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SUMMARY OF THE EPA-MANDATED PERFORMANCE ASSESSMENT VERIFICATION TEST RESULTS FOR THE INDIVIDUAL AND GROUNDWATER PROTECTION REQUIREMENTS

WPO # 47258

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[1] See Memorandum from Susan Y. Pickering to Margaret S.Y. Chu dated 25 July 1997, "Quality Assurance requirements for the performance assessment verification."

SNL WIPP QAP 9-6 SWCF-A:1.2.0.5.3.1:CO/CCA: QA: PAVT GROUNDWATER PROTECTION

1.0 INTRODUCTION

Two prior reports (WPO #46674 and WPO #46702) describe the results obtained from the U.S. Environmental Protection Agency (EPA)-Mandated Performance Assessment Verification Test (PAVT) of the U.S. Department of Energy's Performance Assessment Analyses supporting the Waste Isolation Pilot Plant (WIPP) Compliance Certification Application (CCA). The following sections present a summary comparison of the PAVT and CCA dose calculations, estimated concentrations of ^{226}Ra and ^{228}Ra at the accessible environment boundary, and estimated concentrations of gross alpha particle activity, including ^{226}Ra but excluding radon and uranium, at the accessible environment boundary [as required in 40 CFR § 191.15(a), 40 CFR § 141.15(a), 40 CFR § 141.15(b), and 40 CFR § 141.16(a)]. Additional supporting information and a description of the calculations is provided in Appendix A.

1.1 Summary of Differences Between the PAVT and CCA Calculations For Individual and Groundwater Protection Requirements

In both the PAVT and CCA calculations presented herein, a very conservative bounding-analysis approach is used to estimate potential doses, radium concentrations, and gross alpha particle activity. Using this approach, the calculated maximum potential dose (millirems) to an individual is 0.032 in the PAVT and 0.47 in the CCA. Both of these values are well below the individual protection standard, an annual committed effective dose of 15 millirems as specified in 40 CFR § 191.15(a). The estimated maximum combined concentration (picocuries per liter) of ^{226}Ra and ^{228}Ra in the accessible environment is 0.49 in the PAVT and 0.14 for the CCA. Both of these values are also well below the acceptable standard of 5 picocuries per liter as specified in 40 CFR § 141.15(a). Estimated concentrations of gross alpha particle activity (picocuries per liter), including ^{226}Ra but excluding radon and uranium, at the accessible environment boundary are 2.4 in the PAVT and 7.2 for the CCA. Again, both of these values are below the acceptable standard of 15 picocuries per liter as specified in 40 CFR § 141.15(b). Finally, in both the PAVT and CCA, the average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water is shown not to produce an annual dose equivalent to the total body or any internal organ greater than the acceptable standard of 4 millirem per year specified in 40 CFR § 141.16(a).

2.0 MODELING RESULTS

In both the PAVT and CCA, contaminant transport to the accessible environment boundary (subsurface land withdrawal boundary (LWB)) in the undisturbed repository scenario occurred only in Marker Bed 139 (MB139) to the south of the repository. In the PAVT, fifteen of the 300 realizations show concentrations at the accessible environment boundary greater that 10^{-18} curies per liter in MB139 at the accessible environment boundary compared to nine realizations in the CCA. Values less than 10^{-18} curies per liter are considered to be negligible. As in the CCA, maximum doses occur at 10,000 years and are dominated by ^{239}Pu. Table 1 shows the concentrations of radionuclides at the LWB in MB139 at 10,000 years calculated in the PAVT. Table 2 shows the corresponding concentrations for the nine nonzero release CCA realizations (WPO #42959). As shown, ^{239}Pu concentrations tend to be lower in the PAVT than in the CCA. This behavior is primarily due to lower Salado ^{239}Pu solubilities in the PAVT; this issue is discussed in detail in a prior report (WPO #46674).

