit Above Repository (init.)	N	DRS file	ERMS# 536134
EXITPLEN	Exit pipe length	N	DRS file	ERMS# 533995
EXITPDIA	Exit pipe diameter	N	DRS file	ERMS# 536134
FRCHBETA	Forch Beta	Y	PAPDB	ERMS# 534287 ERMS# 535944
MAXPPRES	Max pump pressure	N	DRS file	ERMS# 536134
STPDTIME	Stop Drilling Time	N	DRS file	ERMS# 536134
REPOTRAD	Outer Radius	Y	PAPDB	ERMS# 534287 ERMS# 536134
REPOSTCK	Total Thickness	Y	PAPDB	ERMS# 534287 ERMS# 534575

1. DRS file: Input control file to DRSPALL, for example DRS_CRA1_R1_S1.DRS
2. PAPDB: PA Parameter Database. Note that these parameters were inserted into PAPDB in March, 2004.

References

Lord, D.L., Rudeen, D.K. SNL/DOE response to EPA's 2004 WIPP CRA review item G-6. Memo to Record dated July 22, 2004. ERMS# 536134. Carlsbad, NM: Sandia National Laboratories.

EPA Comment
G-6a Parameters and the Parameter Database

DOE must identify all parameters that are considered to be "control" parameters or have other designations (e.g., drilling parameter or model geometry parameter) that are used in PA, but which are not listed in the PAPD [PAPDB].

Response

The input files for each code contain all code control or configuration parameters that are not listed in the Performance Assessment Parameter Database (PAPDB). Code control or configuration parameters are used primarily for these purposes: grid cell dimensions and elevations; parameters setting initial conditions, (such as the quantity of Cellulosic Plastic and Rubber materials in each grid cell); numerical control, (such as the tolerance limit to determine convergence); model control, (such as the number of radionuclides to be transported); and output control, which determine the data to be written in code output files. The input files for codes run under OpenVMS 7.3-1 (all but MODFLOW and PEST) are archived in Software Configuration Management System (SCMS), as identified in the execution document (ERMS 530170) per SNL WIPP NP 9-1. The input files for codes run under Linux 6.1 (MODFLOW and PEST) are archived using Concurrent Version System (CVS), as documented in the analysis packages for these codes. Since these input files are archived, all input data for the CRA PA, including code control and configuration parameters, are always available for review by the EPA (see also response to C-23-8).

The User's Manual for each code describes the content of each code's input file. Table 1, below, lists the User's Manuals and associated ERMS numbers for codes used in the CRA. Table 2, below, lists the analysis packages and associated ERMS numbers for codes used in the CRA.

Table 1. User's Manuals for Codes Used in the CRA

Code and Version	User's Manual	ERMS#
BRAGFLO 5.00	Version 5.00	525702
PANEL 4.02	Version 4.02	526652
NUTS 2.05A	Version 2.05	246002
CUTTINGS_S 5.10	Version 1.00	532340
DRSPALL 1.00	Version 1.00	524780
PEST 5.51	Version 5.51	523967
MODFLOW-2K 1.6	Version 1.6	522194 & 522197
SECOTP2D 1.41A	Version 1.02	245734
CCDFGF 5.00A	Version 5.00	530471

Table 2. CRA Analysis Packages and ERMS numbers

Code and Purpose	CRA Analysis Package Title	ERMS #
BRAGFLO Salado Flow	Analysis Package for BRAGFLO, Compliance Recertification Application	530163
NUTS Salado Transport	Analysis Package for Salado Transport Calculations, Compliance Recertification Application	530164
MODFLOW/PEST Culebra Flow Fields	Analysis Report for AP-100 Task 1, Development and Application of Acceptance Criteria, for Culebra Transmissivity (T) Fields	531136
SECOTP2D Culebra Transport	Analysis Report for AP-100 Tasks 4-6, Extraction of Flow Field Values for SECOTP2D, Scaling of Flow Field for Climate Change, and Radionuclide Transport	532320
MODFLOW/PEST Culebra Flow Fields	Task 4 of AP – 88 Conditioning of Base T-Fields to transient heads	531124
MODFLOW Culebra Flow Fields	Task 5 of AP – 88 Evaluation of Mining Scenarios	531138
PANEL Radionuclide Mobilization	Analysis Package for PANEL, Compliance Recertification Application Revision 1	532349
BRAGFLO Direct Brine Releases	Analysis Package for Direct Brine Releases, Compliance Recertification Application	532344
CUTTINGS_S Cuttings and Cavings Releases	Analysis Package for Cuttings and Cavings, Compliance Recertification Application	533541
DRSPALL Calculation of Spall Volumes	Analysis Package for DRSPALL, Compliance Recertification Application, Part I, Calculation of Spall Volumes	532766
DRSPALL/CCDFGF Spall Releases	Analysis Package for DRSPALL, Compliance Recertification Application, Part II, CCDF Analysis	533986
CCDFGF Total Releases	Analysis Package for CCDFGF, Compliance Recertification Application	530169
Execution Document	Execution of Performance Assessment for the Compliance Recertification Application (CRA1), Revision 0	530170

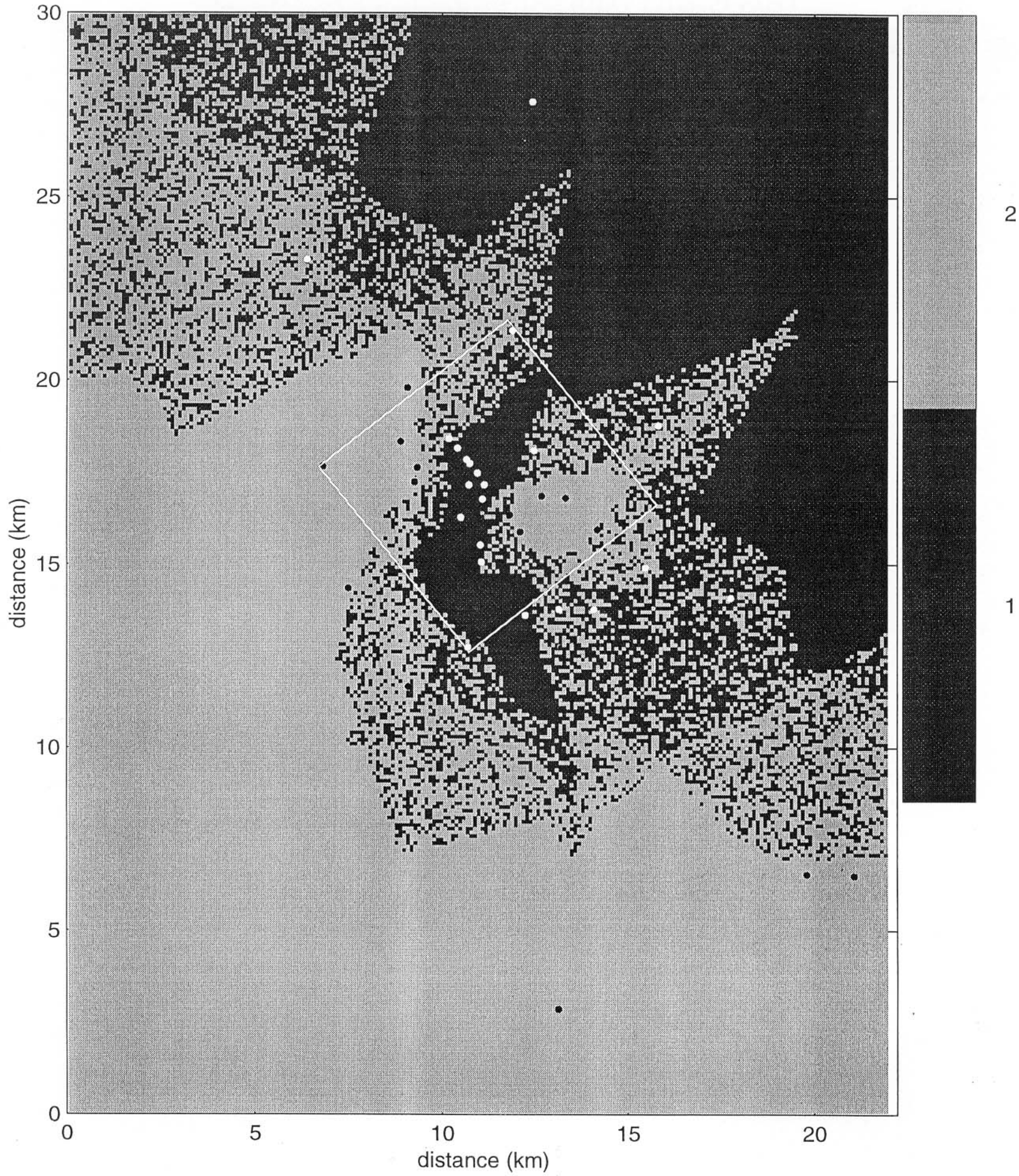
EPA Comment
G-7 Transmissivity Fields

Our preliminary review has raised questions about the technical justification for modeling a low transmissivity field for the Culebra in the southeastern part of the WIPP site. This approach contrasts greatly with the modeling approach used in the original Compliance Certification Application and could directly affect estimated ground water travel times. For these reasons, we anticipate that the use of such a model must be supported either by further analysis and justification of its effects (or lack thereof) on the performance assessment results, or by the presence of empirical data demonstrating the existence of such a low transmissivity field (i.e., monitoring data from a new well drilled in the vicinity).

DOE Response

While the conceptual model for the Culebra as a confined aquifer did not change from the CCA to the CRA-2004, the way in which the initial (pre-calibration) transmissivity (T) distribution within the Culebra was defined did change. The CCA relied almost entirely on geostatistical methods to define the distribution of T within the Culebra. The Culebra was divided into two zones (what we might call “high T” and “low T”) using Indicator Categorical Simulation and the known spatial distribution of wells showing high T and low T (DOE, 1996, Appendix TFIELD, Section TFIELD.3.1). Within the model domain, each cell was stochastically assigned to either the high-T or low-T zone in a sequential but spatially random manner. This assignment was made on the basis of the probability defined by the category(ies) of the three nearest already-categorized cells combined with the overall probability of high or low T defined by the relative proportions of high-T and low-T wells in the WIPP monitoring well network. This approach resulted in the “speckled” distribution of high (category 2) and low (category 1) T shown in CCA Figure TFIELD-17. T values were then assigned to each model cell in the two zones based on variograms of T values measured in each of those zones. Because the CCA T field calibration process started with approximately equal mixtures of high- and low-T categories south of the WIPP site boundary, it had the capability of creating throughgoing high-T features relatively easily. Such a high-T zone was suggested by LaVenue et al. (1988) as being necessary to achieve good calibration to steady-state heads in the southern WIPP region.

