December 15, 2010

Mr. Thomas Gutmann, Director
Waste Disposition Programs Division
U.S. Department of Energy
Savannah River Operations Office
P.O. Box A
Aiken, SC 29802

SUBJECT: SECOND REQUEST FOR ADDITIONAL INFORMATION ON THE 2009 PERFORMANCE ASSESSMENT FOR THE SALTSTONE DISPOSAL FACILITY AT THE SAVANNAH RIVER SITE, DOCKET NUMBER PROJ0734

Dear Mr. Gutmann:

The U.S. Nuclear Regulatory Commission (NRC) staff is currently reviewing the "2009 Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site" (PA) dated October 2009, and the associated documentation. This review is being conducted in accordance with Section 3116 (b) of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005, which requires NRC to monitor disposal actions taken by the U.S. Department of Energy (DOE) for the purpose of assessing compliance with the performance objectives set out in 10 CFR Part 61, Subpart C. The PA is an update to the Performance Assessment performed in support of the "Draft Section 3116 Determination, Salt Waste Disposal, Savannah River Site," dated February 28, 2005.

We have enclosed a second Request for Additional Information (RAI), RAI-2009-02, which is a list of comments for which the NRC staff needs responses from DOE before the NRC can complete its review. The first RAI, RAI-2009-01, was submitted to DOE on March 31, 2010, and DOE provided a response to that RAI on July 22, 2010. The staff's initial assessment of the adequacy of the responses to that RAI was discussed at a public teleconference between NRC and DOE on September 2, 2010.

As was expressed in the September 2, 2010, public teleconference, the staff reviewed the responses to RAI-2009-01 and, though several of the responses adequately addressed NRC staff comments, a number of them either did not provide enough information, or did not fully address all the NRC comments. From the review of the information provided by DOE thus far, the staff cannot yet determine whether or not the Saltstone disposal actions will comply with the performance objectives in Part 61. The staff is particularly interested in the expected degradation case, or the "base case." It appears that the base case may not sufficiently reflect relevant known conditions, may not adequately account for uncertainty and variability, and may not be supported by an adequate technical basis. Several of the NRC comments in the enclosure explore this issue further.

To meet the current schedule for NRC to complete its review of the 2009 PA by June 15, 2011, we are requesting your response to the RAI by March 15, 2011, in order to provide NRC adequate time to review your response and document our findings. It is important that DOE provide a comprehensive response to the enclosed RAI to avoid another round of questions from the NRC, which could substantially delay the scheduled completion of our review. Please let us know if you believe more time is needed to respond to any of the enclosed comments, after you have had a chance to review them. It may be worthwhile to spend a little more time now to provide a comprehensive response, which could result in a short delay in completing our review, in order to prevent a much longer delay that could result from NRC asking another round of questions. To facilitate preparation of your response to the RAI, the NRC staff would be happy to meet with your staff and your contractors to clarify the RAI, or discuss proposed responses, as soon as you have had a chance to review the enclosed RAI comments.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice for Domestic Licensing Proceedings and Issuance of Orders," a copy of this letter will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records component of NRC's Agencywide Documents Access and Management System (ADAMS Accession Number ML100820097). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html.

If you have any questions, please contact Nishka Devaser, Project Manager in the Division of Waste Management and Environmental Protection, by email at Nishka.Devaser@nrc.gov, or by phone at (301) 415-5196.

Sincerely,

/RA/

David L. Skeen, Acting Deputy Director
Environmental Protection
and Performance Assessment Directorate
Division of Waste Management
and Environmental Protection
Office of Federal and State Materials
and Environmental Management Programs

Enclosure: RAI

To meet the current schedule for NRC to complete its review of the 2009 PA by June 15, 2011, we are requesting your response to the RAI by March 15, 2011, in order to provide NRC adequate time to review your response and document our findings. It is important that DOE provide a comprehensive response to the enclosed RAI to avoid another round of questions from the NRC, which could substantially delay the scheduled completion of our review. Please let us know if you believe more time is needed to respond to any of the enclosed comments, after you have had a chance to review them. It may be worthwhile to spend a little more time now to provide a comprehensive response, which could result in a short delay in completing our review, in order to prevent a much longer delay that could result from NRC asking another round of questions. To facilitate preparation of your response to the RAI, the NRC staff would be happy to meet with your staff and your contractors to clarify the RAI, or discuss proposed responses, as soon as you have had a chance to review the enclosed RAI comments.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice for Domestic Licensing Proceedings and Issuance of Orders," a copy of this letter will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records component of NRC's Agencywide Documents Access and Management System (ADAMS Accession Number ML100820097). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html.

If you have any questions, please contact Nishka Devaser, Project Manager in the Division of Waste Management and Environmental Protection, by email at Nishka.Devaser@nrc.gov, or by phone at (301) 415-5196.

Sincerely,

David L. Skeen, Acting Deputy Director
Environmental Protection
and Performance Assessment Directorate
Division of Waste Management
and Environmental Protection
Office of Federal and State Materials
and Environmental Management Programs

Enclosure: RAI

ML103400571

OFC	DWMEP:PM	DWMEP:LA	DWMEP:BC	DWMEP:BC	DWMEP
NAME	NDevaser	AWalker-Smith	CMcKenney	GSuber	DSkeen
DATE	12/07/10	12/07/10	12/14/10	12/14/10	12/15/10

OFFICIAL RECORD COPY

RAI-2009-02

Second Request for Additional Information for the 2009 Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site

December 2010

Structure of Comments

The U.S. Nuclear Regulatory Commission (NRC) staff's review comments are separated into topical areas to facilitate the U.S. Department of Energy's (DOE's) responses (SRR-CWDA-2010-00033). Documents published by DOE are referenced by number. Section or table references provided without an associated document title or reference refer to sections or tables in the document "*Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site, SRR-CWDA-2009-00017*" (SRR-CWDA-2009-00017). DOE responses to the first Request for Additional Information (RAI), *RAI-2009-01* (NRC, 2010b), can be found in the "*Comment Response Matrix for NRC RAIs on the Saltstone Disposal Facility Performance Assessment, SRR-CWDA-2010-00033"* (SRR-CWDA-2010-00033) and are referred to in this document as "DOE RAI response".

All comments have been combined in this document; the same naming and numbering system is used as was provided in the first RAI. Comments from RAI-2009-01 maintain their original name and number and where new comments are introduced in a section, the next sequential number is used. Table 2 below lists all the comments with a "Status of Comment" designation assigned for simpler navigation. "Status of Comment" designations are defined in Table 1 below. The format for the follow-up comments, which are continued comments from RAI-2009-01, is to provide the original comment and identification, a discussion of the inadequacy of the DOE response, and a path forward. New information requests have the same format as in the first RAI package. Clarifying comments from RAI-2009-01 that received adequate responses are not repeated in this document, the Clarifying Comments section of this document consists only of new comments and those from RAI-2009-01 that require additional clarification.

Individual comments may have multiple items for which NRC is seeking additional information. Extra care should be taken to ensure that all items are addressed in the responses to ensure that further additional information is not needed. If items are not addressed, the NRC will be unable to complete its technical evaluation report, or will not be able to reach conclusions on the DOE analysis.

The path forward provided for each comment is one recommended approach to resolution; the NRC staff understands that there may be more than one method for adequately addressing the technical issues raised in the comments. Appropriate responses to some comments may depend on the nature of the resolution of other comments. It will be important for DOE to ensure internal consistency of the responses, especially if any changes are made to analyses supporting the performance assessment (PA).

New Research

During previous onsite monitoring visits and meetings with DOE, site staff stated that ongoing research was being performed in a number of areas. If any new documents have been published by DOE or its contractors in the areas listed below, please provide these documents to the NRC.

- Saltstone variability testing and product quality assurance
- Vault degradation - hydraulic properties
- Reduction and sorption of Tc in the saltstone wasteform
- Vault cracking and transport through cracks
- Drainage layer plugging
- Engineered cap performance
- Results of studies performed with the core samples removed from Vault 4
- Current inventory of all radionuclides in Vault 4

Common Acronyms

FDC	Future Disposal Cell
LFRG	Low-Level Waste Disposal Facility Federal Review Group
MOP	Member of the Public
NDAA	Sect. 3116, National Defense Authorization Act Fiscal Year 2005
PA	Performance Assessment
SCDHEC	South Carolina Department of Health and Environmental Control
SDF	Saltstone Disposal Facility
SPF	Saltstone Production Facility
SRS	Savannah River Site
TER	Technical Evaluation Report
WD	Waste Determination

Comment Topics

Performance Assessment Methods (PA)
Inventory (IN)
Infiltration and Erosion Control (IEC)
Saltstone Performance (SP)
Vault Performance (VP)
Far-field transport (FFT)
Air Pathway (AP)
Inadvertent Intrusion (II)
Biosphere (B)
ALARA analysis (A)
Clarifying Questions (C)

Table 1: Status of Comment Classification Definitions

Status of Comment	Classification Definition
New	New
Complete	Comment addressed; no further questions needed
Incomplete	Additional information requested
Monitoring	Accounted for in monitoring
Clarify	Additional clarification requested