It is emphasized that the concentrations presented in Tables 1 and 2 greatly overestimate potential concentrations at the LWB because of numerical dispersion in the NUTS transport calculations. Numerical dispersion is caused by the coarse lateral gridding between the repository and LWB, and large time steps in the transport calculations. This conclusion is further supported by the fact that the maximum amount of brine volume flowing across the LWB in MB139 in the PAVT is 2250 m^3 (WPO #46674) and 128 m^3 in the CCA (WPO #40514). Both of these values are much smaller than the pore volume of MB139 between the repository and LWB, which is approximately 155,000 m^3 (WPO #40514). Therefore, the predicted brine volumes crossing the LWB during the 10,000 year regulatory period likely do not originate in the repository, instead these brine volumes are initially present in the marker beds. However, in order to have a quantitative bounding estimate to compare to the standards, the following calculations are presented even though estimated concentrations only represent numerical dispersion effects and, therefore, greatly overestimate concentrations at the accessible environment boundary.

3.0 INDIVIDUAL PROTECTION STANDARD

The maximum doses corresponding to the concentrations shown in Tables 1 and 2 are presented in Table 3 for the PAVT and in Table 4 for the CCA. As shown, the calculated doses for the PAVT are much smaller than the CCA values with a maximum PAVT value of 0.032 millirems versus a maximum 0.47 millirems in the CCA. This trend is consistent with the lower ^{239}Pu solubilities and concentrations noted previously. These values are well below the 40 CFR 191.15(a) individual protection standard of 15 millirems.

4.0 COMBINED ^{226}Ra AND ^{228}Ra

A bounding analysis very similar to the one performed for the CCA was used to estimate the radium concentrations transported to the subsurface LWB (WPO #42959). As in the CCA, radium concentrations are calculated by applying a scaling factor derived from tracer calculations. These tracer calculations are performed using the NUTS code by transporting a passive tracer in the flow field generated by BRAGFLO. However, this analysis differs from the one used in the CCA (as described in WPO #42959 and Chapter 8 of the CCA) in two respects: (1) Radium concentration in the repository is estimated using the brine volume in the repository at time = 0 years (this quantity (5550 m^3) is the same for both the PAVT and CCA); and (2) a dilution factor is used in this analysis. The brine volume at time = 0 years must be used in order to be consistent with the passive tracer calculation and allow scaling of the radium concentration in the repository.

In the CCA, the brine volume in the repository at 10,000 years (12,500 m^3) was used instead of the brine volume at time = 0 years[1]. In the CCA, and in the analysis presented here, brine volume in the repository is divided into the total mass load in the repository to estimate the radium concentration in the repository (see steps 1 and 2 below). Therefore, the radium concentration in the repository was under estimated in the CCA since the 10,000 year brine volume value (12,500 m^3) is more than a factor of 2 greater than the initial value of 5550 m^3. The dilution factor is used in order to be consistent with the dose calculations reported in Section 8.1 of the CCA for the individual protection requirements (40 CFR § 191.15(a)). That is, brine in the anhydrite interbeds has total dissolved solids (TDS) concentration of about 324,000 parts per million (WPO #42959); this represents a concentration that could not be consumed by humans. For the bounding analysis described here, the brine is diluted by a factor of 32.4 to a TDS concentration of 10,000 parts per million, which is the upper limit for potable water.

It should be noted here that the mass and activity values for ^{226}Ra and ^{228}Ra in the radionuclide inventory that are reported in Chapter 8 of the CCA (see Table 8-4) correspond to decommissioning at year 1995 (Table 5). However, the analysis (WPO #42959) and reported results in Chapter 8 are based on mass and activity values that correspond to decommissioning at year 2033 (Table 6) (WPO #43843). Values in Table 6 should have been reported in Table 8-4.

A key component of the bounding analysis is the passive tracer calculation using the NUTS code (WPO # 40515). This calculation is used to scale the estimated releases of ^{226}Ra and ^{228}Ra. For the PAVT, the tracer calculation (vector 38 of replicate 1) shows that an initial tracer concentration in the repository of 1 kg/m^3 results in a concentration at the accessible environment boundary of 9.2E-07 kg/m^3. Vector 38 is used because this vector has the highest tracer concentration at the accessible environment boundary. In the CCA, the maximum tracer calculation is vector 46 of replicate 1. This tracer calculation resulted in a concentration at the accessible environment boundary of 2.5E-07 kg/m^3 (WPO #42959). Dividing each of these tracer concentrations by the initial concentration of 1 kg/m^3 yields scaling factors for the PAVT and CCA equal to 9.2E-07 and 2.5E-07, respectively.

