This note book was prepared specifically to support the YM SAR review, and it is referenced in Volume 3 of the SER. Therefore, it will need to be available in ADAMS before Volume 3 is published. NRC staff directed that the analysis contained in this notebook be removed from the SER and placed in this notebook.

SN 1056E Note.

SCIENTIFIC NOTEBOOK #1056E

Calculations Supporting the Biosphere Characteristics Section, Volume 3, Technical Evaluation Report for the NRC Review of the DOE Yucca Mountain Repository License Application

by

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October 12, 2010

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[Patrick LaPlante, October 12, 2010]

This notebook was created in response to an NRC request to provide supporting documentation of calculations that are referenced in the Biosphere Characteristics section of the current draft of the Technical Evaluation Report. The calculations were not originally documented as “in-process” entries in a scientific notebook because the Chapter, as initially planned, was not expected to include additional staff calculations and therefore no scientific notebook was created for the work, nor was one available at the time when calculations were developed to address NRC comments. While the calculation methods are described in the Technical Evaluation Report, and the actual calculations were saved in a spreadsheet that is included in a CD attachment to this notebook, the following documentation provides a more transparent and complete record of the work.

[Patrick LaPlante, October 13, 2010]

Title: Spreadsheet Calculations Supporting Comparison of the Mass of Soil and Ash Inhaled Based on DOE and NRC Derived Input Parameters

Participants: Patrick LaPlante

Objective: Conduct separate calculations of the mass of soil and ash inhaled based on DOE and NRC derived input parameters to evaluate the DOE derived input parameter values for mass loading that were used in the Biosphere model in the DOE Total System Performance Assessment Model.

Work Plan: The mass of soil/ash inhaled by the reasonably maximally exposed individual is an intermediate result of the inhalation dose calculations conducted in the applicant’s biosphere model (ref) and in the NRC TPA Code (ref).

Conceptually, the calculation addresses biosphere transport processes that i) cause particulate matter on the ground surface to be resuspended to air and that ii) cause the airborne particulate matter to be inhaled by the receptor.

Mathematically, the calculations in the TPA 5.1 code compute the mass of soil/ash inhaled as the product of input parameters for mass loading, exposure time, and breathing rate. The TPA 5.1 code uses constant breathing rates and separate inputs for mass loading and activity times that can vary based on location and degree of surface disturbing activities (i.e., Outside Heavy Disturbance, Outside Light Disturbance, Inside Heavy Disturbance, Inside Light Disturbance). The DOE modeling approach is similar in that it has stratified the input parameters to address indoor/outdoor locations and human activity levels that correlate with surface disturbing activities (active outdoors, inactive outdoors, inactive indoors, active indoors) but also stratifies the input parameters further based on various receptor/employment categories (Non Workers, Commuters, Local Outdoor, Local Indoor) and activity level/location. In addition, the DOE modeling approach adds an input parameter for the fraction of the total population represented by each receptor/employment category (with the sum of all fractions equal to one allowing a single receptor to be modeled as a “composite individual” based on the characteristics of the different population groups). The DOE and NRC input parameters were used to calculate resuspension and inhalation of contaminated soil from a groundwater exposure scenario and resuspension and inhalation of contaminated volcanic ash from a volcanic ash exposure scenario.

Based on this understanding of the DOE and NRC modeling approaches, input parameters, and exposure scenarios, a series of separate calculations were implemented on the attached spreadsheet (file: *MassLoad.DailySoilInhalation.comp.xls*) to calculate the mass of ash inhaled in a standardized manner to inform the staff's review of the DOE derived mass loading values and their impact on calculated doses relative to the NRC derived mass loading values. These calculations include the following as labeled (in bold below and on the aforementioned spreadsheet in column A):

[Patrick LaPlante, October 14, 2010]

Calculation A: **DOE Groundwater**

This calculation computes the mass of soil inhaled for the groundwater exposure scenario using the DOE input parameters for mass load, exposure time, breathing rate, and fraction of population. Values for these input parameters were central point values (reported as "mean, mode, average") from the DOE SAR Table 2.3.10-10. The calculation presents results for each population group and also sums the mass of soil inhaled for all population groups in the row labeled "Grand Total for Exp Scenario". Conceptually the grand total is the amount of ash inhaled per day by an individual receptor (who's characteristics are a weighted sum of characteristics of the local population).