Table 2: Comment Status

Comment	Description	Status
PA-1	Individual Radionuclides Dose Contribution in Sensitivity Cases	Complete
PA-2	Probabilistic Sensitivity Analyses for Bulk Saltstone Degradation	Complete
PA-3	Determination of Key Radionuclides	Incomplete
PA-4	GoldSim Benchmarking Based Only on Key Radionuclides	Incomplete
PA-5	GoldSim Benchmarking Factors and Parameter Adjustments	Incomplete
PA-6	Analyses to Times Beyond Performance Period Based only on Key Radionuclides	Clarify
PA-7	Limited Model Support for PA	New
PA-8	Base Case Assumptions inconsistent with Current and Expected Future Conditions	New
PA-9	Conservatism of the Synergistic Case Assumptions is not Clear	New
PA-10	Saltstone System Flow Assumptions Appear to be Optimistic	New
PA-11	GoldSim Model for Uncertainty and Sensitivity Analyses may not Accurately Assess Dose	New
PA-12	Dose from Vault 1 Containerized Waste From Vault 4 Leaching	New
PA-13	Dose Consequences from Vault Releases Prior to Completion of Closure Cap	New
PA-14	Calcareous Zones	New
IN-1	Exceedance of Assumed Total Inventory in Vaults 1 and 4	Complete
IN-2	Uncertainty Distributions for Radionuclide Inventories in GoldSim Calculations	Incomplete
IN-3	Distribution of Radionuclide Inventory Among FDCs	Incomplete
IN-4	Inventory in Sheet Drain Systems and Transfer Lines At Closure	Incomplete
IN-5	Th-230 and Ra-226 Inventory and Identification of Key Radionuclides	New
IN-6	Potential Changes to SDF Feed Tank and Sampling	New
IEC-1	Infiltration of Water from Perimeter Drainage Channel	Complete
IEC-2	Materials Used to Backfill Around Disposal Cells	Complete
IEC-3	Long-Term Performance of Closure Cap Side Slopes	Monitoring
IEC-4	Effect of Transition from Bahia Grass to Pine Tree Forest on Closure Cap	Monitoring
IEC-5	Differential Settlement of Backfill	Complete
IEC-6	Hydraulic Conductivity of Infiltration and Erosion Cap Foundation Layer	Complete
IEC-7	Implications of Saturated Conditions Above The Lateral Drainage Layer	New
IEC-8	Long-Term Performance of Filter Fabric and Lateral Drainage Layers	New
SP-1	Basis for Assuming Saltstone is Hydraulically Undegraded for 20,000 Years	Incomplete
SP-2	Basis for Assumed Extent of Saltstone Fracturing	Incomplete

Comment	Description	Status
SP-3	Basis for Assumed Moisture Characteristic Curve for Saltstone	Incomplete
SP-4	Characteristic Curves Do Not Reflect Non-Equilibrium Flow	Incomplete
SP-5	Support Needed for Intact Saltstone Hydraulic Conductivity	Incomplete
SP-6	Basis for Effective Diffusivity of Intact and Degraded Saltstone	Incomplete
SP-7	Basis for Assumptions in Simulation of Sulfate Attack using STADIUM	Incomplete
SP-8	Initial Grout Mineralogy Assumed in Expansive Phase Precipitation Study Inconsistent with Other Research	Incomplete
SP-9	Groundwater Composition Uncertainty Not Considered in Estimation of Eh & Ph Transitions	Complete
SP-10	Plutonium and Neptunium Sorption Coefficients in Cementitious Materials	Incomplete
SP-11	Evaluation of K_d Values for “Middle” and “Old” Age Cementitious Materials	Monitoring
SP-12	Model Support for Eh–pH Evolution in Cementitious Materials	Incomplete
SP-13	Effect of Limiting The Shrinking-Core Model for Eh Evolution to Tc	Incomplete
SP-14	Basis for Assumed Iodine and Radium K_d Values in Cementitious Materials	Incomplete
SP-15	Basis for Assumed Tc Pseudo-K_d of 1,000 mL/g	Incomplete
SP-16	Basis for Reduction Capacity Used for Tc Transitions in Shrinking-Core Model	Complete
SP-17	Basis for Neglecting Gas-Phase Diffusion of Oxygen in Saltstone	Incomplete
SP-18	Basis for Uncertainty Ranges Used for K_d Values of Cementitious Materials	Incomplete
SP-19	Research on Tc-99 Release From Saltstone Inconsistent With Releases in PA	New
VP-1	Applicability of Vault 1 and 4 Degradation Mechanisms to FDCs	Complete
VP-2	Neglecting of Disposal Unit Degradation Mechanisms Other than Sulfate Attack	Incomplete
VP-3	Assumption of Completely Reducing Disposal Unit Floors	Incomplete
VP-4	Effect of Inventory Effects in Vault 1 and 4 Floors	Complete
VP-5	Incorporation of FDC Hydrotest Observations in PA	New
VP-6	No Physical Basis for Bypassing of Flow Through Vault 1 and 4 Walls	New
FFT-1	Uncertainty Ranges Used for Site Soils K_d Values	Incomplete
FFT-2	Site-Specific K_d Value Measurements for Sorption of Radium to Soil	Complete
FFT-3	K_d of Selenium in Vadose and Backfill Soils	Incomplete
FFT-4	Effect of Calcareous Zones on Far Field Transport	New
AP-1	Inclusion of Dose from Radon in Air Pathway Dose Assessment	Complete
AP-2	Consideration of Saltstone Degradation and Cover Moisture Content in Air Pathway Dose Calculation	Complete
II-1	Potential Pathways of Exposure for An Inadvertent Intruder	Incomplete
II-2	Calculation of Intruder Dose Calculated Based on the Unrealistic Case A	Incomplete
B-1	Exclusion of Biotic Transfer Factors from Uncertainty Analysis	Incomplete
B-2	Exclusion of Poultry and Eggs in Dose Assessment	Incomplete
B-3	Radionuclide Build-Up in Irrigated Soils	Incomplete
B-4	Soil to Plant Transfer Factors	New
B-5	Drinking Water Ingestion Rate Inconsistent With Assumed Receptor and Scenario	New
A-1	ALARA Considerations	Incomplete
C-4	Consideration of Presence of Selenium as Selenate in Solution	Clarify

Comment	Description	Status
C-8	Radionuclides included in PORFLOW Cases B - E	Incomplete
C-22	PORFLOW Hydraulic Conductivity	New
C-23	Geomembrane Placement Quality	New

Performance Assessment Methods

PA-1 **Comment:** The contribution of individual radionuclides to the dose was not provided for several deterministic sensitivity cases.

NRC Response: The answer to this RAI was adequate.

PA-2 **Comment:** Probabilistic sensitivity analyses were not provided for cases representing bulk saltstone degradation.

NRC Response: The answer to this RAI was adequate, but note that the NRC staff have concerns about the methodology used in the GoldSim analyses (see PA-11).

PA-3 **Comment:** The determination of key radionuclides described in Section 5.2.2 of the PA may not have captured all of the risk significant radionuclides. The determination of key radionuclides is significant to the results of the PA because many of the analyses used to support the PA only include the key radionuclides (e.g., the PORFLOW analyses for Cases B-E).

NRC Response: The NRC discussion on PA-3 has been combined with PA-4. See below for details.

PA-4 **Comment:** Benchmarking based only on key radionuclides identified in the base case analysis does not provide adequate support for the interpretation of alternate-case GoldSim model results.

DOE Response Discussion: In the DOE RAI response for PA-3, DOE indicated that the inventory list used in the GoldSim model included the less mobile radionuclides even if they were not determined to be key radionuclides. This aspect of the response was adequate.

However the response went on to indicate that the dose comparisons for the three key radionuclides Ra-226, Tc-99, and I-129 show good agreement, providing assurance that the behavior of additional radionuclides simulated in the GoldSim model for alternate cases is appropriate. NRC disagrees with this conclusion for two reasons. First, the code comparisons do not show particularly good agreement. The charts are presented with logarithmic scales starting from very low values. The many order of magnitude presentation of very low fluxes and concentrations makes the peak differences appear to be smaller. Examination of the flux curves for the radionuclides that have been benchmarked show differences of a factor of 10 to 30 or more, depending on the time period selected. The confidence in the non-benchmarked GoldSim radionuclides should necessarily be less than this, because

they have not undergone the benchmarking exercise. Second, as discussed below for comment PA-5, the benchmarking process itself is not sufficiently transparent to allow NRC to have confidence in the adjustments that were made.

Path Forward: The following options represent acceptable approaches to addressing this issue:

1) Perform a blind comparison of some radionuclides not included in the previous benchmarking (such as Np-237, Pb-210, U-234) for PORFLOW and GoldSim results for some alternate cases to demonstrate the level of confidence that should be assigned to non-benchmarked radionuclides. The blind comparison would be done by running each model for given radionuclides without iteration on benchmarking factors
2) Perform PORFLOW analyses with the additional radionuclides for the alternate cases.
3) Incorporate an appropriate amount of uncertainty in conclusions regarding the non-benchmarked radionuclides in the alternate cases (least recommended) that factors in the level of agreement achieved between the GoldSim and PORFLOW results and that the additional radionuclides will not have been benchmarked.

PA-5 **Comment:** Additional information is needed about the benchmarking factors and other GoldSim parameter adjustments based on benchmarking to the PORFLOW model.

DOE Response Discussion: DOE provided additional information discussing the changes that were made in the benchmarking exercise including the basis for some of the changes. The modifications made to account for the different release modeling of Tc was clear, as was the need to make modifications based on the different dimensionality of the flow fields. However, DOE did not sufficiently address the modifications to the saturated zone in reference to the PORFLOW “dilution” provided in the original NRC comment.

Although the PORFLOW model is being used for the base (compliance) case, the GoldSim model is used to understand the impact of key uncertainties. Some of those uncertainties, as discussed above, NRC believes should be represented in the base case. Conceptually, the benchmarking process was used to achieve better agreement between the results for the different models. The NRC concern is if the modifications cannot be clearly explained as having a physical basis tied to the conceptual representation of the two different models, then neither model representation may have sufficient predictive power of the future risks from the disposal facility. The benchmarking should increase confidence that each calculation appropriately represents the physical processes and therefore that the risks to future receptors has been appropriately estimated, and it should not be an exercise in getting the results of computer programs to match.

Path Forward: Provide greater transparency in the benchmarking adjustments. For example, one acceptable approach would be to provide a comparison of the results

(unbenchmarked) then a stepwise comparison after each benchmarking change, with each change linked to the conceptual model explaining the physical basis for the change. A diagram of the model, such as a cross section, with the benchmarking changes and the magnitude of the changes would be very useful to help the NRC develop the confidence in the benchmarked model results that the DOE has.

PA-6 **Comment:** Results of analyses run to times beyond or far beyond the performance period appear to underestimate dose by excluding radionuclides and pathways based on their contribution to the base case analysis at 10,000 or 20,000 years. Although an estimate of the dose at extremely long times is not likely to be necessary for a compliance determination, it is important to understand the basis for any reported results and, when reporting the information, to note important limitations.