The development of the initial (pre-calibration) Culebra T distribution for the CRA-2004 is discussed in Sections TFIELD-3.0 and 4.0 of Attachment TFIELD to Appendix PA of DOE (2004). The Culebra was first divided into four T zones on the basis of geologic factors delineated on maps (Powers 2002a,b; 2003): dissolution of the upper Salado (“very high T”), no halite in the Rustler above the Culebra (“high T” OR “low T”), halite present above the Culebra but not immediately underneath (“low T”), and halite both immediately underneath and above the Culebra (“very low T”). Within these zones, T’s were assigned on the basis of a correlation defined by Holt and Yarbrough (2002) relating T to the depth to the Culebra. In the zone where no halite is present above the Culebra



Note: Black dots indicate boreholes that are associated with Category 1; white dots are boreholes associated with Category 2.

Figure TFIELD-17. Example of Categorical Simulation over a Model Domain using Two Categories

T may be either high or low, a high-T indicator variogram was constructed, and the variogram parameters were used in conditional indicator simulations of high-T subzones. Transmissivities within the high- and low-T subzones were then assigned using the correlation discussed above.

The assignment of T in the region south of the eastern portion of the southern WIPP site boundary (south of H-11) was strongly affected by wells P-17 and H-17. The high-T indicator variogram had a correlation length of 1790 m. Because P-17 and H-17 both have low Culebra T and are only 1793 m apart, their combined influence on the region between them is much greater than the influence of the nearest high-T well (H-11), over 1600 m north. Although the probability of placing a high-T subzone between H-17 and P-17 was not zero during the modeling process, it was low enough that high T did not occur there in any of the 150 T fields that were later calibrated. Rather than go beyond the data and "hardwire" a high-T zone between H-17 and P-17 to ensure similarity with the CCA T fields, the geostatistical model based on the available data was honored, resulting in low T's.

The EPA requested "… empirical data demonstrating the existence of such a low transmissivity field …". The following discussion explains how recent water-level data support the existence of low transmissivity. LaVenue et al. (1988) suggested that a high-T zone extending south from H-11 was necessary to explain relatively high hydraulic gradients from DOE-1 to H-11 to H-17/P-17. For the CCA, the gradients in this area reflected the best estimates of undisturbed heads that could be inferred from decades-long hydrographs for the individual wells. These inferred heads presupposed that except for perturbations introduced by WIPP shaft sinking, shaft leakage, and hydraulic testing, heads in the Culebra were at steady state and a meaningful gradient could be calculated using heads from different years. Rising water levels observed since the CCA cast doubt on the assumption of steady-state conditions. For the CRA-2004, heads from only late 2000 were used to define equilibrium-state conditions (Beauheim, 2002). The gradients calculated from these temporally equivalent head measurements in the southeastern portion of the WIPP site are significantly lower than the gradients defined for the CCA (Table 1). Using the recent more reliable and more defensible estimates of gradients, model calibration does not require creation of a throughgoing high-T zone to the south.

Table 1. Comparison of CCA and CRA-2004 gradients in southeastern portion of WIPP site.

Well	UTM X (m) (NAD27)[1]	UTM Y (m) (NAD27)[1]	CCA Freshwater Head (m amsl)[2]	CCA Gradient from DOE-1 (m/km)	CRA (2000) Freshwater Head (m amsl)[2]	CRA Gradient from DOE-1 (m/km)
DOE-1	615203	3580333	914.3	--	916.55	--
H-11b4	615301	3579131	912.4	-1.5755	915.47	-0.8942
H-17	615718	3577513	911.0	-1.1512	915.37	-0.4104
P-17	613926	3577466	909.3	-1.5931	915.20	-0.4307

[1] Gonzales (1989)
[2] Beauheim (2002)

In summary, although transmissivities in the region of H-17 and P-17 are lower in the CRA-2004 T fields than in the CCA T fields, they are fully consistent with the actual T and head data in that region. The lower T's in the CRA-2004 T fields in this region appear to be responsible for the longer off-site travel times relative to the CCA T fields. However, in neither the CCA PA nor the CRA-2004 PA is radionuclide release through the Culebra a significant contributor to total releases to the accessible environment. Therefore, the longer travel times in the CRA-2004 T fields do not affect PA results.

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EPA Comment
G-8-1 DRSPALL Parameter Sensitivity Study Needed

Two sensitivity studies are needed to clearly explain implementation of the DRSPALL model. These involve sensitivity to the drilling damage zone (DDZ) thickness, and sensitivity to the initial stress on the waste.

1. Sensitivity to DDZ Thickness
The existence of a DDZ is conceptually valid, but the constant of 16 cm thickness of that zone used in DRSPALL was selected by SNL (as approximating the drill bit radius) without detailed justification. The spallings peer panel stated that he actual DDZ thickness could be considerably less than 16 cm. A sensitivity study was performed by SNL that simultaneously reduced the DDZ thickness from 16 to 2 cm (a factor of 8) and reduced the DDZ permeability from 1.0E-14 to 1.0E-15m^2 *(a factor of 10). The resulting lack of sensitivity demonstrated in that analysis may be because these two changes had offsetting influences. That is, a smaller DDZ would tend to increase repository gas pressure bleedoff, while a smaller DDZ permeability would tend to decrease bleedoff. Looking at this mathematically when the distance from the borehole to the repository is less than the DDZ thickness, the gas mass flow rate through the DDZ becomes a function of the ratio of DDZ permeability to DDZ thickness (DRSPALL Design Document, ERMS 529878, Equations 4.2.1 and 4.2.2). Thus, simultaneously decreasing both parameters likely has less impact on repository bleedoff than if only on parameter had been changed.*

A sensitivity study should be performed where only the DDZ thickness is changed. The study should be conducted in the following way:

- *Select a DRSPALL parameter set that yields a strong spallings release using the current standard model.*
- *Hold all parameters constant except the DDZ thickness*
- *Run 5 cases with DDZ thickness set to 1, 2, 4, 8, and 16 cm.*
- *Compare repository pressure history, tensile failure volumes, spallings release volumes, and other pertinent performance indicators.*

DOE Response

An analysis was run that met the description outlined by EPA above to determine the sensitivity of DDZ thickness. The details of this analysis were presented both in an oral exchange with EPA in Carlsbad, NM on May 24, 2004, and in Lord and Rudeen, 2004.

The following conclusions were drawn from this analysis.

- The single CRA vector (V016) calculations with L_{DDZ} = 1, 2, 4, 8 and 16 cm showed no sensitivity to DDZ thickness for a single set of model parameters.

- The fifty-vector sensitivity study which included a user defined L_{DDZ} cumulative distribution showed very minor spallings volume sensitivity to DDZ thickness over the range of CRA sampled parameters.
- The sensitivity study for the Conceptual Model Peer Review showed no sensitivity to DDZ permeability.
- The Peer Review study also implied no sensitivity to DDZ thickness because the combination of fixed DDZ thickness and the permeability range spanned the range of effective permeability implied by the DDZ thicknesses requested by the EPA.

The results of this study demonstrates that the DRSPALL model exhibits no measurable sensitivity to the DDZ length parameter over the range of values (1 to 16 cm) deemed reasonable for this parameter.

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EPA Comment
G9a[8] Probability of Significant Microbial Degradation of CPR

DOE has continued to employ a conceptual model developed by Wang and Brush (1996a and 1996b) that assumes a 0.5 probability of significant microbial degradation of CPR occurring in the repository. This probability estimate was based on limited data, at the time of the CCA, regarding whether microbes capable of consuming CPR will be present and active in the repository, whether sufficient electron acceptors will be present and available, and whether sufficient nutrients will be present and available. However, experimental evidence developed since the time of the initial CCA (e.g., Francis and Gillow, 2000; Gillow and Francis, 2003) has indicated viable microorganisms capable of degrading CPR are likely to be present in the repository (Appendix BARRIERS-2.5.2). In addition, sulfate present in brine and in minerals in the Salado Formation surrounding the repository are likely to be available for reaction, so sufficient electron acceptors may be expected to be present. Current inventory estimates also include phosphate in the waste, which could be a source of nutrients for microbial degradation (Leigh and Sparks-Roybal, 2003). Please clarify how DOE considered this information and whether it will increase the probability of significant microbial degradation of CPR in the repository, and provide documentation of the analysis.

In summary, DOE needs to evaluate whether the assumed probability of significant microbial degradation of CPR in the repository should be increased given the experimental data developed since the CCA and the current inventory estimates.

DOE Response

This response summarizes an analysis of the uncertainties associated with significant microbial degradation of CPR and discusses how the uncertainties are considered in the choice of the probability distribution for significant microbial activity.

Uncertainties Associated with Microbial CPR Degradation

The implications of any available new (post-CCA) information on the sources of the uncertainty pertaining to the probability of significant microbial activity and significant microbial gas generation in the WIPP is discussed by Brush (2004). This analysis concludes that there is still significant uncertainty as to whether significant microbial activity and significant microbial gas generation will occur in the WIPP, and that there is no technical justification for increasing the probability of significant microbial activity beyond that used in the CCA.

Table 1, reproduced from Brush (2004), summarizes the sources of uncertainty pertaining to significant microbial activity and the influence of new information, if any, on the probability of significant microbial degradation of CPR. Of the seven areas of uncertainty identified, new information appears to increase the probability of significant

[8] EPA's original comment G-9 was answered in two parts, now labeled as G-9a and G-9b.

microbial activity in only one case. In three cases, new information decreases the likelihood of microbial activity. In the other cases, no significant new information is available.

In addition, it should be noted that the laboratory study of microbial gas generation carried out by Francis and Gillow at Brookhaven National Laboratory (Francis and Gillow 2000, Gillow and Francis 2003) was not designed to quantify the probability of significant microbial activity in the WIPP. These studies were designed to quantify the rates of microbial gas production under possible WIPP conditions *in the event of significant microbial activity* (Brush 2004).