Using the two scaling factors and incorporating the two changes described above, the total concentration of radium (^{226}Ra and ^{228}Ra combined, both contact handled and remote handled) at the subsurface LWB for both the PAVT and CCA is calculated as follows:

1. Calculate the total mass load at 10,000 years by multiplying each mass loading in column 5 of Table 6 by the ratio of activity loadings at 10,000 years and decommissioning, respectively (column 4/column 3) and sum each contribution. The total mass load is equal to 0.097 kg (in both the PAVT and CCA).

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[1] Note that in Chapter 8 of the CCA, this brine volume (12,500 m^3) is mistakenly identified as brine projected to flow across the accessible environment boundary (LWB)

2. Calculate the total mass concentration at the subsurface LWB by dividing the total mass load by the brine volume at time = 0 years (5550 m^3 in both the PAVT and CCA calculation), multiply this quantity by the scaling factor (9.2E-07 for the PAVT calculation and 2.5E-07 for the CCA calculation), and divide by the dilution factor 32.4.

Steps 1 and 2 yield total radium concentrations (picocuries per liter) at the accessible environment boundary equal to 0.49 (0.49 for ^{226}Ra and 2.17E-05 for ^{228}Ra) for the PAVT calculation and 0.14[2] (0.14 for ^{226}Ra and 1.42E-03 for ^{228}Ra) for the CCA calculation. Both of these values are well below the regulatory standard of 5 picocuries per liter. Again, it should be emphasized that these calculations, as described in Section 2, are extremely overconservative because of numerical dispersion in the NUTS transport calculations that is caused by the coarse lateral gridding between the repository and LWB, and large time steps in the transport calculations.

5.0 GROSS ALPHA PARTICLE ACTIVITY INCLUDING ^{226}Ra BUT EXCLUDING RADON AND URANIUM

Gross alpha particle activity including ^{226}Ra but excluding radon and uranium is estimated by summing the concentration values provided in Table 1 for ^{241}Am, ^{239}Pu, ^{238}Pu, and ^{230}Th and adding the calculated value for ^{226}Ra (0.49 picocuries per liter in the PAVT and 0.14 picocuries per liter in the CCA). The result is 2.4 picocuries per liter for the PAVT and 7.2 picocuries per liter for the CCA. Both of these values are below the standard of 15 picocuries per liter.

6.0 ANNUAL DOSE EQUIVALENT TO THE TOTAL BODY OR ANY INTERNAL ORGAN FROM THE AVERAGE ANNUAL CONCENTRATION OF BETA PARTICLE AND PHOTON RADIOACTIVITY FROM MAN-MADE RADIONUCLIDES

The maximum annual committed effective dose (millirems) to an individual is 0.032 in the PAVT (see Table 3) and 0.47 in the CCA (see Table 4). These values are well below the regulatory standard of 4 millirem annual dose equivalent specified in 40 CFR § 141.16(a). In addition, since the PAVT and CCA dose values include alpha particle radioactivity, as well as beta particle and photon radioactivity, they are very conservative in the sense that the regulatory limit is only for beta particle and photon radioactivity.

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[2] If the total radium concentration reported in Section 8.2 of the CCA (note that this concentration is based on an incorrect brine volume) is divided by the dilution factor 32.4, the result is 0.06 picocuries per liter.

7.0 REFERENCES

Summary of EPA-Mandated Performance Assessment Verification Test (Replicate 1) and Comparison With the Compliance Certification Application Calculations, WPO # 46674

Supplemental Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and Comparison With the Compliance Certification Application Calculations, WPO # 46702.

Analysis Report For Estimating Dose Due to Drinking Water For Undisturbed Performance at the Top of the Salado, Culebra, and Selected Marker Beds Supporting the Compliance Certification Application, WPO # 42959.

Analysis Package for the Salado Flow Calculations (Task 1) of the Performance Assessment Analysis Supporting the Compliance Certification Application, WPO # 40514.

EPAUNI: Estimating Probability Distribution of EPA Unit Loading in the WIPP Repository for Performance Assessment Calculations, WPO # 43843.

Analysis Package for the Salado Transport Calculations (Task 2) of the Performance Assessment Analysis Supporting the Compliance Certification Application, WPO # 40515.