DOE Response Discussion: The answer to this RAI was mostly adequate, but NRC staff has one clarifying question about this RAI response. The first sentence in Section 5.5.1.5 of the PA states, "The peak groundwater pathways doses associated with key radionuclides are calculated for 40,000 years in order that the dose behavior well past the performance period can be evaluated". However, the RAI response implies that the calculation described in this section included all radionuclides. Although the dose at 40,000 years is outside of the period of compliance, the information presented in Figure 5.5-9 may be misleading if all radionuclides were not included in this PORFLOW calculation.

Path Forward: Please provide a list of the radionuclides that were included in the PORFLOW calculation described in Section 5.5.1.5.

PA-7 **Comment (New):** Model support for the PA is limited and plans for development of additional support are not provided.

Basis: Model support is essential to developing confidence that the PA provides for decisions that are protective of public health and safety. Model support is intended to develop confidence that an appropriate model was used. DOE has done a much better job at explaining the calculations. However, with respect to model support, DOE has referenced ongoing research or provided sensitivity analyses. NRC acknowledges the ongoing research and is fully supportive of it. The sensitivity analysis is useful to understand how the results may change with changes in data or models. However they are of limited use in determining whether the current representation is appropriate and sufficient. The likelihood of making a poor decision increases if model support is limited. NUREG-1854 (NRC, 2007) provides information on appropriate forms of model support.

Path Forward: Provide acceptable model support for the PA model. If research is ongoing, provide a description of the plans to develop model support including when the information is scheduled to be developed. Consult NUREG-1854 (NRC, 2007) for additional information regarding approaches acceptable to NRC.

PA-8 **Comment (New):** The base case does not represent the current and reasonably expected future conditions.

Basis: The PA base case scenario is unrealistic and non-conservative in that it (i) does not reflect relevant known conditions, (ii) does not adequately account for uncertainty and variability, and (iii) does not have adequate technical bases.

The base case model is inconsistent with known conditions. Significant site characteristics that have not been adequately incorporated into the model include the following:

- Fractured saltstone is not considered in the base case even though fracturing of saltstone has been observed. In addition, shrinkage has been observed and is not included in the model. (Comment SP-2)
- The PA models appear to be inconsistent with observed, advective contaminant releases from Vault 4. (Comments SP-6)
- Material interfaces have shown to be relevant to performance; however they are not considered in the PORFLOW model. (Comment VP-5)

The base case model does not adequately account for uncertainty in initial, temporal, and spatial conditions. NRC concerns with parameter and conceptual model uncertainty include the following:

- The hydraulic conductivity and effective diffusion coefficient for saltstone are time-invariant as the base case model does not adequately account for temporal variation. (Comment SP-1; SP-6)
- The initial hydraulic conductivity of saltstone does not fully account for uncertainty in scaling from laboratory conditions to full-scale, as-emplaced saltstone. (Comment SP-5)
- The PA does not account for uncertainty in the predictions of Eh-pH evolution for cementitious materials. (Comment SP-12)
- The PA does not account for uncertainty with respect to vault degradation mechanisms. (Comment VP-2)

The base case does not have adequate technical bases. NRC concerns with limited model support include the following:

- Model support for geotextile filter fabrics and the lateral drainage layers is not commensurate with their expected long-term performance and risk significance. (Comment IEC-8)
- The moisture characteristic curves implemented in the base case for intact and fractured cementitious materials, which significantly reduce flow, lack adequate support considering their risk significance. (Comments SP-3; SP-4)

- The chemical stability of saltstone provides a significant barrier to transport; however, the basis for the Eh-pH evolution of cementitious materials is very limited. (Comment SP-12)
- The basis for the adopted technetium pseudo-K_d of 1,000 mL/g is inaccurate and insufficient. (Comment SP-15)
- The selected biotic transfer factors lack site-specific data and have very limited support. (Comment B-1)
- There is not a sufficient technical basis to exclude the chicken and egg pathway. (Comment B-2)
- The effects of radionuclide build-up in irrigated soils may be underestimated. (Comment B-3)
- The soil to plant transfer factors may be too low due to the elimination of the leafy plant component. (Comment B-4)

DOE has supported the base case with alternative scenarios and one-off sensitivity analyses. Alternative scenarios can be considered towards compliance determination; however, limitations with the assumptions and parameterization make the conservatism of the alternate cases and the synergistic case unclear (see Comment PA-9).

DOE has used one-off sensitivity analyses to evaluate the risk significance of certain parameters that are not incorporated into the base case model to demonstrate that the individual parameters do not appreciably impact the estimated dose to the Member of the Public (MOP) during the compliance period. However, this type of analysis, which may result in an insignificant increase in the base case dose, will only identify local sensitivity within the parameter space. When (i) many uncertainties exist, (ii) the margin between compliance and the base case dose is relatively small, and (iii) it is not clear how all of the uncertainties are interrelated, then the resultant dose from the inclusion of these uncertainties could be significant on a cumulative basis even if the increases for individual one-off analyses are insignificant on an absolute basis.

Path Forward: DOE should establish a base case that has adequate technical bases and appropriately reflects uncertainties to demonstrate with reasonable assurance that the performance objectives can be met.

PA-9 **Comment (New):** Conclusions about the conservatism of the synergistic case are not clear as certain assumptions appear to be overly optimistic, while other assumptions are potentially conservative.

Basis: The synergistic case was developed by DOE, based on comments received from the LFRG, to evaluate the impact of simultaneously changing multiple material parameters to account for several potential increased degradation mechanisms from the base case. The PA describes this case as pessimistic. However, NRC staff

believes that certain assumptions within the synergistic case render the degree of pessimism or conservatism indeterminate.

NRC staff is unable to assess the adequacy of the synergistic case without additional understanding of the balance between (i) the potential conservatism of the flow through the cracked saltstone and (ii) the model limitations that are applicable to all of the cases in the PA. The general limitations of the PA cases include the following: flow through the vaults and saltstone (see Comments PA-10; IEC-8; SP-1; SP-2; SP-3; SP-4; SP-5; SP-6; VP-3; and VP-6); chemical stability of cementitious materials (see Comment SP-12); and appropriateness of the biosphere calculations (see Comments B-1; B-2; B-3; B-4; and B-5). In addition, the synergistic case appears to only include the key radionuclides determined in the base case. Differences in the conceptualization between the synergistic case and the base case could change the key radionuclides (e.g., short-lived radionuclides may be risk significant in the synergistic case with the earlier degradation of the closure cap and the presence of fast pathways and the advective flow present in the synergistic case could result in a set of key radionuclides that differs from the diffusion-dominated base case.)

Path Forward: The appropriateness of the synergistic case depends on the extent that DOE relies on the synergistic case to demonstrate compliance with the performance objectives. If compliance determination rests heavily on the synergistic case (i.e., the synergistic case is used to estimate the impact from key uncertainties, lack of model support, limited information), DOE should (i) provide discussion on the balance between potential optimisms and conservatisms within the synergistic case, (ii) address the limitations applicable to all of the cases in the PA, and (iii) address the potentially limited subset of radionuclides.

PA-10 **Comment (New):** Assumptions in the PA regarding the conceptual model and parameterization may result in unsupported modeled flow rates through saltstone.

Basis: Several engineered barriers in the PA provide a significant and long-term impediment to the flow of water through the saltstone wasteform. However, DOE has very limited data to support the performance of several of these key barrier components, which include:

- Hydraulic conductivity of saltstone being hydraulically undegraded for 20,000 years in the base case. (See Comment SP-1)
- Saltstone as not being fractured in the base case. (See Comment SP-2)
- Moisture characteristic curves that are implemented for intact saltstone. (See Comment SP-3)
- Moisture characteristic curves that are implemented for fractured saltstone and concrete. (See Comment SP-4)
- Initial hydraulic conductivity of saltstone that does not adequately account for uncertainty. (See Comment SP-5)

- Geotextile filter fabrics and the lateral drainage layers that provide long-term shedding of water around the vaults. (See Comment IEC-8)
- Neglecting disposal unit degradation mechanisms other than sulfate attack. (See Comment VP-2)
- Degradation of the vault walls that can result in the bypassing of flow around the saltstone as a potential modeling artifact. (See Comment VP-6)

Model support for these flow-related components is limited, however DOE assumptions and parameter selections indicate a consistent bias towards constrained flow through the saltstone wasteform that is unsupported. Reducing the flow of water through the modeled Saltstone system has a compounded effect in that less water is available for the transport of contaminants and the lifespan of reducing conditions in the cementitious materials is prolonged. The timing of the chemical transitions for the walls, floors, and saltstone are dependent on the number of pore volumes that pass through these cementitious materials. Higher flow rates would result in more rapid chemical transitions and generally a more rapid release of redox sensitive radioelements (e.g., Tc-99).

As a scoping calculation, NRC staff determined that the flow through saltstone, the floors, and the walls would be more than a factor of 10 higher at the 500 year time period, if the geotextile filter fabric fails at 500 years (i.e., the lower lateral drainage layer has properties similar to the overlying backfill) and the moisture characteristic curves for saltstone and fractured cementitious are comparable to literature values. As a first order approximation, the dose would increase by this factor based on the increased flow rate through saltstone and the floors. However, the contaminant release is compounded due to a more rapid change in chemical transitions for cementitious materials. The timing of these chemical transitions for these cementitious materials would be less than 1/10 of the time assumed in the PA. It appears that the chemical transitions for saltstone, the floors, and the walls would occur well before the 10,000 year compliance period. This result would have a significant dose impact as transitions for saltstone, the floors, and the walls are assumed in the PA to occur beyond the 10,000 year compliance period. It should be noted that these scoping calculations still likely contain significant optimisms; for example, the assumption of intact saltstone in the base case, the assumed hydraulic conductivity of saltstone, the limited degradation mechanisms for the disposal units, and the assumption that 100% of the blast furnace slag is available for reaction with the infiltrating water (WSRC-TR-2008-00283).

Path Forward: Verify that the modeled flow rates are (i) physically reasonable and (ii) consistent with the conceptual models for the various cases.

Provide a level of data support for flow through the Saltstone system commensurate with the risk significance of this topic, or use parameter values that are technically defensible. If research is ongoing, provide a description of the plans to develop model support including when the information is scheduled to be developed. Even if research is ongoing, the compliance case needs to be adequately supported based on information that is available at the time the compliance case is developed.