The transport of naturally occurring sulfate (SO_4^{2-}) into WIPP disposal rooms would influence the metabolic pathway (i.e., sulfate reduction) that microbial communities could utilize to degrade CPR in the event that significant microbial activity occurs. However, there is no reason to conclude that naturally occurring SO_4^{2-} would increase the *probability* of microbial activity (Brush 2004).

The estimated amount of phosphate (PO_4^{3-}) contained in TRU waste to be emplaced in the WIPP has increased since the CCA. However, there continues to be significant uncertainty regarding the bioavailability of any phosphate emplaced (Brush 2004).

Choice of Probability Distribution Model

The presence of significant microbial action in the repository is modeled as a Bernoulli random variable, where a value of zero indicates no significant microbial action, and a value of 1 indicates significant microbial action. The Bernoulli random variable is specified by a single parameter *p*, which is the probability that significant microbial action takes place. In the 1996 CCA and the 2004 CRA, *p* took the value of 0.5 (U.S. DOE 1996, 2004). This choice is consistent with the principle of maximum entropy (Jaynes 1979), which states that the probability distribution that uniquely represents or encodes our state of information is the one that maximizes the uncertainty while remaining consistent with our information. Uncertainty in the probability distribution of a discrete random variable is typically quantified by the Shannon information entropy, $H = -k\sum p_i \ln p_i$, where p_i are the probabilities assigned to the discrete states of the system. In the case of determining the parameter *p*, or the probability of significant microbial action in the repository, the uncertainties discussed above indicate that there is essentially no relevant epistemic information that can be used to estimate *p*. All that is known is the two possible choices: that microbial action can occur or that it cannot occur. In this case, $H = -k\left[p \ln p + (1-p)\ln(1-p) \right]$, so the value of the parameter *p* that maximizes uncertainty is 0.5. Following the same reasoning, the consumption by microbes of cellulosics only or of cellulosics, plastics and rubbers, given that significant microbial action occurs, was also modeled as a Bernoulli random variable. Again, the lack of any epistemic information to estimate the probability of consumption of cellulosics only, combined with the principle of maximum entropy, led to the assignment of a probability of 0.5 to each outcome.

Table 1. Net Effects of New (Post-CCA) Information on the Probability of Significant Microbial Activity and Significant Gas Generation in the WIPP (Brush 2004).

Source of Uncertainty	Change[1]	Remarks
1. Presence of viable microbes at the time of closure	↑	The presence of viable microbes in the WIPP was not considered to be a significant source of the uncertainty at the time of the CCA. Recent results imply that viable fermenters and methanogens are present in the underground workings.
2. Sterilization of the waste and other contents of the repository	No changes	The DOE position on sterilization has not changed since the CCA. However, MgO could inhibit or even preclude microbial activity, and thus reduce the probability of significant microbial activity.
3. Survival of microbes for a significant fraction of the 10,000-year regulatory period	↓	Microbial gas production has ceased or nearly ceased after about 0.1% of the 10,000-year regulatory period. Thus, significant microbial activity appears less likely than it did at the time of the CCA, when gas production was still occurring. Furthermore, MgO will likely decrease the probability of long-term microbial survival because of: (1) its inhibitory or even biocidal properties and (2) its ability to maintain dry conditions.
4. Presence of sufficient H_2O	↓	Implementation of the Option D panel-closure system in PA has decreased the H_2O content of the repository prior to human intrusion, decreased the probability of significant microbial activity prior to human intrusion, and decreased the probability of survival of viable microbes thereafter. Incorporation of MgO hydration and more realistic hydrologic properties for the DRZ in PA would further decrease the amount of H_2O in the repository prior to human intrusion and the likelihood of survival of viable microbes.
5. Presence of sufficient biodegradable substrate	↓	Microbial gas production has ceased or nearly ceased after consumption of just 3-4% of the papers initially present. It thus appears less likely that microbes would consume all cellulosic materials in the repository than it did at time of the CCA, when microbial activity was still occurring.
6. Presence and availability of sufficient electron acceptors	No changes	No significant new information pertaining to this issue has been identified since the CCA.
7. Presence and availability of sufficient nutrients	No changes	No significant new information pertaining to this issue has been identified since the CCA.

1. Indicates whether new (post-CCA) information pertaining to each issue increases (↑), decreases (↓), or has no net effect (no changes) on the probability of significant microbial activity and concomitant gas production.

The principle of maximum entropy has been used in WIPP PA since 1990 to assign distributions to uncertain parameters in a consistent, unbiased manner (Tierney 1990, 1996a). The restriction of cumulative distribution functions for uncertain parameters to a few forms, listed in Tierney (1996a), reflects the application of this principle, and ensures that the uncertainty analysis includes the greatest possible range of uncertainty consistent with the available knowledge of the repository system.

For ease of computation, the two uncertain Bernoulli variables (for the presence of significant microbial action, and for the consumption of cellulosics only given that microbial action occurs) were combined into a single parameter (WAS_AREA:PROBDEG) with a delta probability distribution function (Tierney 1996b). Let P_1 represent the probability of occurrence of significant microbial CPR degradation and P_2 represent the probability of occurrence of plastics and rubber biodegradation in the event of significant microbial cellulosics degradation. If P_1 and P_2 are both 0.5, then the logic diagram in Figure 1 shows that they can be combined into a delta distribution with three discrete outcomes.

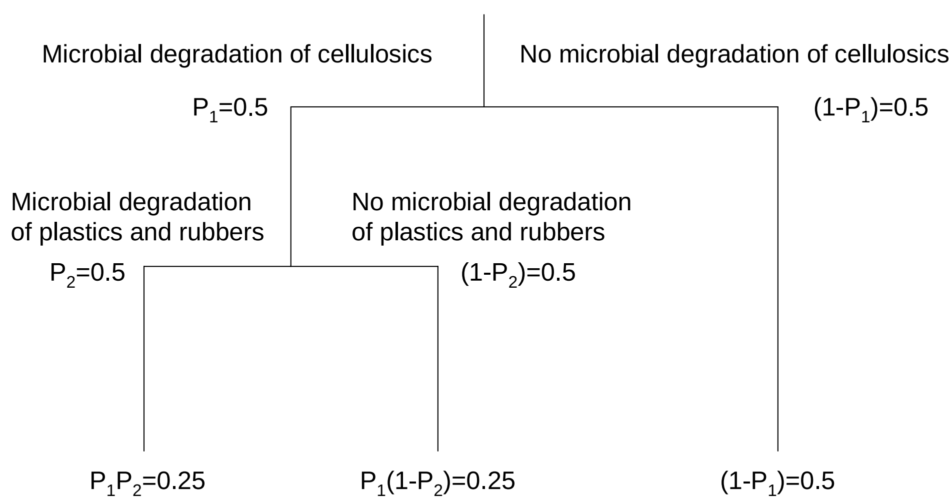

Figure 1. Delta Probability Distribution for Microbial Degradation of CPR (WAS_AREA:PROBDEG)

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EPA Comment
G-9b

… DOE also needs to assess the potential impact of a higher probability of significant microbial populations existing in the repository on microbial colloid formation and the mobilization of actinides, as well as on microbial gas generation rates.

DOE Response

The potential impact of changes in the probability of significant microbial degradation of CPR on gas generation, actinide mobilization, and releases can be assessed using results from the 2004 CRA Performance Assessment (CRA-PA). The methodology can be outlined as follows:

- Segregate CRA-PA vectors into biological vectors (BV's) and non-biological vectors (NBV's).
- Compare BV and NBV gas volumes and repository pressures using BRAGFLO simulation results.
- Compare BV and NBV actinide mobilization using results from PANEL concentration (PANEL-CON) runs.
- Compare BV and NBV Culebra releases, direct brine releases, spall releases, and total releases using results from CCDFGF runs.

Vectors from Replicate R1 of the CRA-PA are shown in Table 1, sorted by the value of WAS_AREA:PROBDEG, the variable that acts as a switch for microbial activity. PROBDEG is modeled using a delta distribution. In every replicate, 50 vectors will have PROBDEG=0 (no microbial activity), 25 vectors will have PROBDEG=1 (microbial degradation of cellulosics only), and 25 vectors will have PROBDEG=2 (microbial degradation of cellulosics and plastics). NBV's correspond to PROBDEG = 0, while BV's correspond to PROBDEG > 0.

Table 1. Segregation of CRA Vectors Based on Microbial Activity

Vector	PROBDEG	Vector	PROBDEG	Vector	PROBDEG	Vector	PROBDEG
1	0	57	0	5	1	2	2
3	0	58	0	6	1	4	2
7	0	59	0	9	1	10	2
8	0	60	0	12	1	14	2
11	0	61	0	16	1	15	2
13	0	62	0	17	1	18	2
19	0	63	0	23	1	22	2
20	0	65	0	28	1	26	2
21	0	66	0	34	1	27	2
24	0	69	0	39	1	29	2
25	0	70	0	42	1	30	2
31	0	71	0	43	1	40	2
32	0	74	0	46	1	41	2
33	0	75	0	47	1	45	2
35	0	80	0	52	1	51	2
36	0	81	0	53	1	64	2
37	0	83	0	73	1	67	2
38	0	84	0	77	1	68	2
44	0	88	0	78	1	72	2
48	0	92	0	85	1	76	2
49	0	94	0	86	1	79	2
50	0	95	0	87	1	82	2
54	0	96	0	91	1	89	2
55	0	97	0	99	1	90	2
56	0	98	0	100	1	93	2

Gas Generation and Repository Pressure

Gas generation and repository pressures are calculated using the BRAGFLO code. BRAGFLO CRA-PA results for replicate R1, scenario S1 (undisturbed) are shown in Figures 1 and 2, respectively. Cumulative gas generation is given by the ALGEBRA variable GASMOL_W. Waste panel pressure is reported in the ALGEBRA variable WAS_PRES. The data presented in these plots have been extracted from the ALGEBRA output files ALG2_CRA1_R1_S1_V*vvv*.CDB, where $vvv \in [001,100]$. All of the files referenced are stored in CMS library CRA1_BFR1S1 on the WIPP PA Alpha Cluster.