Calculation B: DOE **Volcanic Ash**

This calculation is mathematically identical to Calculation A, however, the DOE input parameters used in this calculation (specifically mass loading and exposure times) apply to the volcanic ash exposure scenario. Values for these input parameters were central point values (reported as "mean, mode, average") from the DOE SAR Table 2.3.10-10. Because the DOE mass loading input parameters for the "post-volcanic condition" were derived by DOE to represent only the post eruption *change* in mass loading above nominal mass loading conditions (as represented by Equation 6-5 in BSC, 2006 and discussed in the footnote to Table 7-1 in BSC, 2006), to obtain the total mass loading for post-volcanic conditions, the value used in the spreadsheet is the sum of both the DOE nominal mass loading value and the post-volcanic mass loading value for each receptor environment (e.g., active outdoors, inactive outdoors etc.) reported in Table 2.3.10-10 of the DOE SAR.

Calculation C: NRC **TPA 5.1 Values**

This calculation computes the mass of soil/ash inhaled using input parameters for mass loading, exposure time, and breathing rate derived by NRC and CNWRA for the TPA 5.1 code (Table, 17-1 in Leslie et al., 2007). Exposure time input parameters were converted from the time fractions provided in Table 17-1 to hours/day by multiplying those inputs by 24 hr/day. Similarly, the reported breathing rate of 270 cm^3/s was converted to 9.72e-1 m^3/hr (i.e., [270 cm^3/s / 1e6 cm^3/m^3] x 60 s/min x 60 min/hr). The calculation is similar to Calculations A and B but is simpler than those calculations because the approach used for TPA 5.1 inputs does not stratify the individual receptor into receptor/employment groups but does address indoor/outdoor location as well as heavy/light disturbance which is conceptually comparable to "active" and "inactive" categories used for Calculations A and B. Therefore, the calculation is more 'generalized" than A and B but it does calculate the total mass of soil/ash inhaled by an individual receptor that can be compared with the results of A and B. The grand totals are provided for each exposure scenario (although they are not labeled in the spreadsheet).

Calculation D: **DOE Mass Load w/ TPA 5.1 Exp Time and BR**

This calculation is mathematically identical to Calculation C, however, the mass load input parameters are from DOE (the same values for mass loading that were used in Calculations A and B). This calculation is conducted to compare how results from Calculation C (based on NRC values) would change using the DOE mass loading values (and all other parameters remain the same as Calculation C).

Calculation E: **All DOE Inputs except NRC Mass Load Values Used**

This calculation is mathematically identical to calculation B, however, the mass loading values derived by NRC and CNWRA for the TPA 5.1 code discussed for Calculation C (above) are used in place of the DOE values. This calculation is conducted to compare how results from Calculation B would change using the NRC mass loading values (and all other parameters remain the same as Calculation B).

Results:

The calculated total grams of soil or ash inhaled for each calculation are reported for each exposure scenario as follows:

<u>Groundwater Exposure Scenario</u>:
Calculation A: **DOE Groundwater** = 3.3 mg/d
Calculation C: NRC **TPA 5.1 Values** = 4.1 mg/d
Calculation D: **DOE Mass Load w/ TPA 5.1 Exp Time and BR** = 10.3 mg/d

<u>Volcanic Ash Exposure Scenario</u>:
Calculation B: DOE **Volcanic Ash** = 7.0 mg/d
Calculation C: NRC **TPA 5.1 Values** Volcanic Ash = 17.4 mg/d
Calculation D: **DOE Mass Load w/ TPA 5.1 Exp Time and BR** Volcanic Ash= 19.0 mg/d
Calculation E: **All DOE Inputs Except NRC Mass Load Values Used** Ash = 8.7 mg/d

Discussion and Conclusions:

The results for the groundwater exposure scenario show the calculated daily mass of soil resuspended and inhaled based on the DOE input parameters (Calculation A) was 80% of the value based on NRC input parameters (Calculation C). This comparison shows fairly close agreement (within the context of total system dose calculation results that can vary by orders of magnitude) but accounts for differences in all the input parameters that were included in the calculations. To further isolate the effect of mass loading on the results, a comparison of Calculation D with Calculation C results (i.e., all parameters except mass loading the same, same computation) indicates the DOE values for mass loading cause the mass of soil inhaled to be 2.5 times larger than the same result computed using the NRC staff's derived mass loading values. This indicates the applicant's selected mass loading values are more conservative than the values that the NRC staff independently derived from available scientific data. Therefore, the magnitude of the applicant's derived values for mass loading, when evaluated in the context of their effect on dose to the reasonably maximally exposed individual (i.e., using this calculation of soil mass inhaled), produce dust inhalation results that are greater than results based on independently derived mass loading and other applicable input parameters, as identified in Leslie, et al., Table 17-1 (2007).