PA-11 **Comment (New)**: The GoldSim probabilistic model used for sensitivity and uncertainty analyses is not adequately supported.

Basis: NRC staff has several concerns with the methodology used in the GoldSim calculations:

1) NRC staff has numerous concerns with the implementation of the PORFLOW calculations that provide the input into the GoldSim Calculations (see e.g., PA-8 and PA-10).

2) The GoldSim model incorporates all five cases (Case A-E), and the assumed probability of each case occurring is considered in the uncertainty calculations. NRC staff believes that the probabilities of each case provided in Table 5.6-3 of the PA are unrealistic. For example, the actual probability of Case A is essentially 0 for Vaults 1 and 4 because this case assumes that the saltstone does not crack during the performance period and the saltstone is already known to have cracks. However, in Table 5.6-3, the probability assumed for Case A is 95% for Vault 1 and 85% for Vault 4.

3) The results of the GoldSim model may not be applicable to radionuclides other than the ones that the benchmarking was performed for (see PA-4 and PA-5). In addition, there does not appear to be a good correlation between the PORFLOW and GoldSim results even for the radionuclides that were benchmarked (see Figures 5.6-1 to 5.6-25 in PA and PA-5).

4) It is not clear that there is adequate basis for the uncertainty distributions used (e.g., the uncertainty distributions for inventory [see IN-2] and the uncertainty distributions for K_d values [see SP-18]).

Because the GoldSim model was not used as the basis for demonstrating compliance, the NRC staff did not review these calculations to the same extent as the compliance case (Case A) was reviewed. If DOE decides to use this case to demonstrate compliance, the NRC staff will focus more on these calculations and new questions may be identified.

Path Forward: The concerns listed above need to be addressed. The amount of information needed for this comment depends on the extent to which the GoldSim model will be relied on to demonstrate compliance with the performance objectives of 10 CFR 61. These concerns need to be addressed to the degree that this model is not used to demonstrate compliance or for model support.

PA-12 **Comment (New)**: The dose consequences from the disposal of containerized Vault 4 waste in Vault 1 should be evaluated.

Basis: The NDAA states that, "(t)he Commission shall, in coordination with the covered State, monitor disposal actions taken by the Department of Energy". As part of this coordination, SCDHEC and NRC staff discussed a letter written by SCDHEC to the DOE regarding the potential disposal of containerized Vault 4 waste in Vault 1 (SCDHEC, 2010). In this letter, a request for the disposal of containerized waste from Vault 4 operations and soil remediation is described.

The NRC staff requires more information about this waste in order to assess compliance with the performance objectives of 10 CFR 61. In particular, the NRC staff must understand the origin and amount of this material. This is possibly important to monitoring the performance of Vault 4 because if this waste primarily consists of soil that has become contaminated due to seeps from Vault 4, then this might show that Vault 4 is not performing as expected. It also would be useful to evaluate whether the PORFLOW model accurately predicts the inventory that has seeped out of Vault 4. If the amount of inventory that has reached the outside of Vault 4 and the surrounding soil is significant, this may indicate that the model underestimates the release from this vault. Also, if any residual radioactivity remains in the soil surrounding Vault 4 following this remediation, this radioactivity could move through the subsurface more rapidly than predicted, especially since the site does not yet have a cover to limit the infiltration.

NRC staff is also interested in the effect of this additional waste on the expected dose from Vault 1. In particular, NRC staff is interested in how much additional inventory will be placed in Vault 1 and the effect of this inventory on the expected dose. It is possible that the long-term performance of containerized waste will be different than the long-term performance of grout. An evaluation of the potential effect of the containerized waste on long-term performance should be performed.

Path Forward: Please provide the following information:

1) The inventory of radionuclides that has seeped from Vault 4, including the amount (concentrations and total activity) and location of this inventory.
2) A comparison of the inventory that has seeped from Vault 4 to the inventory predicted by the PORFLOW model to be released from the vault to confirm that the modeling calculations are accurate.
3) An assessment of the dose due to residual radioactivity remaining outside of Vault 4, if any.
4) The inventory in the additional waste that will be added to Vault 1 and the expected dose from this inventory.
5) An evaluation of whether the presence of containerized waste is consistent with the assumptions in the PA for Vault 1 and the potential effect of this waste on the calculated dose.

PA-13 **Comment (New):** The dose consequence from early releases from the vaults prior to completion of the closure cap is not considered.

Basis: The performance assessment calculations assume that the closure cap will result in a signification reduction in the infiltration reaching the vaults starting at the first year of the model. However, the closure cap is not expected to be constructed until the end of the operational period, and there will be no reduction in the amount of precipitation reaching the vault roofs and walls before that time. The reported average precipitation rate for the site is 49 in/yr (124 cm/yr), which is significantly higher than the assumed initial infiltration rate (0.00042 in/yr [0.0011 cm/yr]). It is likely that the amount of leaching will be higher before the closure cap is installed because more water could contact the saltstone during this time. This is especially true for Vaults 1 and 4 because these vaults have had problems with water leaking through the roof and cracks forming in the walls. It is important to understand the potential for early releases to the environment during the time between the placement of the saltstone and the installation of the closure cap and the potential future dose from these releases because these releases could be significant compared to future releases.

In addition, the rate of degradation of the vaults might be higher before the backfill and cover are installed. For example, the larger amount of water reaching the vaults during this time could cause the concrete to age more rapidly. Also, the vaults will be exposed to more of the freeze/thaw cycle prior to the backfill being placed around the vaults. The saltstone wasteform would likely experience faster rates of oxidation due to higher rates of oxygen transport associated with air movement through the system compared to post-closure configurations.

Path Forward: Provide an assessment of the dose consequences from the increased amount of water the vaults will be exposed to prior to completion of the closure cap. Also, provide an assessment of the effect of the vaults being initially uncovered on the integrity of the vaults and the oxidation of saltstone.

PA-14 **Comment (New):** The PA does not discuss the existence or implications of calcareous material, or soft zones, underlying Z-Area.

Basis: Two supporting PA documents (K-ESR-Z-00001; K-ESR-Z-00002) addressed geotechnical issues regarding the calcareous zones at Z-Area that support 10 CFR Part 61.44. In addition to potential stability impacts, these zones have potential implications for other aspects of the future performance of the SDF (e.g. cover integrity, saltstone integrity, and far-field flow and transport [see Comment FFT-4]). It is not clear how these features were or were not considered. As NRC staff only recently became aware of these features, additional information may be requested.

Path Forward: Provide any additional documentation of calcareous features at Z-Area, including any documentation regarding how these features were addressed in the PA as well as data or analyses from any core, geophysical logs, cone

penetrometer test logs and geotechnical borings.

Inventory

IN-1 **Comment:** The reported inventory of some of the radionuclides disposed of in Vaults 1 and 4 as of March 31, 2009 (X-CLC-Z-00027) exceeds the total inventory of these radionuclides assumed in the PA for these vaults (Tables 3.3-1 and 3.3-3 in the PA), even when accounting for the decay of these radionuclides to the year 2030.

NRC Response: The answer to this RAI is adequate.

IN-2 **Comment:** More information is needed about the basis for the uncertainty distributions for the radionuclide inventories used in the GoldSim calculations.

DOE Response Discussion: In the PA, it is stated that "(t)he source variation deals with variability associated with the ability to predict inventories. This source variation not only includes material variability within the waste tanks, but also includes process treatment uncertainty and analytical uncertainty." The ratios of the measured saltcake concentration to the concentration predicted by the Waste Characterization System (WCS) calculations were used as the basis for developing these distributions. The previous NRC comment addressed the basis of using the ratio information for a subset of the radionuclides and applying the ratio for the distributions for all radionuclides.

In the response to this comment, DOE stated that the exclusive use of C-14, Cs-137, Pu-239, Sr-90, and U-238 ratio information in developing the uncertainty distributions was due to the lack of data for the other radionuclides.

NRC staff understands that limited information is available on these ratios, but the uncertainty distributions are not adequately justified and may not be appropriate for the following reasons:

1) The basis for using salt concentration ratios to represent uncertainty in the supernate is not provided.
2) It is not clear how the uncertainty in removal efficiencies is being represented by uncertainty in the WCS predictions.
3) The basis for using the same uncertainty distributions for radionuclides that are expected to be removed during treatment and those that are not (e.g., Tc) is not clear.
4) It is not clear why the inventory uncertainty factors are used for Vaults 1 and 4. Most of the inventory for these vaults has already been placed into the vaults, so there should not be significant uncertainty associated with either the WCS predictions or the treatment removal efficiency since the inventory in this waste has already been directly measured.

The uncertainty distributions assumed for Sr-90, Cs-137, and U-238 are biased towards being less than one such that the use of these uncertainty distributions would result in the mean inventory in the calculations being decreased. This could cause the dose calculated in the GoldSim model for these radionuclides to be underestimated (biased in an arbitrary way to low values).

Path Forward: As was true for PA-11, the amount of additional information needed on this topic depends on the extent to which DOE intends to use the GoldSim model results for compliance or model support. If the GoldSim model is going to be used for compliance, the basis for the ranges is not adequate. In that case, either more information is needed to justify the distributions, or the distributions should be changed to distributions that are defensible.

IN-3 **Comment:** Information is needed on the process that will be used to ensure that the inventory will be distributed among the FDCs in a configuration that provides reasonable assurance that the performance objectives will be met.

DOE Response Discussion: The DOE response to this comment stated that the probabilistic model incorporated the variability in the disposal sequence of the waste. As noted in (PA-11 and IN-2) NRC staff has concerns with the methodology used in the GoldSim probabilistic model, including the uncertainty distributions used for the inventory.

The DOE response stated that the process of moving the waste through the tank farm to the SPF would tend to move the concentrations of radionuclides in the waste towards the average due to mixing of the waste. NRC staff agrees with this assessment, but there will still be some variability in the concentrations of radionuclides in the different FDCs. Because the compliance case is based on all of the FDCs having a concentration at the average concentration, it would be necessary for the NRC staff to monitor the inventory in each FDC to the average concentration. Information on the methodology that will be used by DOE to assess the actual configuration of inventory in the FDCs would be extremely useful for the NRC to have when writing the updated monitoring plan.