Table 1. Concentrations of Radionuclides Within Salado Marker Bed 139 (South) at the Subsurface Land Withdrawal Boundary (PAVT)

		Concentration (curies/liter)				
Realization	Vector No.	^{241}Am	^{239}Pu	^{238}Pu	^{234}U	^{230}Th
1	Replicate 1 Vector 26	N[1]	5.96E-17	N	N	N
2	Replicate 1 Vector 38	1.04E-15	3.75E-13	N	3.21E-14	4.09E-15
3	Replicate 1 Vector 58	N	3.21E-16	N	2.41E-18	N
4	Replicate 1 Vector 93	N	1.61E-18	N	N	N
5	Replicate 2 Vector 23	N	5.23E-18	N	1.73E-18	N
6	Replicate 2 Vector 47	N	9.29E-18	N	N	N
7	Replicate 2 Vector 49	N	9.90E-16	N	N	N
8	Replicate 2 Vector 64	7.65E-17	1.61E-13	N	1.36E-14	7.81E-16
9	Replicate 2 Vector 65	N	3.40E-16	N	4.14E-17	3.53E-18
10	Replicate 2 Vector 92	N	7.66E-18	N	N	N
11	Replicate 3 Vector 11	N	9.64E-16	N	1.16E-17	N
12	Replicate 3 Vector 52	N	9.21E-16	N	N	N
13	Replicate 3 Vector 53	2.51E-18	2.61E-15	N	2.61E-18	5.82E-18
14	Replicate 3 Vector 76	N	4.07E-18	N	N	N
15	Replicate 3 Vector 77	9.37E-18	4.72E-14	N	7.07E-16	6.78E-17
16-300	-	N	N	N	N	N

[1] Values less than 10^{-18} curies per liter are considered to be negligible.

Table 2. Concentrations of Radionuclides Within Salado Marker Bed 139 (South) at the Subsurface Land Withdrawal Boundary (CCA)

		Concentration (curies/liter)				
Realization No.	Vector No.	^{241}Am	^{239}Pu	^{238}Pu	^{234}U	^{230}Th
1	Replicate 1 Vector 46	1.36E-17	4.33E-12	N[1]	5.82E-13	2.10E-14
2	Replicate 2 Vector 16	N	5.13E-14	N	6.77E-15	1.89E-17
3	Replicate 2 Vector 25	N	1.35E-15	N	1.65E-16	7.00E-18
4	Replicate 2 Vector 33	1.32E-17	7.18E-14	N	9.76E-15	9.36E-16
5	Replicate 2 Vector 81	N	6.23E-18	N	N	N
6	Replicate 2 Vector 90	N	5.20E-16	N	7.40E-17	N
7	Replicate 3 Vector 3	3.50E-18	3.08E-13	N	4.32E-14	1.07E-16
8	Replicate 3 Vector 60	5.98E-17	7.41E-14	N	9.09E-15	2.30E-15
9	Replicate 3 Vector 64	5.42E-17	5.85E-12	N	7.61E-13	4.68E-15
10-300	-	N	N	N	N	N

[1] Values less than 10^{-18} curies per liter are considered to be negligible.

Table 3. Calculated Maximum Annual Committed Effective Doses (PAVT)

Realization No.	Vector No.	Maximum Annual Committed Effective Dose (millirems)
1	Replicate 1 Vector 26	4.6E-06
2	Replicate 1 Vector 38	3.2E-02
3	Replicate 1 Vector 58	2.6E-05
4	Replicate 1 Vector 93	1.3E-10
5	Replicate 2 Vector 23	4.4E-07
6	Replicate 2 Vector 47	7.5E-07
7	Replicate 2 Vector 49	8.2E-05
8	Replicate 2 Vector 64	1.3E-02
9	Replicate 2 Vector 65	2.6E-05
10	Replicate 2 Vector 92	6.5E-07
11	Replicate 3 Vector 11	7.9E-05
12	Replicate 3 Vector 52	7.1E-05
13	Replicate 3 Vector 53	2.1E-04
14	Replicate 3 Vector 76	3.4E-07
15	Replicate 3 Vector 77	3.9E-06
16-300	-	N[1]

[1] Doses derived from concentration values less than 10^{-18} curies per liter are considered to be negligible and are not reported.