The results for the volcanic ash exposure scenario show the calculated daily mass of ash resuspended and inhaled based on the DOE input parameters (Calculation B) was 40% of the value based on NRC input parameters (Calculation C). This comparison shows a notable difference in results but this comparison accounts for differences in all the input parameters that were included in the calculations. To further isolate the effect of mass loading on the results, a comparison of Calculation D with Calculation C results (i.e., all parameters except mass loading the same, same computation) indicates the DOE values for mass loading cause the mass of ash inhaled to be 9 percent larger than the same result computed using the NRC staff's derived mass loading values (i.e., general agreement in the context of total system dose results that vary by orders of magnitude). This indicates the applicant's selected mass loading values are consistent with the values that the NRC staff independently derived from available scientific data. Therefore, the magnitude of the applicant's derived values for mass loading, when evaluated in the context of their effect on dose to the reasonably maximally exposed individual (i.e., using this calculation of soil mass inhaled), produce dust inhalation results that are consistent with results based on independently derived mass loading and other applicable input parameters, as identified in Leslie, et al., Table 17-1 (2007).

The difference in results from calculations B and C for the volcanic ash exposure scenario, considered in the context of the much smaller difference among calculations C and D suggests differences in parameters other than mass load are influencing the calculated results. To evaluate this further, Calculation E was conducted to see how the results would compare if the more refined DOE inputs were used and held constant while the mass loading was varied (i.e., Calculation E uses the NRC mass loading and Calculation B is the same calculation except the DOE mass loading is used). In this comparison the NRC mass loads produced a result that was 24 percent higher than from the same calculation with DOE mass loading values (not a large difference in the context of total system performance assessment results that can vary over orders of magnitude). This result considered with the results of comparing Calculations C and D (showing DOE mass loads producing higher mass of ash inhaled when the simpler NRC breathing rates and exposure times are used) suggests that while the mass loading values are generally consistent, the more refined DOE approach to breathing rates, exposure times, and population fractions has a general lowering effect on the mass of ash inhaled relative to the simpler and more conservatively derived NRC inputs for these other (i.e., not mass loading) input parameters. This is an understandable effect of DOE using a more refined modeling approach and input parameters relative to what was done for the TPA 5.1 code. These other DOE input parameters were reviewed in detail as documented in the "Inhalation Exposure Model" section of the TER.

References:

BSC. 2006. "Inhalation Exposure Input Parameters for the Biosphere Model."

ANL–MGR–MD–000001. Rev. 04. ACN 01. Las Vegas, Nevada: Bechtel SAIC Company, LLC.

Leslie, B., C. Grossman, and J. Durham. 2007. "Total-system Performance Assessment (TPA) Version 5.1 Module Descriptions and User Guide." Rev. 1. ML072710060. San Antonio, Texas: CNWRA.

Attachment: The excel file *MassLoad.DailySoilInhalation.comp.xls* is archived on the CD Labeled "File Archive for Biosphere Characteristics Section of Volume 3 of the Technical Evaluation Report for the NRC Review of the DOE Yucca Mountain Repository License Application"

Title: Calculate Drinking Water Biosphere Dose Conversion Factors Using DOE Input Parameters and Compare with DOE ERMYN Model Results

Participants: Patrick LaPlante

Objective: Calculate drinking water biosphere dose conversion factors (BDCFs) using DOE input parameter values that were used in the Biosphere model for the DOE Total System Performance Assessment Model and compare with drinking water biosphere dose conversion factors derived from information reported in the DOE SAR.

Work Plan:

Drinking water BDCFs are calculated by DOE as the product of the radionuclide concentration in groundwater, the annual drinking water consumption rate, and the radionuclide-specific ingestion dose coefficient (DOE SAR Section 2.3.10.3.1.9 describes the ingestion dose model and cites Section 6.4.9 in SNL, 2007; specifically see Equation 6.4.9-2 in SNL, 2007 for the drinking water dose calculation used to calculate DOE BDCFs).

1. Obtain the DOE values for drinking water consumption rate and ingestion biosphere dose coefficients from documentation in the DOE SAR for radionuclides Tc-99, C-14, Pu-239, I-129, Pu-242, Np-237, Ra-226, and Am-243. Radionuclides are those that contribute most to DOE total system performance assessment results as shown in Tables 16-1 and 16-2 in the biosphere characteristics chapter of the NRC TER and as discussed in the technical review section of that chapter (i.e., section 2.2.1.3.14.3).

2. Calculate the BDCFs as the product of the radionuclide concentration in water, the drinking water consumption rate, and the radionuclide-specific dose coefficient obtained in step 1. A unit concentration of 1 Bq/m^3 is assumed for each radionuclide groundwater concentration to match what is used in the DOE SAR (see DOE SAR Table 2.3.10-12).