As one would expect, there are considerable differences between the NBV's and BV's in terms of the amount of gas produced and the corresponding pressures generated. The gas generation rate at early times is larger for BV's, as is the maximum cumulative gas generation over the 10,000-year regulatory period. Visual inspection shows the maximum cumulative gas generation for the BV's is approximately 1.5 times higher than that of the NBV's. The range in the amount of gas generated for the BV's is approximately 1.4 times that of the NBV's. Results for repository pressure show trends which are very similar to those discussed for gas generation. Results for the disturbed scenarios are not shown since they are similar to those shown for the undisturbed case.

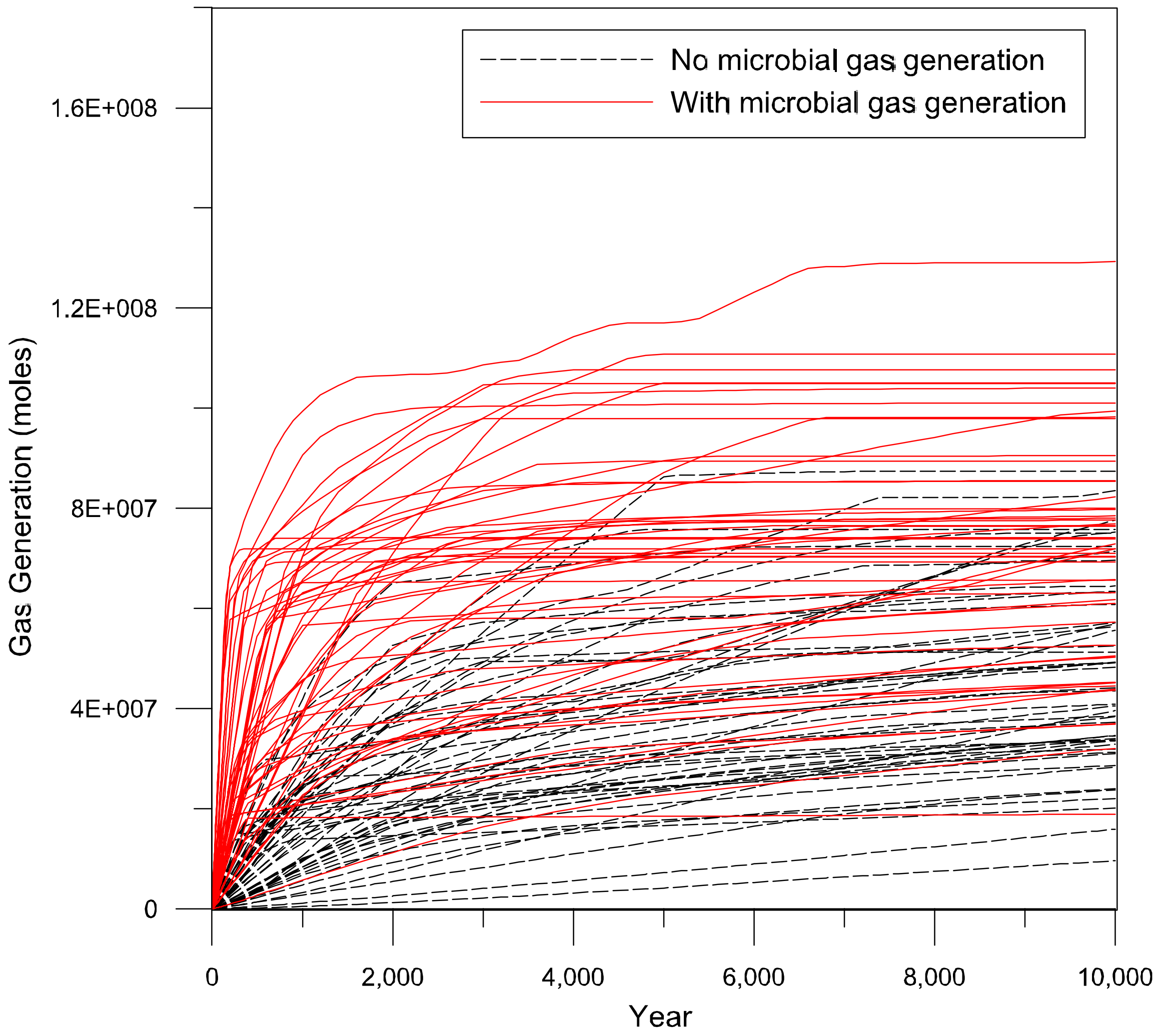

Figure 1. Total Gas Generation in Repository: Replicate R1, Scenario S1

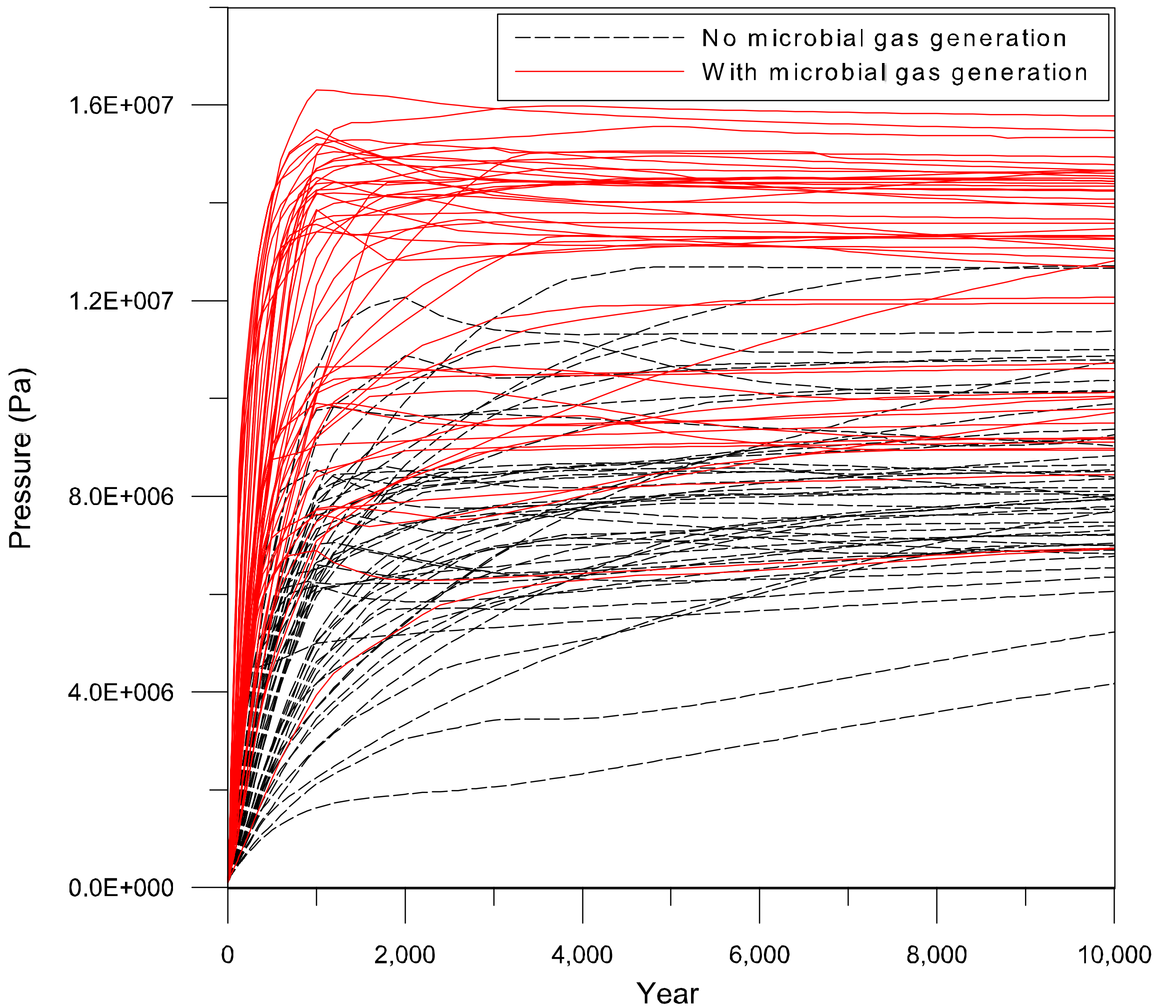

Figure 2. Repository Pressure: Replicate R1, Scenario S1

Actinide Mobilization

Microbial activity can increase actinide mobilization due to the formation of microbial colloids. Actinide mobilization is computed using the PANEL code. Total radionuclide concentration in EPA units obtained from PANEL concentration (PANEL-CON) runs for CRA-PA, Replicate R1, Scenarios S1 and S3, are shown in Figures 3 and 4, respectively. These plots show the PANEL variable CNETOTAL, which includes contributions from radionuclides in solution, as well as humic, microbial, intrinsic, and mineral fragment colloids. The plotted data has been extracted from the PANEL output files PANEL_CON_CRA1_R1_S*s*_V*vvv*.CDB, where $s = 1,3$ and $vvv \in [001,100]$. These files are stored in CMS library CRA1_PANEL on the WIPP PA Alpha Cluster. CNETOTAL

Scenario S1 results assume the repository brine composition is represented by Salado brine, while Scenario S3 assumes that Castile brine best represents repository brine composition. Salado brine results presented in Figure 3 show that the range of concentrations for BV's and NBV's are very similar, although the central tendency of the BV's is somewhat higher. Castile brine results presented in Figure 4 display similar trends, but the maximum concentrations for the BV's are somewhat higher than for NBV's. This could potentially influence Culebra and direct brine releases because these release modes are associated with intrusions. (Castile results for actinide mobilization are used to compute releases for scenarios that include E1 intrusions).