Table 4. Calculated Maximum Annual Committed Effective Doses (CCA)

Realization No.	Vector No.	Maximum Annual Committed Effective Dose (millirems)
1	Replicate 1 Vector 46	3.4E-01
2	Replicate 2 Vector 16	4.3E-03
3	Replicate 2 Vector 25	1.1E-04
4	Replicate 2 Vector 33	5.8E-03
5	Replicate 2 Vector 81	5.1E-07
6	Replicate 2 Vector 90	4.3E-05
7	Replicate 3 Vector 3	2.5E-02
8	Replicate 3 Vector 60	6.2E-03
9	Replicate 2 Vector 64	4.7E-01
10-300	-	N[1]

[1] Doses derived from concentration values less than 10^{-18} curies per liter are considered to be negligible and are not reported.

Table 5. Total Inventory and Mass Loading of ^{226}Ra and ^{228}Ra (Inventory decayed to year 1995)

Radionuclide	Waste Type	Total Inventory at Decommissioning[1] (curies)	Total Inventory at 10,000 years[1] (curies)	Mass Loading (kilograms) at Decommissioning
^{226}Ra	CH	1.16E+01	9.21E+01	1.17E-02
^{226}Ra	RH	3.58E-05	2.88E+00	3.63E-08
^{228}Ra	CH	7.47E-01	9.14E-01	3.19E-06
^{228}Ra	RH	7.77E-02	9.26E-02	3.32E-07

[1] Values for activities are from Table 5.4-10 of Sanchez et al. 1997, EPAUNI: Estimating Probability Distribution of EPA Unit Loading in the WIPP Repository for Performance Assessment Calculations, Version 1.01, in SWCF-A:1.2.07.1.1:PA; QA: EPAUNI, WPO No. 43843.

Table 6. Total Inventory and Mass Loading of ^{226}Ra and ^{228}Ra (Decommissioning at year 2033)

Radionuclide	Waste Type	Total Inventory at Decommissioning[1] (curies)	Total Inventory at 10,000 years[1] (curies)	Mass Loading (kilograms) at Decommissioning
^{226}Ra	CH	1.14E+01	9.25E+01	1.15E-02
^{226}Ra	RH	2.79E-04	2.89E+00	2.82E-07
^{228}Ra	CH	9.10E-01	9.14E-01	3.89E-06
^{228}Ra	RH	9.23E-02	9.26E-02	3.94E-07

[1] Values for activities are from Table 5.4-10 of Sanchez et al. 1997, EPAUNI: Estimating Probability Distribution of EPA Unit Loading in the WIPP Repository for Performance Assessment Calculations, Version 1.01, in SWCF-A:1.2.07.1.1:PA; QA: EPAUNI, WPO No. 43843.

APPENDIX A - CALCULATIONAL PROCEDURE AND SUPPORTING INFORMATION

Software Used for Analysis

NUTS **[NU-1]**
PREGENII, **Version 6.21 [PRE-1]**
GENII-A , Version 2.10 [GEN-1], [GEN-2], [GEN-3]

Platform

These programs were run on the DEC Alpha System under VMS Operating system.

Points of Contact

Code Sponsor: **PREGENII and POSTGENII** Ron D. McCurley Org. 6848,NMERI (505) 272-7227

Code Sponsor: **GENII-A** Leo J. Rahal , Org. 6849, Geo-Centers Inc. (505) 766-9629

Radionuclide source data was obtained from the **NUTS [NU-1]** output through the **Compliance Assessment Methodology Contoller** (CAMCON) library data access process **[CAM-1]**. All calculations will be performed within the **Configuration Management System** (CMS) environment to ensure QA procedures are followed.

Calculational Procedure

The following information describes the calculational procedure used to evaluate doses at selected times and locations. These input and output files are listed in Table A-1. The input files were generated using the procedure outlined below. The Description column indicates the location, vector number and time for the input data obtained from the NUTS code. The output files are generated by running these input files according to the command @run_gi2 100 where 100 is the number associated with the data file gi2_calc100.inp for example. The PREGENII program can produce input files at only one selected time. For the purpose of this analysis the time selected was 10,000 years after closure . The GENII-A **[GENI-1]** dose code determined the dose corresponding to this selected time.