Path Forward: Provide a description of the strategy that will be used to assess the dose from the actual inventory disposed of in the FDCs.

IN-4 **Comment**: More information is needed about the inventory expected to remain in the sheet drain systems for Vault 4 and the FDCs and the inventory expected to remain in the transfer lines at the time of closure.

DOE Response Discussion: In the response to this comment, DOE staff stated that a cold cap containing clean water will be placed over the saltstone monolith and that the sheet drain system will therefore be filled with clean water at the time of closure. DOE also stated that the drainwater system will be emptied to the maximum extent practical prior to closure.

NRC staff agrees that the bleed water from the clean grout will likely dilute the

concentration of material in the feed water collection system, but the system will likely still contain some residual amount of radionuclides because the system is likely to respond like a stirred tank reactor and not with plug flow dynamics. NRC staff is interested in understanding the volume and possible concentration of radionuclides remaining in these systems.

The DOE response also stated that the transfer lines will be removed and disposed of as LLW, so they will not contribute to dose. NRC staff finds that this portion of the response is adequate.

Path Forward: Provide information on the volume of liquid that is expected to remain in the drain water collection system for Vault 1, Vault 4, and the FDCs. Provide an estimate of the inventory that could remain in these systems at the time of closure.

IN-5 **Comment (New)**: Additional information is needed about the Th-230 inventory assumed for Vault 4 and the process used to confirm that all risk-significant radionuclides have been identified as key radionuclides as waste is disposed and final inventory information becomes available.

Basis: One of the key radionuclides identified in the current PA is Ra-226, which is created by ingrowth from Th-230. Neither of these radionuclides was identified as key radionuclides in the 2005 PA. Because of this, the NRC staff is concerned that the process used to predict the inventory for the purpose of the PA may not be capturing all risk-significant radionuclides. Key uncertainties in DOE's ability to estimate disposal inventories may not be adequately accounted for in the estimates. When updated inventory information is developed as waste is disposed, it is important to verify that any changes between the predicted and actual inventory do not result in significant changes to the predicted dose or to the list of key radionuclides. NRC staff is interested in the process used by DOE to confirm this.

Additionally, NRC staff would like information on the basis for the assumed inventory of Th-230 in Vault 4 (i.e., was this inventory based on measurements or a calculated value) and NRC staff would like more information on the reason for the underestimation of the Th-230 and Ra-226 inventory in the 2005 PA. This information would help the NRC staff to better understand the cause of this and to have confidence that this type of problem will not occur in the future.

Path Forward: Provide a description of the process that will be used to verify that all key radionuclides have been identified as additional waste is disposed and a more certain inventory is developed. Provide information on the cause of the underestimation of Th-230 and Ra-226 inventory in the previous PA.

IN-6 **Comment (New):** Additional information is needed about potential changes to the salt solution feed batch preparation tanks and the sampling methodology that will be used for these tanks.

Basis: As part of the coordination with the State required by the NDAA, the NRC and SCDHEC staff discussed a copy of a letter from SCDHEC to the Department of Energy regarding the replacement of Tank 50 as the feed tank for the SPF (SRR-ESH-2010-00030). According to this letter, DOE is proposing to install two 60,000-gallon (2.3E5 L) Salt Solution Receipt Tanks at the SPF as a replacement for Tank 50 as the feed tank.

NRC staff would like information on the sampling approach that will be used for these tanks to assess the inventory of radionuclides that will be disposed of at the SDF. Because the proposed tanks are much smaller than Tank 50 (60,000 gallons [2.3e5 L] instead of 1.3 Mgal [4.9e6 L]), a smaller amount of waste will be mixed in each tank, and the cycle of filling and emptying the tanks will occur more often. The sampling strategy for these tanks may need to be different than for Tank 50. More frequent sampling may be required, particularly if the waste entering these tanks is heterogeneous and there is significant inter-batch variability.

This information would be useful for NRC staff in the preparation of the updated plan for monitoring the disposal of salt waste disposal at the SRS.

Path Forward: If Tank 50 is going to be replaced as the salt solution feed tank, please provide updated information on the sampling approach that will be used to verify the inventory that is sent to the SDF.

Infiltration and Erosion Control

IEC-1 **Comment:** The PA does not describe what portion of the water entering the perimeter drainage channel will infiltrate back into the native soil or backfill, or what, if any, effect such infiltration will have on vadose zone or saturated zone flow.

NRC Response: The DOE response is adequate. The comment will be tracked with monitoring of the final closure cap design.

IEC-2 **Comment:** The cross-sections of disposal units in WSRC-STI-2008-00244 illustrate the lower backfill layer and other materials in the closure cap covering the cells, but do not indicate what materials will be used to backfill around the cells.

NRC Response: The DOE response is adequate.

IEC-3 **Comment:** Additional information is needed to support conclusions about the long-term performance of the side slopes of the closure cap.

NRC Response: No additional information is requested, the final cap design will be tracked in monitoring.

IEC-4 **Comment:** During the transition from Bahia grass to a pine tree forest the closure cap could be affected by external factors such as drought or fire, thus changing the assumptions required for the stability calculation.

NRC Response: No additional information is requested, as the final cap design will be tracked to be monitored.

IEC-5 **Comment:** Differential settlement could occur due to the presence of the relatively rigid disposal cells within the lower backfill and non-uniform thickness of the backfill. This could affect the drainage efficiency of the upper drainage layer and the integrity of the geomembrane layer.

NRC Response: The DOE response is adequate. The comment will be tracked with monitoring of the final closure cap design.

IEC-6 **Comment:** Additional justification is needed for the hydraulic conductivity assigned to the foundation layer of the infiltration and erosion cap.

NRC Response: The DOE response is adequate.

IEC-7 **Comment (New):** The PA should evaluate the potential implications of saturated conditions above the lateral drainage layer in the closure cap.

Basis: Table 47 in WSRC-STI-2008-00244 indicates that beyond 3,200 years the lateral drainage layer is unable to remove a large portion of the infiltrating water, the system saturates above the filter fabric layer, and runoff increases. If saturation occurs, pore pressure build-up in the overlying closure cap layers could directly affect cover stability, vegetation, hydraulic performance of cover materials, and erosion.

Path Forward: Provide (i) the saturation for individual cover layers with respect to time and (ii) the average head on top of each layer for all time periods. If saturated conditions are physically reasonable, provide discussion of the effects of closure cap saturation on stability, vegetation, erosion, and the performance of cover materials under hydrostatic pressure.

IEC-8 **Comment (New):** The PA should provide a technical basis for the long-term performance of the geotextile filter fabric and the upper and lower lateral drainage layers.

Basis: The geotextile filter fabric and the upper and lower lateral drainage layers significantly limit infiltrating water (e.g., the PORFLOW model files indicate that greater than 99% of the water infiltrating through the closure cap is shed via the lower lateral drainage layer at 8,000 years). Accordingly, the performance of the lateral drainage layers can have a significant effect on the dose as was noted in DOE's response to C-12 (RAI-2009-01).

The performance of these layers is subject to degradation of the filter fabric layer and the subsequent infilling of the porosity within the lateral drainage layer. As stated in WSRC-STI-2008-00244, "sufficient data is not currently available to estimate the service life of the filter fabric" but that "it will degrade due to oxidation and root

penetration". Calculations were presented in Appendix I that account for the reduction in hydraulic conductivity of the lateral drainage layer due to the migration of colloidal clay into the lateral drainage layer. However, it is not clear why larger particles (which would decrease the effective lifetime of the lateral drainage layers) were excluded from these calculations, as there is very limited data regarding the service life of filter fabrics and degradation of the filter fabric is likely to result in the conveyance of larger particles. Infilling of the lateral drainage layers with particles larger than colloids may accelerate infilling and result in a more rapid decrease in the hydraulic conductivity of this layer. A decrease in hydraulic conductivity would limit the ability of the lateral drainage layer to shed water, leading to an infiltration rate that is greater than estimated in the PA.

In addition, Figure 4.2-15 in the PA illustrated the change in vertical hydraulic conductivity with respect to time for the lower lateral drainage layer. The PORFLOW model files and Appendix E of SRNL-STI-2009-00115 indicate that vertical hydraulic conductivity of this layer is one order of magnitude greater than stated in the PA.

Path Forward: Due to the risk significance of the lower lateral drainage layer, provide (i) data quantifying the percentage of infiltrating water being shed versus transmitted with respect to time via this layer, (ii) justification for excluding the migration of particles larger than colloids from the overlying backfill materials to the lateral drainage layer, and (iii) support for the long-term performance of this layer. In addition, discuss the apparent discrepancy in the vertical hydraulic conductivity of the lower lateral drainage layer in the PA and the PORFLOW model.

<u>Saltstone Performance</u>

SP-1 **Comment:** Additional justification is required for the assumption that saltstone is hydraulically undegraded for 20,000 years.

DOE Response Discussion: The DOE response focused on on-going research for overall assessment of degradation and in the case of sulfate attack, short-term experimental measurements that have been completed. The DOE response did not specifically address the NRC comments that had been replicated from a previous review on the expansive phase report.

The PA has to account for what is known and conservatively include the impact of uncertainties that are not yet fully understood. Considering the ongoing research, NRC staff believes it is optimistic to assume no hydraulic degradation over 20,000 years. The effects of degradation are evaluated in sensitivity cases, but the conservatism of those cases is unclear. Because the effects are included in a sensitivity case and not in the compliance case, it means the effects are not included in the case used to demonstrate compliance with the performance objectives.

The DOE response focused on sulfate attack whereas NRC was interested in a basis for neglecting degradation via all mechanisms. For example, the disposal facilities have embedded steel, some of which is exposed to the atmosphere now or will be

exposed to the soil after facility closure. Much of that steel can be seen today to have already experienced corrosion. It is unrealistic to assume that the carbon steel will experience no corrosion. Corrosion of the steel would cause disruption of the surrounding concrete or saltstone.

Previous NRC comments on the expansive phase report to which DOE deferred a response include the following:

1) The conclusions of the expansive phase precipitation report are based on geochemical modeling results. It is unclear whether there are data and observations available for comparison to constrain the modeling calculations.