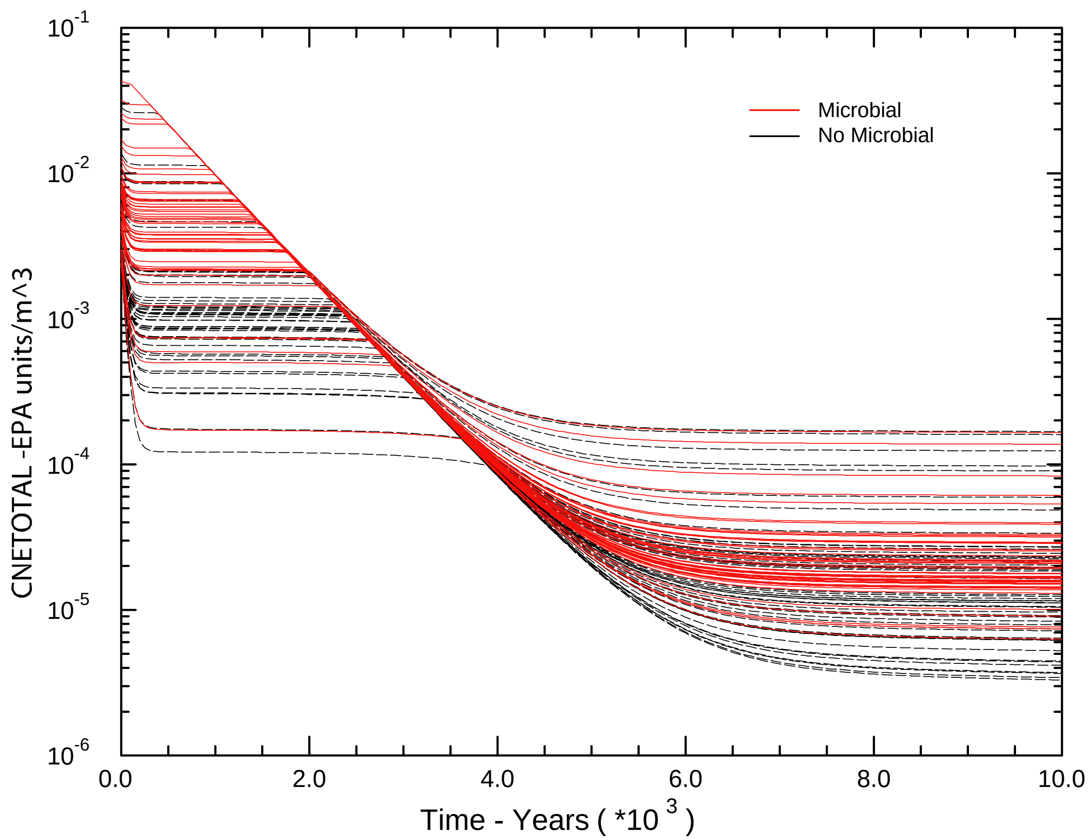

Figure 3. Total Radionuclide Concentration in Panel – Replicate R1, Scenario S1 (Salado Brine)

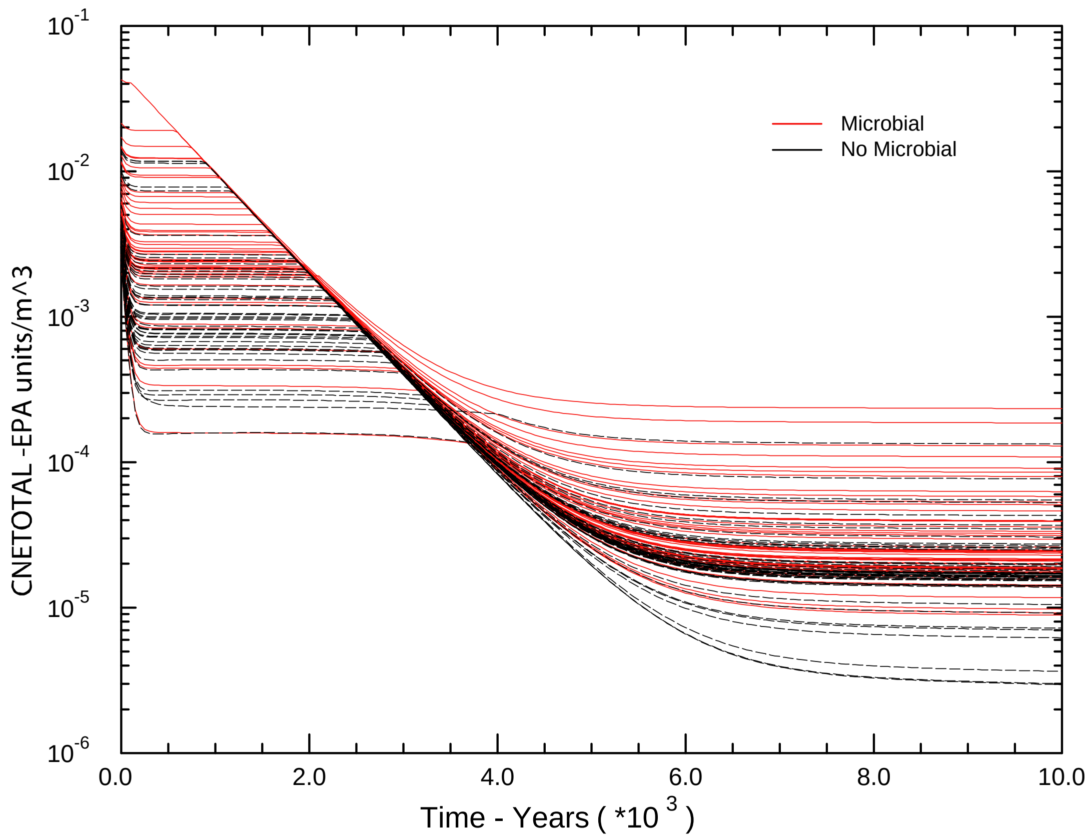

Figure 4. Total Radionuclide Concentration in Panel – Replicate R1, Scenario S3 (Castile Brine)

Releases

The probability of radionuclide releases to the accessible environment are computed by the CCDFGF code, which assembles results obtained from calculations performed with a number of different process models (e.g., BRAGFLO, PANEL, NUTS, SECOTP2D, CUTTINGS_S, and EPAUNI) to produce complementary cumulative distribution functions (CCDF's). CCDFGF uses a Monte Carlo procedure to evaluate stochastic uncertainty about future states of the repository. The potential impact on releases of changing the probability of significant microbial activity can be assessed by the same method used for gas generation, repository pressure and actinide mobilization.

CCDFGF results from CRA-PA, Replicate R1, for Culebra releases, direct brine releases, spall releases and total releases, segregated into NBV's and BV's are shown in Figures 5 through 8. The data for these plots have been extracted from the CCDFGF output file CCGF_CRA1_R1.OUT, which is stored in CMS library CRA1_CCGF on the WIPP PA Alpha Cluster.

Culebra Releases

One might expect releases from the Culebra to be sensitive to microbial activity because of increased radionuclide mobilization (in Castile brines) due to the presence of microbial colloids. Microbial colloids are removed from transport through filtration. Attenuation is so effective that associated actinides are assumed to be retained within the disposal system and are not transported. However PA conservatively assumes that the actinides are available for transport as simple solutes. However, matrix diffusion and sorption in the Culebra retard transport of solutes such that the probability of significant releases from the Culebra is very low and does not appear to be sensitive to microbial activity. Note that Figure 5 displays only a few curves because very few vectors show any release from the Culebra.

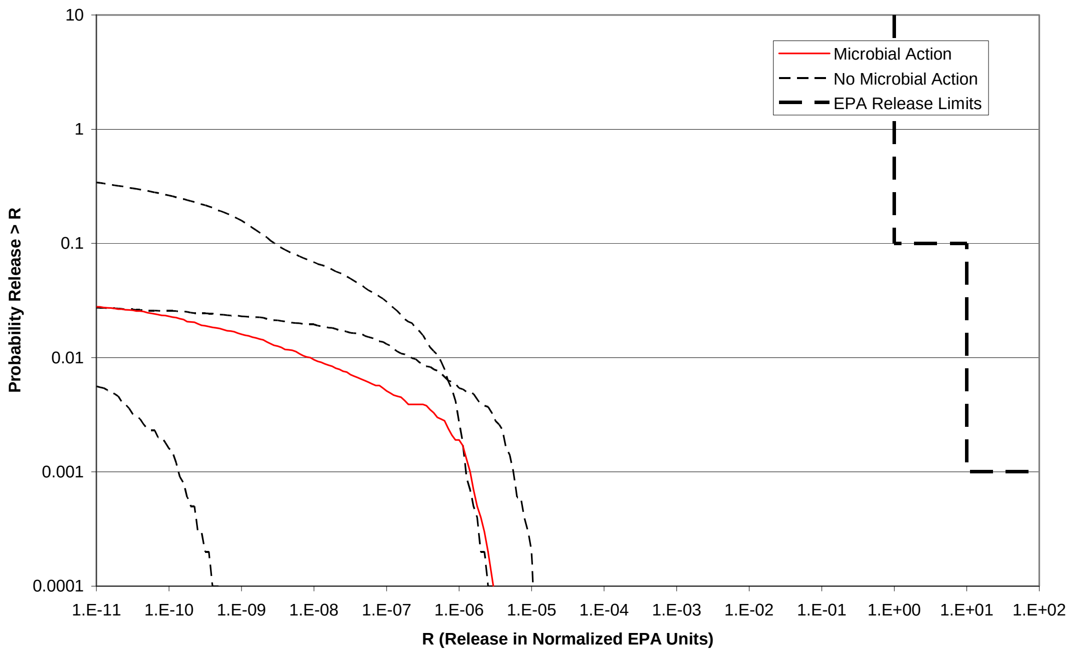

Figure 5. Releases from the Culebra: Replicate R1

Direct Brine Releases

One might expect direct brine releases to be somewhat sensitive to microbial activity because of increased radionuclide mobilization (in Castile brines), gas generation, and repository pressures. However, CCDFGF results indicate that releases for the BV's are only slightly larger than for the NBV's. Direct brine releases also depend upon other factors such as Castile brine reservoir volume and pressure, which may have a greater influence than the consequences of microbial activity. Figure 6 illustrates direct brine releases.