PREGENII :

A collection of files , similar to those included in this report for executing all jobs including 3 replicates were built. They include the following structures for each replicate and for each time selected to compute the dose using **GENII-A**:

1) An **ALGEBRA [ALG-1],[ALG-2]** command procedure that writes a start-up vector 001 **CAMCON Data Base** (CDB) file for PREGENII. PREGENII always needs a start-up vector 001 file, but does not need any other vector to run). If the original CDB'S from the **NUTS** calculation do not include a vector 001, then it will be assumed that the releases are identically zero. Therefore, any vector present having zero releases will be copied as a vector 001 file.

2) **ALGEBRA** Version 2.35 was used on all vectors produced by **NUTS** with non-zero releases to translate the values found in the target elements (the element variable values) to equivalent nodal variable values. For conservatism the nodal values used will be the value in that target element, since that is the maximum release, spatially.

3) **PREGENII** produced a suite of **GENII-A** input files for all vectors having non-zero releases and for the first vector (regardless). If the first vector has zero releases, PREGENII will reflect that in the **GENII-A** input file.

Listing of Input and Output Data Files for Dose Calculation: Marker Bed 139 (Table A-1) using EPA Verification Data from NUTS.

Table A-1 Input and Output Files for Dose Calculation (1)

INPUT FILE	OUTPUT FILE	DESCRIPTION
1. gi2_calc311.inp	gi2_calc311_trn.out	r1s1v026 10,000 yrs. MB139s
2. gi2_calc312.inp	gi2_calc312_trn.out	r1s1v038 10,000 yrs. MB139s
3. gi2_calc313.inp	gi2_calc313_trn.out	r1s1v058 10,000 yrs. MB139s
4. gi2_calc314.inp	gi2_calc314_trn.out	r1s1v093 10,000 yrs. MB139s
5. gi2_calc315.inp	gi2_calc315_trn.out	r2s1v023 10,000 yrs. MB139s
6. gi2_calc316.inp	gi2_calc316_trn.out	r2s1v047 10,000 yrs. MB139s
7. gi2_calc317.inp	gi2_calc317_trn.out	r2s1v049 10,000 yrs. MB139s
8. gi2_calc318.inp	gi2_calc318_trn.out	r2s1v064 10,000 yrs. MB139s
9. . gi2_calc319.inp	gi2_calc319_trn.out	r2s1v065 10,000 yrs MB139s
10. gi2_calc320.inp	gi2_calc320_trn.out	r2s1v092 10,000 yrs. MB139s
11. gi2_calc321.inp	gi2_calc321_trn.out	r3s1v011 10,000 yrs. MB139s
12. gi2_calc322.inp	gi2_calc322_trn.out	r3s1v052 10000 yrs. MB139s
13. gi2_calc323.inp	gi2_calc323_trn.out	r3s1v053 10000 yrs. MB139s
14. gi2_calc324.inp	gi2_calc324_trn.out	r3s1v076 10000 yrs. MB139s
15. gi2_calc325.inp	gi2_calc325_trn.out	r3s1v077 10000 yrs. MB139s

Footnote 1:

Input files GI2_CALC311.INP, through GI2_CALC325.INP, were generated using PREGENII.
Data was read from NUTS output file in CMS.
To run these data files type the following command: @RUN_GI2 311 where 311 is the number associated with the data file GI2_CALC311.INP, for example.
An output file GI2_CALC311_TRN.OUT is generated.
The edit command EDT filename was used to view input and output files.

Footnote 1: Continued

Legend:

r1 replicate 1 of NUTS OUTPUT
r2 replicate 2 of NUTS OUTPUT
r3 replicate 3 of NUTS OUTPUT
s1 undisturbed case
v vector number

Radium Transport Calculations [SA-1] . Calculations for Radium 226 and Radium 228 Transport Utilizing A Scale Factor Obtained from the NUTS Screening Analysis (Passive Tracer) [NU-1]

I. Identify maximum inventory values for Radium 226 and Radium 228.

Data appearing in **[EP-1]** suggest that Radium 226 and Radium 228 inventories increase as a function of time because of radioactive ingrowth (radionuclide buildup). In that reference, the initial inventory of all the radionuclide inventory of WIPP Repository CH-TRU and RH-TRU waste were used in calculations in which the initial inventory was decayed up to 10,000 years after closure into the future. Since **[EP-1]** had already performed detailed radioactive decay and buildup calculations, it was not necessary to perform any calculations for this step. The maximum values occurred at 10,000 years after closure with inventories of 95.4 Curies (92.5 from CH and 2.89 from RH) and 1.01 Curies (0.914 from CH and 0.0926 **from** RH) for Radium 226 and Radium 228 **[EP-1 b],** respectively (see the data in Column 6 of Table B-1).