2) The expansive phase study does not consider the effects of organic additives or pozzolanic replacement on the dissolution and precipitation of cement-related compounds, which may have an effect on the generation of expansive phases. Future research could consider the effect that sulfide from the blast furnace slag might have on the phases and reactions present in this system.

3) Experiments that are designed to collect data on initial mineralogical conditions, fundamental thermodynamic data and reaction kinetics would provide much needed model support for this study.

4) Geochemist's Workbench is based on an equilibrium reaction model. However, reaction kinetics could result in metastable products that are often associated with an increase in volume. Subsequent studies might consider expansive phases produced by intermediate or metastable reaction products.

5) The conclusions reached in this study area could be integrated with other ongoing or recently completed studies. Dixon (SRNL-STI-2008-00421) recently completed a study on the physical properties of grout, which included bulk porosity measurements. Updated measurements of the bulk porosity of saltstone grout may be useful in assessing whether expansive phase precipitation is likely to result in grout degradation.

Path Forward: Provide additional basis for assuming no hydraulic degradation of saltstone occurs in the base case or provide an updated base case analysis that reflects estimated saltstone hydraulic degradation (e.g., changes in hydraulic conductivity and effective diffusivity). Specifically, address the comments on the expansive phase report and additional degradation mechanisms. Provide model support for the long-term performance of saltstone and reinforced concrete.

SP-2 **Comment:** A basis is required for the modeled extent of saltstone fracturing.

DOE Response Discussion: The DOE response referenced Case C as including cracks. DOE indicated that the sensitivity studies provide information regarding the effect of crack variability.

NRC does not believe that the impact of cracking on the PA results is adequately captured by Case C, sensitivity analyses that address increased hydraulic

conductivity, or alternate configurations such as Case E as currently represented. The references provided (T-CLC-Z-00006; SRNL-STI-2009-00115, Rev. 1) address cracking mechanisms for Vault 4 due to differential settlement and seismic events. Case C is intended to capture the impact of transverse structural cracks through saltstone caused by these mechanisms. However, a basis is not provided to extend the mechanisms responsible for Vault 4 cracking to saltstone and address fracture mechanisms that are unique to saltstone. Cracking of saltstone has been observed (SRNL-ESB-2008-00017) and the uncertainty and variability in (i) cracking (e.g., number of cracks, crack spacing, crack orientation, crack length, crack aperture, etc.) and (ii) crack evolution (e.g., acceleration of cracking) has not been evaluated. Therefore, it is expected that two longitudinal cracks do not adequately reflect the uncertainty associated with the extent or effects of potential cracking.

Sensitivity analyses with increased hydraulic conductivity do not evaluate the full matrix of the potential effects of cracks. For example, changes to the surface-area-to-volume ratio, which is dependent on crack representation, is not captured by varying the hydraulic conductivity. Removal of radionuclides and leaching of cementitious materials, which can lead to additional fracturing, is strongly correlated to the surface-area-to-volume ratio.

In addition, results from sensitivity analyses with increased hydraulic conductivity and Case E are inconclusive due to the moisture characteristic curves applied in the PA (see Comments SP-3 and SP-4).

Path Forward: Provide a basis for the extent of fracturing included in the base case representation. Demonstrate how the base case model appropriately represents current observations with respect to cracks. Address the mechanisms noted above as well as other mechanisms by which fractures could increase the rate of subsequent fracturing.

SP-3 **Comment:** The moisture characteristic curve for intact saltstone implemented in the PORFLOW model does not sufficiently account for experimental uncertainties and is inconsistent with literature results for material similar to saltstone and other cementitious materials.

DOE Response Discussion: The DOE agreed in their response that the moisture characteristic curve based on the INL dataset is somewhat inconsistent with literature (WSRC-STI-2007-00649). To evaluate the impact of using a modified moisture characteristic curve, the base case was rerun in PORFLOW with the relative permeability set to 1.0. The resulting contaminant release rate was approximately twice that of the base case for Vault 2 during the compliance period. For Vault 4, with the relative permeability equal to 1.0, the release rate of Tc-99 was almost doubled, while the I-129 and Ra-226 rates were each less than a 30% increase over the base case. DOE stated that these increases in release rates would not significantly impact the resulting dose to the MOP during the compliance period.

Increases in contaminant release rates of 30% and 100% for one-off sensitivity

analyses may result in an insignificant increase in base case dose on an absolute basis (i.e. if the base case dose is small). However, when (i) many uncertainties exist, (ii) the margin between compliance and the base case dose is not very large, and (iii) it is not clear how all of these uncertainties are related, then the resultant dose from the inclusion of these outstanding uncertainties could be significant on a cumulative basis even if the increases for individual one-off analyses are insignificant on an absolute basis.

Path Forward: If adequate justification is not available for the moisture characteristic curves implemented in the PA model for intact saltstone, provide updated results for Case A, B, C, D, the synergistic case, and the sensitivity case in Section 5.6.6.7 that use a characteristic curve for intact saltstone that is more consistent with results in the literature.

SP-4 **Comment:** Characteristic curves implemented in the PA are based on a continuum approach that does not reflect non-equilibrium flow.

DOE Response Discussion: The DOE response discussed the effects of transient flow on contaminant leaching. However, NRC staff's concern is the inability of a continuum approach to represent unsaturated flow through porous or fractured media. Unsaturated flow is characterized by non-equilibrium, gravity-driven fingering that can lead to pulsating flow conditions, even in the presence of a steady state infiltration boundary condition (Pruess et al., 1999). Abstraction of unsaturated flow with moisture characteristic curves cannot replicate this flow behavior. Equilibrium flow through unsaturated media can significantly underestimate actual flow rates through a system.

Path Forward: Provide additional model support for unsaturated flow. Model support could include analogs, laboratory experiments, and/or field studies that verify consistency between numerical results and physical measurements. Alternatively, demonstrate that non-equilibrium flow through porous and fractured media does not significantly affect the performance of the system.

SP-5 **Comment:** Additional support is needed for the hydraulic conductivity of intact saltstone that is used in Case A, Case B, Case C, Case D and the synergistic case.

DOE Response Discussion: The DOE response indicated that additional testing of hydraulic and physical properties has continued to be performed and provided a summary of additional test results. DOE indicated that the baseline test results yielded values of 1.3E-9 to 4.0E-9 cm/s which was consistent with the base case value of 2E-9 cm/s used in the PA. They also indicated that sensitivity analyses were performed to examine the impact of a much higher hydraulic conductivity, and the estimated doses were much less than 25 mrem/yr. The DOE response did not address the monitoring follow-up items provided in the original comment pertaining to the measurement of hydraulic properties. The original comment requested justification for logarithmic averaging of the hydraulic conductivity values for the limited data set with an unknown distribution, which was not provided.

Ongoing tests are helpful and fill some important data gaps, but the tests do not capture the full range of conditions that can be expected for actual emplaced saltstone. The test results provided in the comment response have values as large as 9E-9 cm/s for the impact of water to premix ratio and as high as 9E-7 cm/s for a baseline composition with organics, admixtures, and a 60°C cure temperature. Depending on the composition and curing temperature of saltstone, these values could arguably be representative of a reasonable starting point for a base case value. These measurements highlight the need to be conservative when selecting a base case deterministic value for a key parameter such as hydraulic conductivity. As DOE has collected additional measurements, the hydraulic property values have been consistently revised higher. In addition, these hydraulic tests are on laboratory prepared samples which do not account for (i) scale, (ii) emplacement (batching, pumping, curing), (iii) CO_2 contamination, and (iv) permeability evolution.

Path Forward: Provide adequate support for the hydraulic conductivity value that is implemented in the base case for the PA for intact saltstone. Additional support should include a description of how data from laboratory samples is scaled to represent full-scale, as-emplaced saltstone. Additional support should also address the specific analytical concerns raised in the original comment, including the potential impact of atmospheric CO_2 on the results. Provide justification for the logarithmic averaging of hydraulic conductivity for a limited data set or provide additional data to characterize the distribution.

SP-6 **Comment:** Additional basis is required for the values of the effective diffusivity of intact and degraded saltstone used in the base case and sensitivity cases.

DOE Response Discussion: DOE indicated in their response that releases are primarily advection dominated, and calculated Péclet numbers for two separate cases: A and E. Because the Péclet number was large except for very early time periods in Case A, DOE concluded that uncertainty in the effective diffusion coefficient would not have a noticeable impact on calculated peak dose results.

The application of Péclet number as a criterion to neglect the importance of diffusion or advection is problematic (Huysmans and Dassargues, 2004). The importance of these transport mechanisms is more appropriately determined by extracting and comparing the model results. The PORFLOW model output files contain the diffusive and advective releases for each radionuclide at one-year time intervals for 20,000 years. NRC review of this data for key radionuclides (e.g., Ra-226, Tc-99, Pu-239) indicates that (i) diffusion strongly dominates radionuclide fluxes at early time periods (as much as four orders of magnitude) and (ii) continues to dominate throughout the 20,000-year period.

Path Forward: Provide a basis for using the effective diffusivity of intact saltstone in the two sensitivity cases that address degraded saltstone or update the sensitivity cases that address degraded saltstone with a value of effective diffusivity that reflects the physical degradation of the wasteform. Provide adequate technical basis for the value of the effective diffusivity of intact saltstone. Similar to SP-5, the values

assigned should reflect what has been measured and conservatively reflect the uncertainty associated with the results of experiments that are yet to be completed.

SP-7 **Comment:** Additional bases are needed for key assumptions used in the simulation of sulfate attack with the STADIUM code.

DOE Response Discussion: The DOE response discussed the development of STADIUM by Simco Technologies. Data for blended cements have been developed but are part of a proprietary material database and are unpublished. Minor species are neglected because there is no self-diffusion data available. However, the model has been shown to reproduce experimental observations even though secondary phases are neglected.

The DOE response covered most of NRC's concerns. NRC is aware of the high quality of work performed by Simco. However, the use of proprietary unpublished information as a basis does not provide transparency for staff to verify the results. Staff is aware of similar research that has been performed at Vanderbilt University (it may also not yet be published). Research completed as part of the Cement Barriers Partnership showed the modeling results could be sensitive to initial mineralogy.