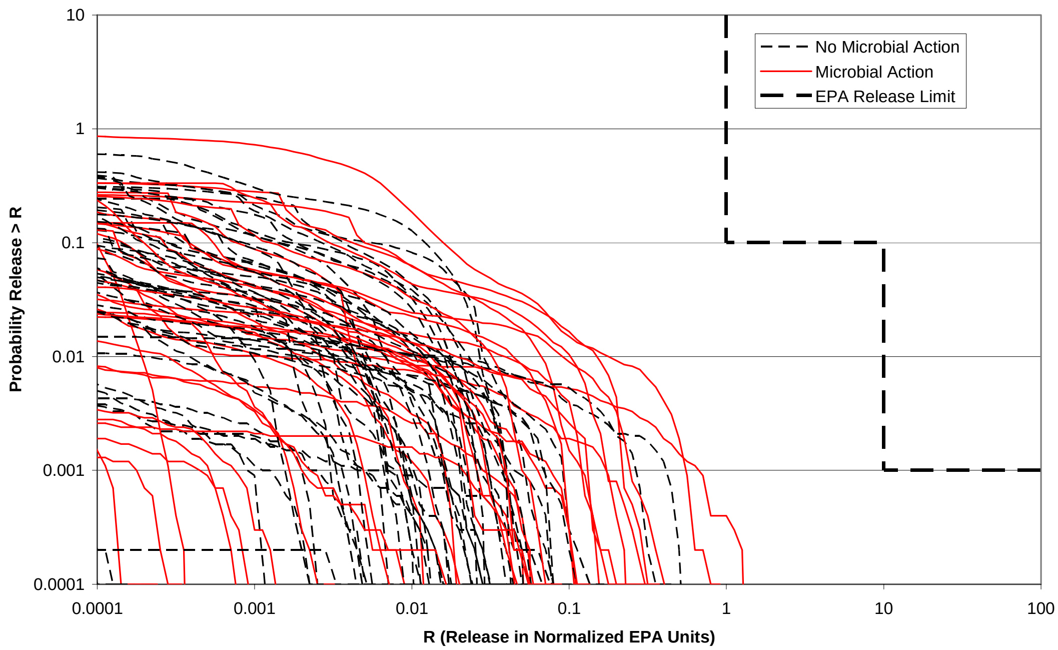

Figure 6. Direct Brine Releases: Replicate R1

Spall Releases

Because microbial activity increases gas generation and repository pressures, one would expect spall releases to be sensitive to microbial activity. The CCDFGF results confirm this expectation. The maximum releases for the BV's is approximately an order of magnitude larger than that for the NBV's (see Figure 7).

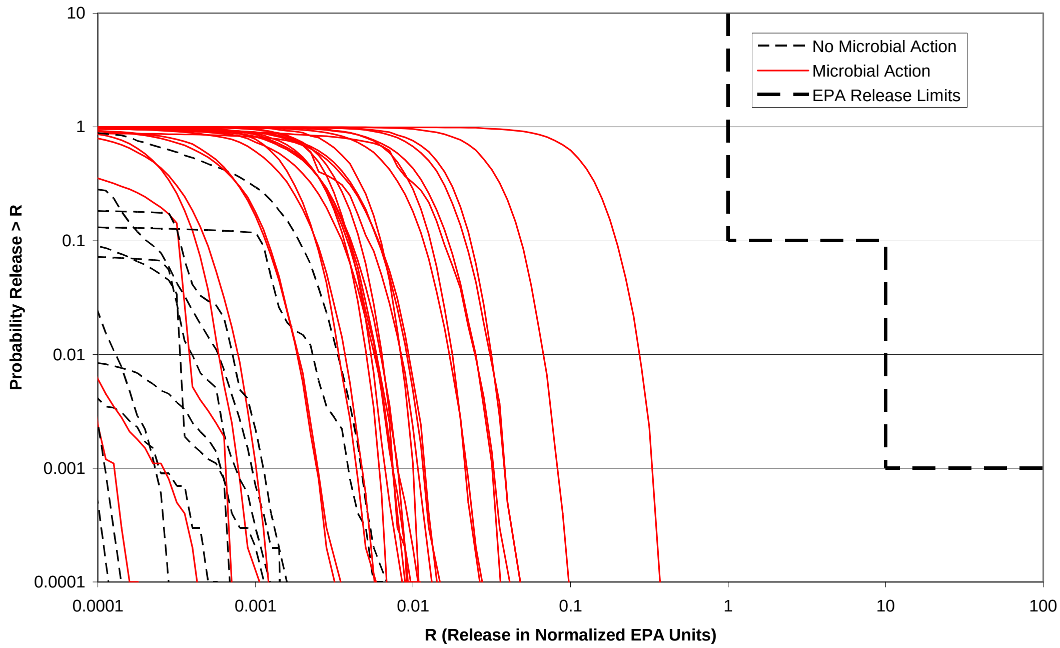

Figure 7. Spall Releases: Replicate R1

Total Releases

One can observe very little difference between the BV's and NBV's in the CCDFGF results for total releases. This is not surprising given that total releases are typically dominated by cavings and cuttings which should not be significantly affected by microbial activity (see Figure 8).

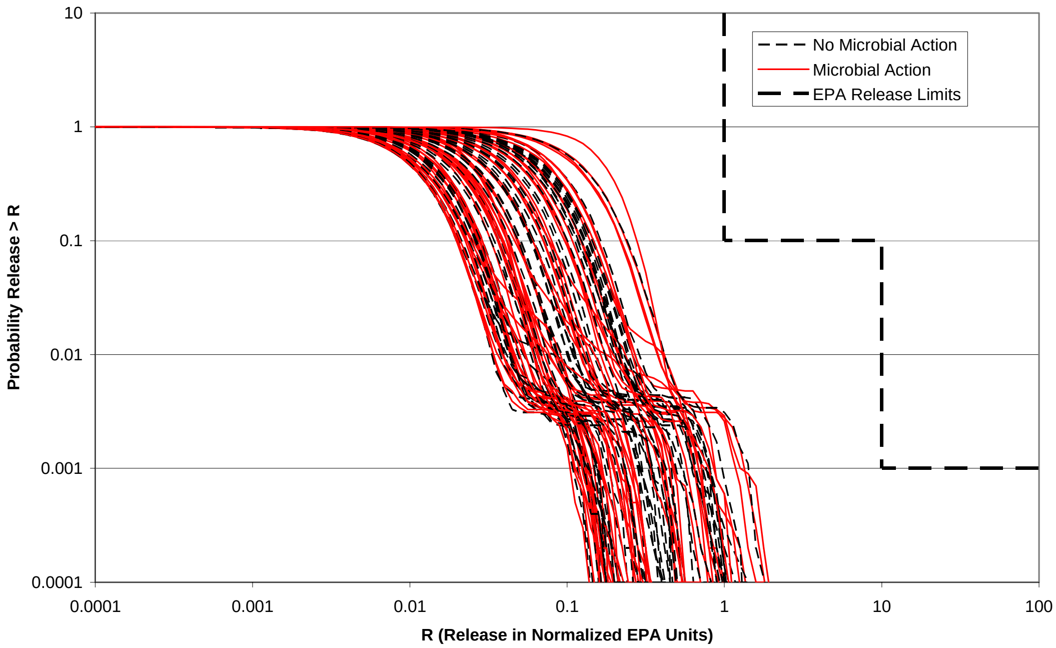

Figure 8. Total Releases: Replicate R1

Conclusions

The potential impact of increased probability of significant microbial activity has been assessed by segregating the results of the 2004 CRA results into biological and non-biological vectors. The largest potential impacts are seen in gas generation, repository pressure, and spall releases. Potential impacts to radionuclide mobilization and direct brine releases are very modest. Potential impact on Culebra releases is negligible. Because total releases are dominated by cavings and cuttings, the potential impact to total releases are quite small.

EPA Comment
C-23-2 Ch 6, pg 6-29, lines 10 to 12

The CRA states that, 'The QA procedures associated with this review process are identified in Section 5.4.2. . . ." However, the procedures do not appear in the location cited. DOE must provide documentation of the QA procedures or identify the correct location in the application where they are described

DOE Response

The reference to CRA Section 5.4.2 is correct. The reference to Section 5.4.2 is to the DOE QAPD which is the upper tier QA document that governs all QA processes. In addition, the remainder of the sentence in this comment was not quoted and points the reader to Appendix PA, Attachment PAR, (Section 2) which describes the parameter process. However, the section in Attachment PAR was not correctly updated for the CRA and describes the process and terms used in the CCA. Attachment PAR was revised to update the text. Specifically, the parameter process has not changed, only the way the process is implemented. New procedures are used, replacing the QAPs with NP procedures and forms. This change was first reported to EPA in the 1999 40 CFR 194. 4(b)(4) report (DOE 1999). Enclosure 3 contains the corrected Attachment PAR.

References

Department of Energy (DOE) 1999, Letter from Iñes Triay, Manager, Carlsbad Area Office to Stephen Page, Director, Office of Radiation and Indoor Air, Table 1: Changes in WIPP Conditions or Activities Reportable under 40 CFR 194.4(b)(4). November 10, 1999. EPA Docket A98-49, IIB-2-6.

EPA Comment
C-23-4 Ch 6, pg 6-83, lines 20 to 26

Please explain the justification for using significantly different properties for the experimental and operations area. That is, DOE must explain why 18% porosity and 10^{-11} m^2 permeability are used in modeling for the characteristics of the experimental and operations area. When DOE presented its case for the final disposition of Panel One, DOE stated that the unfilled, empty, room would achieve a final state comparable to intact salt. Intact salt has a much lower porosity and permeability than what is being modeled for the final state of the experimental and operations area. This parameter inconsistency may affect the compliance modeling.

DOE Response

For the CRA, DOE has continued to use the same material property parameters to represent the experimental and operations areas that it used for the CCA. As outlined below, these parameter values were justified for the CCA, and DOE has determined that the justification remains valid for the CRA PA. A review and clarification of the DOE position on this subject is given below. EPA identifies an apparent inconsistency between a DOE statement made in its case for the final disposition of Panel One (DOE, 2001) and the long-term properties assigned to the experimental and operations areas in PA; this inconsistency is also addressed.

To remain consistent with previous, peer-reviewed conceptual models for the repository and for the Salado, performance assessment assigns constant porosity and permeability to the open operations and experimental areas. As was done for the CCA, the constant values used in the CRA are appropriate for futures in which significant gas generation, both by microbial action and corrosion, occurs early in the repository's future. These values are conservative for all other futures in which gas generation is slower or of lesser extent.