II. Convert the maximum Radium inventories (i.e., at 10,000 years after closure) from units of Curies (radioactivity) to kg (mass).

$$\textbf{mass (kg) = activity (Ci)} \bullet \frac{3.7E+10(dis/\sec)}{Ci} \bullet \tau_{1/2}/\ln 2 \bullet \frac{ATWT(gm/mole)}{Na(atoms/mole)} \bullet \frac{kg}{1000gm} [1]$$

where:

$\tau_{1/2}$: half-life (sec)
ATWT : atomic weight (gm/mole)
Na : Avogadro's constant = 6.0221367E+23 (atoms/mole)

The mass values, using Equation 1, for Radium 226 and Radium 228 are 9.65E-02 kg and 4.30E-06 kg respectively.

Table A-2 Radium Inventory Units Conversion

Nuclide ID	ATWT (a) [gm/mole]	$\tau_{1/2}$ (a) [sec]	Conversion Factor (b)		Activity at 10,000 yrs. after closure (c) [Ci]	Mass at 10,000 yrs. after closure (d) [kg]
			[kg/Ci]	(pCi/l)/(kg/m^3)]		
Ra226	**226.025**	**5.0490E+10**	**1.01E-03**	**9.89E+11**	**95.4**	**9.65E-02**
Ra228	**228.031**	**2.1143E+08**	**4.27E-06**	**2.34E+14**	**1.01**	**4.30E-06**

(a) Data taken from **[SA-2b.]**
(b) Conversion factors calculated using Equation 1.
(c) Data taken from **[EP-lb]**
(d) Calculated using first conversion factor

III. Convert the maximum Radium mass quantities into maximum brine concentrations in the repository.

Divide the Radium mass by the volume of brine in the repository at time t=0. The volume of repository brine as computed by BRAGFLO calculations is 5550 m^3 **[BR-1].** Thus, as can be seen in Table A-3, the maximum brine concentrations in the repository for Radium 226 and 228 are 1.74E-05 (kg/m^3) and 7.75E-10 (kg/m^3), respectively.

IV. Compute the maximum WIPP Repository Radium brine concentrations in water accessible to the environment.

There exists no plausible transport path of radionuclides from the repository to the accessible environment during the regulatory time frame. Therefore bounding concentrating limits were estimated using marker bed values (conservative results were obtained by not taking credit for dilution of the brine as it is transported from the marker beds to the Culebra or the accessible environment). Since Radium transport was not modeled as part of the **[CCA-1]** NUTS analysis, a procedure involving a scaling factor, described below, was used to determine the transport values. This worst case analysis was done by using data calculated with the NUTS code for a simulation of a passive tracer test in which a unit concentration of radionuclides is used as a source term in the repository, and the corresponding radionuclide concentration computed for the marker bed regions. Thus the normalized ratio of results of this NUTS simulation of a tracer test (tracer exercise) can be used to estimate the maximum concentration of any radionuclide in brine transported outside of the repository. The maximum value for the scaling factor was identified to be 9.18E-07 (kg/m^3)/(kg/m^3) obtained from the NUTS (NUTS performs radionuclide transport using flow fields calculated with BRAGFLO) analysis for

Replicate I Scenario 1 (Undisturbed Case) for vector 38 **[NU-3]**. The maximum concentrations are1.60E-11 (kg/m^3) and 7.11E-16 (kg/m^3) for Radium 226 and Radium 228, respectively (Table A-3). These correspond to .49 **pCi/liter** and 2.27E-07 pCi/liter for Radium 226 and Radium 228, respectively after dilution by a factor of 32.4.

Table A-3
Radium Concentration Calculations Based on EPA Verification Tests (PAVT)

Nuclide ID	Nuclide Mass (a)[kg]	Brine Volume (b) [m^3]	Concentration Repository (c)[kg/m^3]	Scaling Factor (d)(kg/m^3)/(kg/m^3]	Marker Bed Concentration	
					[kg/m^3]	(e)[pCi/liter]
Ra226	**9.65E-02**	**5550**	**1.74E-05**	**9.18E-07**	**1.60E-11**	**15.82 (.49)^f**
Ra228	**4.30E-06**	**5550**	**7.75E-10**	**9.18E-07**	**7.11E-16**	**7.03-04 (2.27E-07)^f**
Total						**.49^f**

(a) Data taken from Table A-2

(b) Brine volume from **[BR-1]**

(c) Concentration obtained from nuclear mass by concentration.