3. Because DOE's reported BDCFs are reported only for "all pathways" and not individual pathways such as drinking water (see in DOE SAR Table 2.3.10-12), calculate drinking water BDCFs from the reported DOE ERMYN model results by multiplying the all pathway BDCF from table Table 2.3.10-12 of the DOE SAR by the appropriate drinking water pathway fraction reported for that result in Table 2.3.10-11 of the SAR.

4. Compare the BDCFs calculated based on DOE's reported input parameters in Step 2 with the applicable BDCFs calculated in Step 3 from DOE reported ERMYN model output and DOE reported pathway fractions for that output.

Results:

Table 1: Drinking Water BDCFs Calculated by Staff Based on DOE Input Parameters

Radionuclide	Concentration in Water (Bq/m^3)	Drinking Water Consumption Rate (m^3/yr)[a]	Ingestion Dose Coefficient (Sv/Bq)[b]	Calculated Drinking Water BDCF (Sv/yr per Bq/m^3)[c]
Tc-99	1	0.7305	6.42E-10	4.69E-10
C-14	1	0.7305	5.81E-10	4.24E-10
Pu-239	1	0.7305	2.51E-7	1.83E-7
I-129	1	0.7305	1.06E-7	7.74E-8
Pu-242	1	0.7305	2.38E-7	1.74E-7
Np-237	1	0.7305	1.08E-7	7.89E-8
Ra-226	1	0.7305	2.80E-7	2.04E-7
Am-243	1	0.7305	2.04E-7	1.49E-7

[a] Value from DOE SAR Table 2.3.10-10, L/d converted to m3/yr by multiplying by 0.36525
[b]Value from DOE SAR Table Table 2.3.10-9
cValue is the product of the concentration, consumption, and dose coefficient inputs in columns to the left

Table 2: Drinking Water BDCFs Calculated by Staff Based on DOE ERMYN Model Output and DOE Reported Exposure Pathway Fractions

Radionuclide	DOE All Pathway BDCF Result (Sv/yr per Bq/m3)[a]	DOE Drinking Water Pathway Fraction[b]	Calculated Drinking Water BDCF (Sv/yr per Bq/m3)[c]
Tc-99	1.1E-9	0.417	4.59E-10
C-14	1.9E-9	0.22	4.18E-10
Pu-239	9.5E-7	0.192	1.82E-7
I-129	1.3E-7	0.601	7.81E-8
Pu-242	9.1E-7	0.192	1.75E-7
Np-237	2.7E-7	0.288	7.78E-8
Ra-226	3.8E-6	0.54	2.05E-6
Am-243	8.9E-7	0.168	1.50E-7

[a]Values from DOE SAR Table 2.3.10-12
[b]Values from DOE SAR Table 2.3.10-11
[c]The product of the all pathway BDCF and the pathway fraction (in the two columns to the left)

Table 3: Comparison of Drinking Water BDCFs Calculated by Staff from DOE Input Parameters with Drinking Water BDCFs Calculated from DOE Model Output

Radionuclide	Drinking Water BDCF Calculated from DOE Input Parameters (Sv/yr per Bq/m3)[a]	Drinking Water BDCF Calculated from DOE Model Output and Pathway Fractions (Sv/yr per Bq/m3)[b]	Ratio of Parameter Calculated BDCF to ERMYN Model Output BDCF
Tc-99	4.69E-10	4.59E-10	1.02
C-14	4.24E-10	4.18E-10	1.01
Pu-239	1.83E-7	1.82E-7	1.00
I-129	7.74E-8	7.81E-8	0.99
Pu-242	1.74E-7	1.75E-7	0.99
Np-237	7.89E-8	7.78E-8	1.01
Ra-226	2.04E-7	2.05E-6	1.00
Am-243	1.49E-7	1.50E-7	0.99

[a]Values from last column of Table 1 above
[b]Values from last column of Table 2 above

Discussion and Conclusion:

The results of drinking water BDCFs calculated from DOE input parameters are provided in Table 1. The results of drinking water BDCFs calculated from DOE ERMYN model output and associated drinking water exposure pathway fractions are provided in Table 2. The ratio of these results is provided in Table 3. The BDCFs calculated from DOE input parameters agree with the values calculated from DOE model output and pathway fractions within 2 percent (7 of the 8 comparisons were within one percent). The small variance between the compared values is explained by the DOE modeling results for BDCFs and pathway fractions being presented as mean values from distributions of stochastic ERMYN model output that would not be expected to agree precisely with BDCFs computed from constant value input parameters.

References:

SNL. 2007. "Biosphere Model Report." MDL–MGR–MD–000001. Rev. 02. ERD 01. Las Vegas, Nevada: Sandia National Laboratories.

[Patrick LaPlante, October 15, 2010]
There are no further technical entries in this notebook.

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ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK NO. 1056E

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