Justification for Assigning Constant Porosity and Permeability in the Experimental and Operations Areas in the CCA PA

During the development of the CCA PA, DOE investigated whether it was important to include a dynamic model of creep closure in the experimental and operations area or whether it was sufficient to model these areas as "pre-closed" and assign them constant properties that would tend to maximize the potential for releases. For the DR-3 analysis (Vaughn 1996), DOE ran two sets of BRAGFLO calculations: one in which a porosity surface representing the closure of an empty room was applied to the experimental and operations areas, and one in which the porosity and permeability were held constant. The comparison between these two sets of calculations demonstrated that performance was quite insensitive to whether dynamic closure of these areas was included in the calculations or not (Vaughn 1996). Because of the lack of sensitivity to the inclusion of dynamic closure in the experimental and operations areas, DOE determined that constant properties representing the conditions in these areas after creep closure had reached near equilibrium state was adequate for the purposes of the long-term CCA PA calculations. Using these constant properties is a conservative method for improving computational efficiency.

Constant values for porosity and permeability in the experimental and operations areas are based on the concept that it is conservative in terms of releases if these areas have high permeability and low porosity. High permeability ensures that these regions do not impede brine and gas flow that might contribute to a borehole release and low porosity minimizes the storage capacity for gas in these regions, thus resulting in higher pressures in the waste-filled regions of the repository. For the CCA PA, these regions were assigned a permeability of 10^{-11} m^2. This value was chosen to be greater than the waste permeability and high enough not to impede brine flow due to the one-degree dip. A porosity of 0.18 was determined from calculations of creep closure for an empty room with gas generation (Butcher, 1996). This value represents the lowest porosity experienced where pore pressures are equal to the hydrostatic pressure at the depth of the repository (approximately 8 MPa). Hydrostatic pressure was used as a threshold because pressures must exceed hydrostatic levels in order for pressure-sensitive releases to occur (spallings and direct brine releases). Vectors with higher pressure would have porosity greater than 0.18 in the experimental and operations areas and vectors with lower pressures cannot support releases to the surface.

Updated Models and Parameters for the CRA

In the CRA BRAGFLO calculations, the pressure buildup in the experimental and operations areas is somewhat delayed in comparison to similar results for the CCA because the Option D panel closures delay the flow of gas to these regions. To demonstrate that this constant value of porosity is still valid despite all the changes that have been made to PA for the CRA (e.g., updated inventory, new BRAGFLO grid, Option D panel closures, etc.), DOE has run an updated version of the DR-3 analysis referred to as the multiple closure surface (MCS) analysis. This updated analysis consists of 200 BRAGFLO calculations (scenarios S1 and S2) from the CRA replicate R1 in which the same porosity surface representing closure of an empty room that was used for the original DR-3 runs was applied to the operations and experimental areas. This is an accurate approach because the porosity surface for closure of an empty room does not use the constitutive model for waste that is currently under review for accuracy. Consistent with the DR3 approach, we have kept the permeability of these regions unchanged from the baseline value[9]. Table 1 lists the input files and CMS libraries used for these analyses.

The maximum, mean and minimum pressure and brine saturation in the waste area (WAS_PRES and WAS_SATB) and brine flow up the borehole to the Culebra (BRNBHRCC) are compared for the CRA and the updated DR-3 (MCS) runs in Figures 1 to 5. These plots illustrate that these output variables are only slightly sensitive to

[9] The permeability assigned to the experimental and operations areas for the original DR3 analysis was 10^{-12} m^2, which was the baseline value at the time of the calculations. The present calculations used a permeability of 10^{-11} m^2, which is the baseline value used in the CCA and CRA.

whether porosity is represented as a constant value or as varying dynamically according to predictions from geomechanical calculations. Furthermore, these comparisons demonstrate that the assumption of constant porosity in the experimental and operations areas made in the CRA is conservative, since maximum and mean pressure and saturation in the waste tend to be slightly lower when dynamic closure is modeled in these areas. These results are consistent with the original DR-3 analysis and demonstrate that the basis for the decision to represent the porosity of the operations and experimental areas as a constant value of 0.18 remains valid for the CRA.

Closure of Empty Rooms in Panel One

In the request to close Panel One without completely filling the panel with CH-TRU waste, DOE noted that open, unsupported disposal rooms are expected to close through salt creep, roof fall, and floor heave, and that after a few hundred years, in the absence of significant gas generation, these rooms would approach their unmined state. Scientific investigations of the disturbed rock zone (Hansen, 2003) as well as previous modeling of salt creep (DOE, 2001) provide ample evidence of this expected evolution of the underground in the absence of significant gas generation .
However, to remain consistent with previous, peer-reviewed conceptual models for the repository and for the Salado, and as outlined above, to remain conservative with respect to releases from the repository, performance assessment assigns constant porosity and permeability to the open operations and experimental areas. As was done for the CCA, the constant values used in the CRA are appropriate for futures in which significant gas generation, both by microbial action and corrosion, occurs early in the repository's future. These values are conservative for all other futures in which gas generation is slower or of lesser extent.

Table 1. Run Control Information for the Updated DR-3 (MCS) Analysis

CMS Libraries LIBCRA1V_BFR1S1, LIBCRA1V_BFR1S2	**Class MCS**
Log File:	
BF_ALG2_CRA1V_R1S%V^_STEP3.LOG	Retained
BF_ALG2_CRA1V_R1S%V^_STEP3_MOD.LOG	Only used for R1S1V18, R1S1V98, R1S2V98; Retained
BF_ALG2_CRA1V_R1S%V^_STEP4.LOG	Retained
BRAGFLO Input Files:	
BF2_CRA1_MCS1_R1_S%_V^.INP	Retained
BF2_CRA1_CLOSURE.DAT	From LIBCRA1_BF
BF2_CRA1_MCS1_R1_S%_V^_MOD.INP	Only used for R1S1V18, R1S1V98, R1S2V98
BRAGFLO Output Files:	
BF2_CRA1V_R1_S%_V^.OUT	Created but not kept in library
BF2_CRA1V_R1_S%_V^.SUM	Created but not kept in library
BF2_CRA1V_R1_S%_V^.BIN	Created but not kept in library
BF2_CRA1V_R1_S%_V^.ROT	Created but not kept in library
BF2_CRA1V_R1_S%_V^.RIN	Created but not kept in library
POSTBRAG Input Files:	
BF2_CRA1V_R1_S%_V^.BIN	Created but not kept in library
ALG1_BF_CRA1_R1_V^.CDB	From LIBCRA1_ALG
POSTBRAG Output Files:	
BF3_CRA1V_R1_S%_V^.CDB	Retained
BF3_CRA1V_R1_S%_V^.DBG	Created but not kept in library
ALGEBRA Input Files:	
BF3_CRA1V_R1_S%_V^.CDB	Retained
ALG2_BF_CRA1.INP	From LIBCRA1_ALG
ALGEBRA Output Files:	
ALG2_CRA1V_R1_S%_V^.CDB	Retained
ALG2_BF_CRA1V_R1S%V^.DBG	Created but not kept in library

S% - scenario number
V^ - vector number
"*Created but not kept in library*" refers to files that are generated in the course of running the calculations, but deleted once the calculations have completed in order to conserve disk space. None of these files contain necessary output data nor are they required for run verification or traceability.

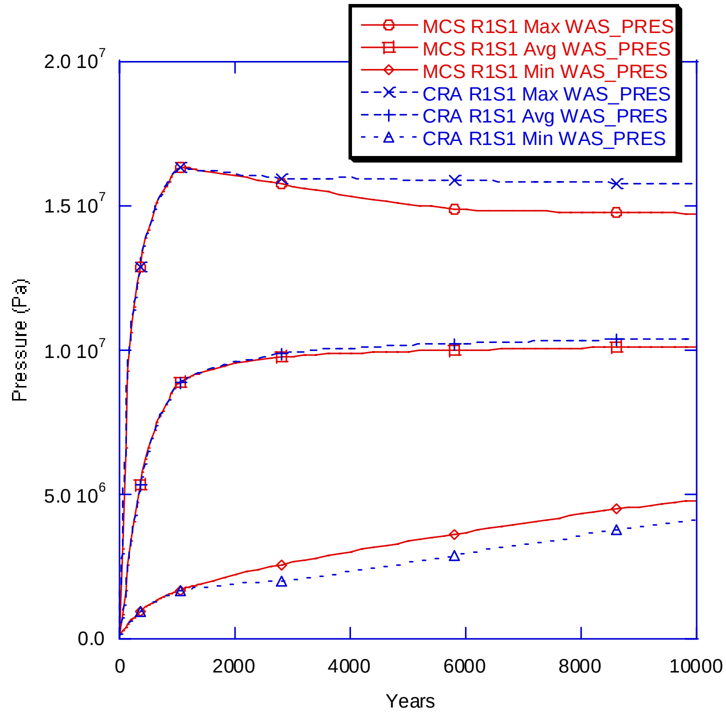

Figure 1. Maximum, mean, and minimum pressures in the single waste panel over time for the CRA and updated DR-3 (MCS) runs, undisturbed scenario.

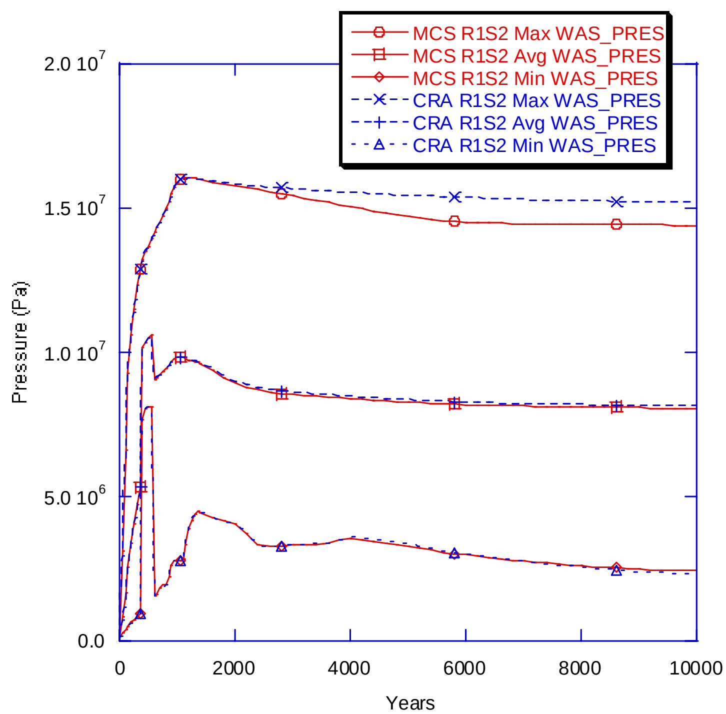

Figure 2. Maximum, mean, and minimum pressure in the single waste panel over time for the CRA and updated DR-3 (MCS) runs, Castile brine pocket intrusion at 350 yrs.