Path Forward: Given the constraints associated with proprietary information, evaluate whether the blended cement formulations that have been evaluated using STADIUM can be compared to the saltstone and concrete formulations used for saltstone disposal. Communicate the relative agreement between predicted and measured values. With respect to minor species, at a minimum an assumption regarding the neglect of minor species should be tracked and reevaluated as future pertinent research is completed. As research is published, provide a comparison of Simco and Vanderbilt assessment results.

SP-8 **Comment:** The initial grout mineralogy used in evaluating expansive phase precipitation is inconsistent with the initial mineralogy used to determine Eh and pH transitions in pore fluids. Depending on which initial mineralogy is more appropriate, the conclusions of either report could change.

DOE Comment Discussion: The DOE response indicated why there were differences in the formulations (basically because of timing of the parallel development of products) and that research was ongoing. They also indicated that the uncertainty in Eh and pH transitions of +/- 50% was applied in the uncertainty and sensitivity analyses.

The explanation of why the differences were present is useful to provide understanding, but it does not address why the differences are acceptable or what the impact of the differences in composition may be on the conclusions of the reports. The uncertainty range for the Eh and pH transitions has not been demonstrated to capture the differences in the number of pore volumes that would result from the variability in the initial mineral compositions. The assigned uncertainty range is speculative, and the effects are limited to alternate cases and therefore are not reflected in the base case results.

Path Forward: Provide a basis for using different initial mineralogies in the calculations described in the basis of this comment, or provide information that demonstrates the calculation results are not significantly affected by the differences in initial mineralogy. Provide a basis for the uncertainty range assigned to the Eh and pH transitions.

SP-9 **Comment:** Uncertainty in groundwater composition was not considered in the Geochemist's Workbench simulations to estimate Eh and pH transitions in pore fluids.

NRC Response: The DOE response is adequate.

SP-10 **Comment:** There are indications that some measured plutonium and neptunium sorption coefficients in cementitious materials could reflect solubility rather than sorption, which could lead to a significant overestimate of plutonium and neptunium sorption.

DOE Comment Discussion: Recent DOE-sponsored research indicated that the dissolved concentrations of plutonium and neptunium were solubility limited rather than sorption controlled (SRNL-STI-2009-00636). DOE further stated that the models supporting the PA (i.e., PORFLOW and GoldSim) do not use solubility constraints but instead utilize apparent K_d values. However, it is not clear that solubility effects could be ruled out for the studies that form the basis for these plutonium and neptunium K_d values (WSRC-STI-2007-00640 and SRNS-STI-2008-00045). The use of K_d values based on sorption experiments in which solubility was actually the controlling process could lead to underestimation of the radionuclide release rates.

The K_d values measured in WSRC-STI-2007-00640 are extremely high; the solubility limit for plutonium may have been exceeded in these experiments. This report does not include information on the plutonium concentration used in these experiments and how it compares to the solubility limit. This report does state that no solids control samples were included to determine if precipitation was occurring, but the results of these samples were not included in the report. SRNS-STI-2008-00045 provides more information about the methodology used to account for the possibility of precipitation, but it is not clear how the information from the no solids control was used. On page 39, it is stated that the concentrations from samples 621-A, B, and C are used as the initial concentration in the calculation of the K_d. However, based on Table 13, it appears that this sample is not a 'no solids' control and that this sample contains simulated saltstone. Additionally, it seems that this sample is in a reducing environment rather than an oxidizing environment.

DOE also stated that the plutonium and neptunium K_d values used in the PA could be overestimated; however these values did not show up as sensitive parameters. In support of this finding, DOE conducted a sensitivity run that set the K_d value for plutonium and neptunium in cementitious material equal to zero in the GoldSim transport model. The results of these sensitivity runs indicated that the dose to the

MOP during the compliance period increased by a factor of less than three for the base case; therefore, DOE concluded that any overestimation of plutonium or neptunium K_d values on cementitious materials would not impact the overall conclusions of the PA.

In addition to the limitations regarding one-off sensitivity analyses (see Comment PA-8), the relative increase in dose from reducing the K_ds to zero was significant. Table 5.5-2 in the PA indicates that for the base case, plutonium and neptunium each contribute less than 0.05 mrem/yr to the total peak dose of 1.4 mrem/yr in the 10,000-year performance period. In the sensitivity analysis with the K_ds for plutonium and neptunium set to zero, the result was that the total dose more than doubled from the original 1.4 mrem/yr. This large relative increase illustrates the sensitivity of the model to the cementitious material K_d for plutonium and neptunium. In light of the sensitivity of the model to these K_d values and the uncertainties in the PA, a one-off sensitivity analysis is not conclusive.

Path Forward: Provide an updated base case that includes technically defensible K_d values for plutonium and neptunium.

Provide information on the no solids control samples in WSRC-STI-2007-00640 and SRNS-STI-2008-00045, including the amount of precipitation observed in the no solids control samples (i.e., provide the initial and final concentrations in these samples). Provide information on the aqueous phase used in the no solids control samples and the pH of these samples. In addition, clarify which samples were used for the initial concentration in the K_d equation on p. 39 of SRNS-STI-2008-00045.

SP-11 **Comment:** In recent experiments used to help define K_d values for cementitious materials, the distinction between "middle" and "old" age conditions was based chiefly on water chemistry—not on the mineralogical assemblage. It is not clear whether the differences in solid phases for the different stages can be neglected.

DOE Comment Discussion: In the response, DOE states: "(d)ecreased sorption as a result of evolving mineral assemblage is not expected to be significant in the wasteform because the timing of re-crystallization of reducing old-age concrete is after the performance period, and because a decreasing trend between middle-age and old-age cement K_ds was implemented in the PA to account for this type of uncertainty." NRC staff does not agree with this statement because the estimation of the timing of the re-crystallization is based on hydraulic assumptions that the NRC staff does not think are supported (see Comments PA-8 and PA-10).

In addition, the comment response states: "(a)s identified above, there is a potential for sorption of key radionuclides onto old-age concrete to decrease with increasing precipitation of quartz as CSH gel dissolves. Any potential impact this may have on underestimating releases from the wasteform are considered insignificant, because countering factors would tend to immobilize these same radionuclides under the old age conditions, either by incorporation into the re-crystallized structures, increased sorption to iron oxyhydroxides, or by increased precipitation of the radionuclide itself, effectively canceling out the effects." NRC staff agrees that some of these factors

may act to mitigate the decreased sorption in old-age concrete due to precipitation of quartz. However, NRC staff does not agree with the proposition that the two competing effects will necessarily cancel each other out. The net effect of competing effects is dependent on how strongly the different effects affect the system.

Finally, the comment response states: "(i)t is also proposed that the K_ds used in the PA are conservative in that they do reflect a decreasing trend in K_ds from middle-age to old-age cementitious material." NRC staff also does not agree with this logic because whether or not something is conservative is dependent on the actual values chosen, not just the trend in the values.

Path Forward: Depending on the results of research on the predicted flow through the cementitious materials, this comment may be more significant in the future if the transitions are predicted to occur during the performance period. NRC staff will continue to track this topic under monitoring.

SP-12 **Comment:** Model support is needed for the process models supporting PA predictions of Eh-pH evolution for cementitious materials.

DOE Comment Discussion: The comment response indicated that research is ongoing, and to account for the preliminary nature of the available information uncertainty and sensitivity analyses were performed.

NRC recognizes that additional work will be done to provide model support, and NRC is highly supportive of that work. However, using uncertainty analysis to account for lack of model support is generally insufficient unless it can be demonstrated:

i) The justification is provided to show that the range of parameter values considered in the uncertainty analysis encompasses the uncertainty in the model,

ii) The uncertainty and sensitivity analyses are reasonably conservative, and

iii) The impact of the uncertainty is limited locally and globally in the analysis.

Since the model is not adequately supported, it is very difficult to define an appropriate representation for the uncertainty analysis. Uncertainty analysis is a useful tool for use in performance assessment, but should be used very cautiously if at all with respect to model support.

Path Forward: Provide model support for the Geochemist's Workbench results regarding pore fluid volumes necessary for transitions in Eh and pH of pore fluids in cementitious materials (SRNL-TR-2008-00283). For example, model support could include a comparison of model results with the results of pH and Eh measurements in accelerated physical testing using higher flow rates than anticipated in full-scale saltstone. Plans for developing model support may provide appropriate basis, because NRC could verify the implementation of those plans in its monitoring role.

However, use of plans for model support could result in the development of information that does not support the decision.

SP-13 **Comment:** The effect of limiting the shrinking-core model to the effects of the Eh evolution of saltstone on Tc should be analyzed.

DOE Comment Discussion: DOE provided information to demonstrate that for key radionuclides the transitions from different Eh and pH conditions are not expected to have a significant influence on the results, and therefore switching to a shrinking core model for those radionuclides is not warranted. Tc-99 was the main radionuclide for which the transitions were expected to have a big impact, and so it was included in the shrinking core model.

NRC's comment also applied to radionuclides that did not contribute at least 0.05 mrem in the all-pathways base case dose. The approach to modeling the release for those radionuclides could cause them to be defined as important or not.

Path Forward: Demonstrate that the key radionuclide list is not impacted by the type of release model (i.e. shrinking core vs. step transitions) applied. For instance, compare the K_d values assigned at different Eh and pH states, the concentrations of those radionuclides in the waste, and their dose conversion factors for key pathways or provide shrinking core model results for those radionuclides.

SP-14 **Comment:** Additional information is needed about the basis for the K_d values used for iodine and radium in cementitious materials.

DOE Response Discussion: In the DOE response to this comment, it is stated that: "(r)esults for iodine partition coefficients onto old-age cements in an oxidizing environment from the same report were not recommended for update because the new results do not correspond to previously reported values (Table 2, WSRC-STI-2007-00640)."

NRC staff disagrees with this statement for two reasons:

1) It is not reasonable to ignore data simply because the results are unexpected, and

2) The reducing grout used in WSRC-STI-2007-00640 is based on a different formulation than saltstone (i.e., it contains sodium thiosulfate as a reducing agent).