(d) Scaling factor derived from passive trace calculations performed with NUTS **[NU-3]**.

(e) Calculated using scaling factor and converted using conversion factor in Table A-2

(f) Diluted by factor 32.4

Similar calculations were performed for the CCA values utilizing the brine volume of 5550 m^3 and the scaling factor of 2.53E-07 obtained from NUTS analysis tracer test for Replicate 1 Scenario 1 (Undisturbed Case) for vector 46 **[NU-2]**. The results appear in Table A-4.

Table A-4
Radium Concentration Calculations Based on EPA Verification Tests (PAVT)

Nuclide ID	Nuclide Mass (a)[kg]	Brine Volume (b) [m^3]	Concentration Repository (c)[kg/m^3]	Scaling Factor (d)(kg/m^3)/(kg/m^3]	Marker Bed Concentration	
					[kg/m^3]	(e)[pCi/liter]
Ra226	**9.65E-02**	**5550**	**1.74E-05**	**2.53E-07**	**4.40E-12**	**4.35 (.134)^{f}**
Ra228	**4.30E-06**	**5550**	**7.75E-10**	**2.53E-07**	**1.96E-16**	**4.59E-02 1.42E-03)^{f}**
Total						**.135^{f}**

(a) Data taken from Table A-2

(b) Brine volume from **[BR-1]**

(c) Concentration obtained from nuclear mass by concentration.

(d) Scaling factor derived from passive trace calculations performed with Nuts **[NU-2]**

(e) Calculated using scaling factor and converted using conversion factor in Table A-2

(f) Diluted by factor 32.4

A comparison of the bounding Radium brine concentrations to acceptable limits.

The maximum concentration of Radium (total) is limited by .49 pCi/liter. Since the acceptable limit **[EPA-lb]** is 5.0 pCi/liter, there is no violation of drinking water standards by brine concentrations if Radium were transported to the Culebra.

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[ALG-2] WIPP PA User's Manual Exception for ALGEBRACDB, Version 2.35. Document Version 1.00, WPO # 37469. February 8, 1996.

[BR-1] Data taken from BRAGFLO output file relating to brine inventory at 10,000 years after closure for Replicate 1 , Scenario 1 (Undisturbed Case) , Vector 38. The directory and file from which these data were taken is as follows:
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[CCA-1] Compliance Certification Application for the Waste Isolation Pilot Plant, United States Department of Energy Waste Isolation Pilot Plant, Carlsbad Area Office, Carlsbad, New Mexico , August 12, 1996.

[CAM-1] User's Reference Manual for CAMCON: Compliance Assessment Methodology Controller Version 3.0 Edited by Rob P. Rechard. SAND90-1983 August 1992.

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[EP-1b] Ibid., Table 5.4-10

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[NU-1] WIPP PA User's Manual for NUTS, Version 2.02. Document Version 1.00, WPO # 37927. May 28, 1996.

**[NU-2] Data obtained from NUTS screening analysis (passive tracer) output data file DISK$TINA_CCA3
:[BF.JDMILLE.CCA.PA_NUTS.R1S1]PA_NUTS_SCN_UND_R1S1_V046.CDB
"Analysis Package for the Salado Transport Calculations (Task2) of the Performance Assessment Analysis Supporting the Compliance Certification Application", WPO # 40515.**

[NU-3] Data obtained from NUTS screening analysis (passive tracer) output data file DISK$TINA_CCA3:[BF.JDMILLE.C97.PA_NUTS.CONC] PA_NUTS_C97_SCN_R1S1_CONC_V038.CDB

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[SA-2] Sandia National Laboratories; Memo from : L.C. Sanchez (Org 6741), to: M. Martell (Org 6749); Subject: "Radionuclide Half-lives and Specific Activities Obtained from ORIGEN2 Data"; dated: March 28, 1996.

[SA-2b] Ibid., Table 2, pg. 6.