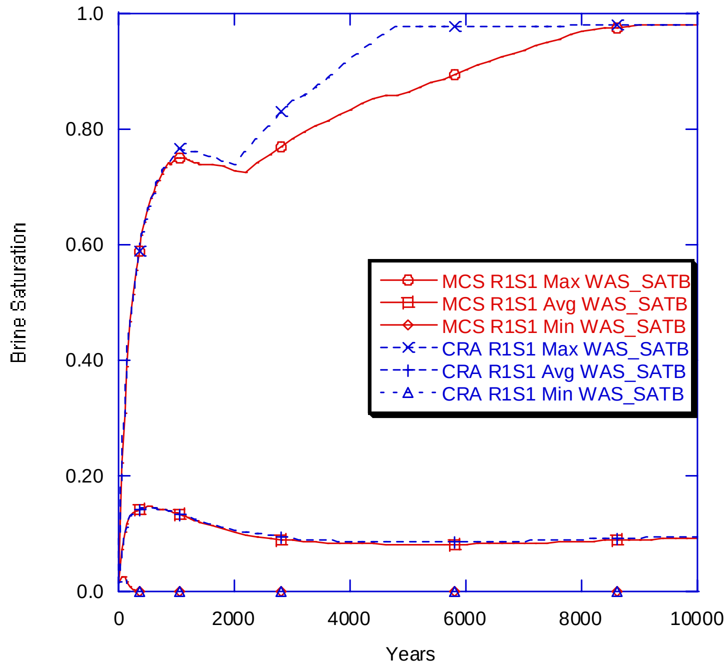

Figure 3. Maximum, mean, and minimum brine saturation in the single waste panel over time for the CRA and updated DR-3 (MCS) runs, undisturbed scenario.

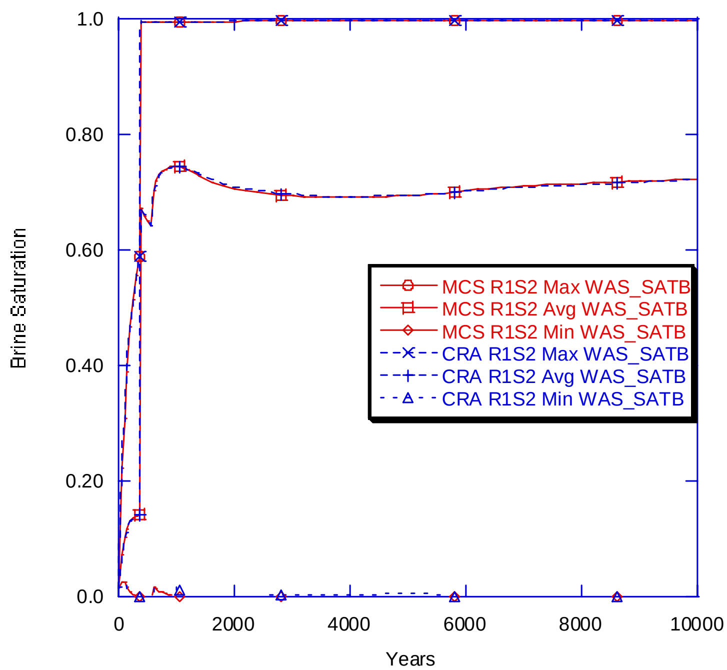

Figure 4. Maximum, mean, and minimum brine saturation in the single waste panel over time for the CRA and updated DR-3 (MCS) runs, Castile brine pocket intrusion at 350 yrs.

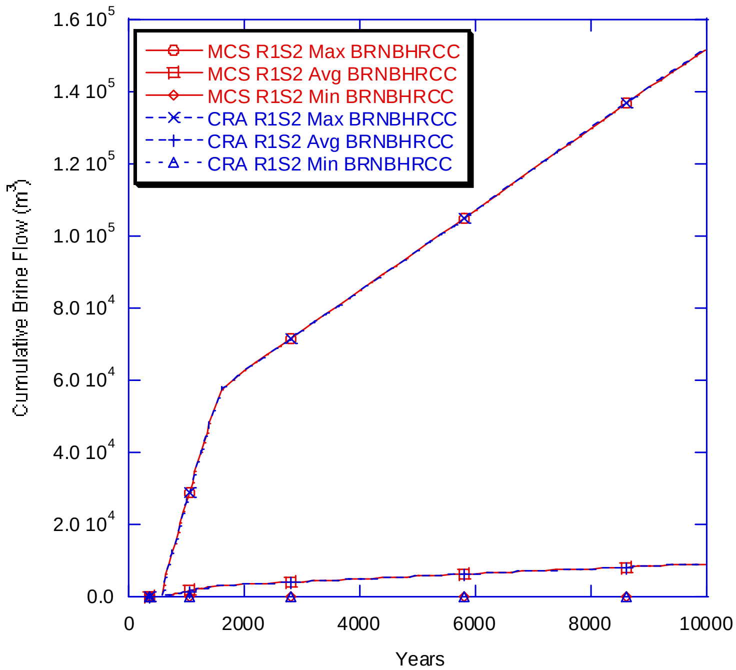

Figure 5. Maximum, mean, and minimum cumulative brine flow up the borehole to the Culebra in the single waste panel over time for the CRA and updated DR-3 (MCS) runs, Castile brine pocket intrusion at 350 yrs.

References

Butcher, B.M. 1996. Memorandum to M.S. Tierney, Porosity of the WIPP North End Excavations, dated February 6, 1996. Sandia National Laboratories. WPO #32281.

DOE. 2001. Letter from Dr. Triay to Mr. Marcinowski dated June 29, 2001. EPA Docket A-98-49, IIB-3-19.

Hansen, F.D. 2003. "The Disturbed Rock Zone At The Waste Isolation Pilot Plant." Sandia National Laboratories. SAND 2003-3407. ERMS # 533365.

Vaughn, P. 1996. Phase I FEPS Composite FEP Records Package Screening Analysis. Sandia National Laboratories. ERMS #418211

EPA Comment
C-23-8 Ch 6, pg 6-154, Section 6.4.11

The CRA states in line 33 that, "codes are executed under the requirements of the SCMS, which creates and maintains a complete record of the input data and results of each calculation." This does not appear to be true for a number of the codes used in the CRA PA. MODFLOW-2000 has the output files only in its SCMS library (LIBCRAlJ4F2K). Test cases for MODFLOW do not appear to be in its library. Nor does SANTOS appear to be in SCMS.

DOE must ensure and provide documentation that all PA codes are fully included in the SCMS system. DOE needs to also assure that all PA calculation input and output files are maintained in SCMS as described in line 33 of chapter 6 page 6-154.

DOE Response

Software Configuration Management is a methodology that provides the supporting tools to identify, control, and track the sources and versions of software used on a computing platform. The basic concepts of software configuration management are expanded to include any files required to run the software (inputs), and files generated by running the software (outputs).

A Software Configuration Management System (SCMS) has been implemented for CRA calculations using the Compaq Code Management System (CMS) for the Open VMS operating system and the Concurrent Version System (CVS) for the Linux operating system to perform the same configuration control, identification, and tracking functions.

CMS and CVS are commercial off-the-shelf software (COTS) and are considered system utilities and therefore exempt from the software QA requirements of the QAPD. This is the same reason we do not qualify Microsoft Word, or Excel, or a Fortran Compiler as received. We qualify their use indirectly through the implementation of both NP 19-1 and NP 9-1 (code configuration status audits, code testing, reviews of the analyses reports, run execution reports, etc.).

MODFLOW-2K, PEST 5.51, SANTOS 2.1.7, and Numbers 1.2 are all under the Concurrent Version System (CVS) control under Linux which is equivalent to CMS used for codes under the Compaq Open VMS 7.3-1 operating system. Moving files from or to the CMS is unnecessary since CVS provides equivalent functionality for traceability and control. The MODFLOW and PEST Runs are documented under two analysis report ("Analysis Report Task 4 of AP-088 Conditioning of Base T-Fields to Transient Heads," ERMS#531124 and "Analysis Report Task 5 of AP-088 Evaluation of Mining Scenarios" ERMS#531138). The SANTOS and Numbers runs are documented under three analysis reports ("Analysis report for Structural Evaluation of WIPP Disposal Room Raised to Clay Seam G," ERMS#531532, "Analysis report for Determination of the Porosity Surfaces of the Disposal Room Containing Various Inventories for WIPP PA," ERMS#533216, and "SNL WIPP Simulations of the Pipe Overpack to Compute Constitutive Model Parameters," ERMS#533188).

The SANTOS output porosity surface curves are stored in SCMS under LIBCRA1_BF as file name BF2_closure.dat which are the exact same surface curves used for the CCA. The original curves were hard coded into BRAGFLO version 4.01. The porosity surface curves are also stored in records as part of records package (ERMS package #235697).

EPA Comment
C-23-9 Ch 6, pg 6-155, line 13 to 18

The CRA states: 'These additional codes are transfer data between codes, prepare input files, model output processing, and perform similar tasks. These codes are executed within the SCMS." This contention does not appear to be true for all of the "additional codes," such as the SANTOS post processor code, NUMBERS and codes related to MODFLOW-2000 or DRSPALL.

DOE needs to make sure that all "additional codes" related to the CRA PA calculations are executed within the SCMS as described on page 6-155

DOE Response

As described in the response to C-23-8, MODFLOW-2K, PEST 5.51, SANTOS 2.1.7, and Numbers 1.2 are all under the Concurrent Version System (CVS) control used with the Linux operating system which is equivalent to CMS under the Compaq Open VMS 7.3-1 operating system. DRSPALL is executed under the SCMS as described in "Execution of Performance Assessment for the Compliance Recertification Application (CRA1)," Revision 0, ERMS#530170.