The radium K_d information provided in the DOE comment response is adequate, but NRC staff would like to note that the K_d value for Ra is risk-significant, so it is important for future research to be done on the sorption of Ra on simulated saltstone instead of relying on literature values based on the sorption of strontium. NRC staff would also like to note that it is important for the performance assessment to adequately account for the uncertainty in this parameter value.

Path Forward: K_d values for I that are consistent with measurements made for simulated saltstone should be used in the PA. NRC suggests that future research include the sorption of Ra onto simulated saltstone, particularly under oxidizing conditions.

SP-15 **Comment:** The basis for the adopted technetium pseudo-K_d of 1,000 mL/g for reducing conditions is not sufficient.

DOE Comment Discussion: The DOE response to this comment states that,

> *"(t)he technetium K_d value selected for the shrinking core model (1,000 mL/g) is a lower bound on the values recommended in SRNL-STI-2009-00636 for cementitious materials of varying age. The selected value also creates margin in comparison to the recommended value (5,000 mL/g) for young and medium age cementitious material. This margin can be used to account for uncertainty in the recommended value."*

NRC staff does not believe that the "recommended values" of 1000 mL/g or 5000 mL/g are applicable to the saltstone wasteform for the following reasons:

1) *The 5000 mL/g value was measured for a formulation that included a strong reducing agent and is very different than the saltstone formulation.*

According WSRC-TR-2006-00004 and WSRC-STI-2007-00640 the "recommended" value of 5000 mL/g K_d is originally based on a measurement value from Bradbury and Sarott (1995). The Bradbury and Sarott (1995) reference states "(i)n some recent work, using Tc(IV) at trace levels (<10E-11 M) and sodium dithionite as reducing agent, distributions of ~5 m^3/kg (5,000 mL/g) have been reported (Bayliss et al., 1991)."

Because saltstone does not have the strong reducing agent sodium dithionite in it, this measured value is in no way applicable to the saltstone wasteform. In addition, the Bayliss et al., reference cited by Bradbury and Sarrott is a symposium presentation that does not seem to be peer reviewed. It is inappropriate to use a non-peer reviewed source as the basis for a key assumption that strongly affects the calculated dose.

Similarly, staff from SRS have also told NRC staff that research described in Lukens et al., (2005) provided evidence that Tc would be reduced in saltstone (see meeting summary at ML101790054 [NRC, 2010b]). NRC staff disagrees with this statement because the reducing agent Na_2S was added to the waste simulant to reduce it in these experiments and this reducing agent is not added to the salt waste processed at the SPF.

2) *SRS staff measured much lower Tc K_d values for saltstone.*

In SRNL-STI-2009-00636, the measured K_d values for Sample Tr547, which has a composition similar to saltstone, ranged from 9.1 to 56 mL/g after 4 days (Table

10.30). It is not clear why this information is not being considered in the PA, and NRC staff believes that in the absence of any relevant experimental data (i.e., using a wasteform formulation that is comparable to saltstone and does not include a strong reducing agent), it is not reasonable to discount experimental results.

3) *If is unclear if the saltstone pore fluid has reducing conditions.*

The redox conditions of waste are important for the release of Tc from the wasteform because under reducing conditions Tc is expected to be retained much more strongly under reducing conditions than under oxidizing conditions. In SRNS-STI-2008-00045, Figure 5, the reported Eh value approaches 0 mV as water flows through the system. Additionally, it is not clear that the Eh measurements were measured correctly. On June 29, 2010, NRC staff and SRS staff held a phone call to discuss the Eh measurements described in this report (see ML101790054 for summary of call). During this call, NRC staff asked what electrode was used and whether the reported values were corrected for the particular reference electrode used (i.e., referenced to a standard hydrogen electrode). SRS site staff stated that the electrode used in their experiments was an Ag/AgCl electrode and that the reported values were read directly from the instrument and were not corrected for the particular electrode used. It is the conclusion of the NRC staff that these redox potentials were incorrectly reported, and based on the half-cell potential of the Ag/AgCl electrode, the true Eh in this system would be 200 mV higher, or less reducing, than was reported.

NRC staff recognizes that the K_d tests for the sorption of Tc onto saltstone were intended to evaluate the transport of Tc through the saltstone once it has been released, rather than the release of Tc. However, because no relevant leaching data has been provided to the NRC, the K_d values measured by SRS for Tc represent the best available information on the release of Tc from the saltstone wasteform.

NRC staff is unable to conclude that the Tc will be retained by the saltstone wasteform to the extent that was assumed in the PA in the absence of appropriate data that clearly demonstrate that this assumption is valid. NRC staff, absent new information and bases on Tc leaching and K_d's, will use the site-specific K_d values measured by SRS staff for the sorption of Tc onto saltstone in their independent modeling analyses and in their conclusions in the TER.

Path Forward: Use a K_d value that is consistent with the values measured by SRS staff for the saltstone wasteform in the PA.

SP-16 **Comment:** The basis for the range of reduction capacities over which the shrinking-core model transitions to oxidizing K_d values for technetium is not clear.

NRC Response: The DOE response is adequate.

SP-17 **Comment:** Neglecting gas-phase diffusion of oxygen appears to be inconsistent with the PORFLOW result that saltstone fractures are not completely saturated.

DOE Comment Discussion: The DOE response indicated that the transport of oxygen via the liquid phase is generally sufficient to keep the fracture faces near the oxygen solubility limit for Case C except at times less than 1,000 years, due to the very low flow through the cover system (and fractures) for those time periods. The impact of not addressing gas phase diffusion for Case E was considered minimal during the compliance period, since the FDC barrier is intact and effectively would maintain saturated conditions, thus supporting the assumption of saturated conditions being a barrier to gas-phase oxygen transport.

It is not clear to NRC staff that the transport of oxygen via the liquid phase for Case C is realistic or conservative as, (i) the flow of oxygen at early times may be underrepresented in the model due to very low flow through the fractures, (ii) the flow through the fractures in Case C remains low throughout the compliance period, and (iii) the difference between the transport of oxygen via the liquid phase and the gas phase may have an appreciable difference on the dose estimates. In regards to Case E, the impact of ignoring gas phase diffusion due to the performance of the FDCs resulting in saturated conditions is not appropriate as (i) the PORFLOW model appears to indicate saturation levels in the fractures for Case E at 40-50% and (ii) the performance of the FDCs as a hydraulic barrier should be reevaluated in light of recent hydrostatic tests (Comment VP-5).

Path Forward: Provide additional basis for neglecting gas-phase oxygen diffusion in cases representing fractured and degraded saltstone or provide updated dose estimates for cases representing fractured and degraded saltstone considering the potential effects of gas-phase oxygen diffusion.

SP-18 **Comment:** Additional justification is required for the uncertainty ranges used for K_d values in cementitious materials.

DOE Comment Discussion: The DOE stated that the selection of the uncertainty distributions used for the K_d values were based on >730 K_d measurements of 8 radionuclides taken from 27 samples collected from the E-Area vadose and aquifer zones, as discussed in WSRC-STI-2008-00285. The provided reference indicated that the 27 depth-discrete samples were collected from a single borehole from E-Area. Variability in the distributions was attributed to general geochemical/geological differences in the site soils. The resulting data was used to estimate the statistical range and distribution of the K_d values for the studied radionuclides. Using these 8 radionuclides as analogues, the distribution coefficient variability was applied to >50 radionuclides. As site-specific cementitious K_d values were not available, the general rules for bounding the sandy sediment were applied to cement. This uncertainty range was considered conservative as SRS sediment is more heterogeneous than cementitious materials, which also contain fewer minerals than natural sediments.

NRC staff agrees that natural SRS sediment is likely more heterogeneous and has more minerals than cementitious materials; however, the heterogeneity and number

of minerals does not dictate the potential range of K_d values. The relatively limited number of minerals in cementitious materials makes these materials less likely to have as large a range of K_d values as a natural soil; however, even two minerals with different surface chemistry can lead to significant variability. Research by Baur and Johnson (2003) demonstrated that the K_d for selenium can vary by more than two orders of magnitude depending on the cement phase.

The limited site-specific K_d data and an insufficient technical basis for adapting K_d values from sediment samples to cementitious materials results in significant uncertainty. An increase in the range of K_d values for cementitious materials over sediment samples is not a basis for uncertainty conservatism. Compensation for insufficient data by an increase in a parameter distribution range provides no additional confidence and it could (i) result an unnecessary degree of conservatism or (ii) result in risk dilution due to an artificial extension in the timing of arrival of a contaminant.

The lack of site-specific data demonstrates the importance of an appropriate base case such that a sensitivity and uncertainty analysis could inform research needs to evaluate the variability of data and reduce data uncertainty. Sorption of radionuclides to cementitious materials provides a significant barrier in the PA. Data support for these K_d values should be commensurate with the assumed risk reduction.

Path Forward: Depending on the extent to which DOE will rely on the GoldSim model, provide additional support for using the sandy-soil-based uncertainty distribution for cementitious materials K_d values and a basis for concluding that this approach does not underestimate uncertainty in radionuclide sorption to cementitious materials. For example, additional support could include laboratory analyses for risk-sensitive radionuclides. Plans for developing data support may provide appropriate basis, because NRC could verify the implementation of those plans in its monitoring role.

SP-19 **Comment (New):** Research related to the release of Tc-99 from saltstone appears to be inconsistent with the Tc-99 releases modeled in the PA.

Basis: As discussed in WSRC-STI-2007-00056, experiments on Tc-99 leaching from saltstone simulated grout were conducted and the results incorporated into PORFLOW modeling. Figure 1 shows the modeled release of Tc-99 according to WSRC-STI-2007-00056 and the 2009 Saltstone PA. The modeled Tc-99 release for WSRC-STI-2007-00056 is approximately 60% over the 10,000-year compliance period for saltstone with a hydraulic conductivity of 1E-9 cm/s, which is slightly less than the assumed hydraulic conductivity in the 2009 PA of 2E-9 cm/s. According to the PORFLOW model files in the 2009 PA, the predicted release of Tc-99 from the saltstone material is 0.6% for the base case and 9.6% for the synergistic case.

The research presented in WSRC-STI-2007-00056 demonstrated the release of Tc-99 due to the presence of residual oxygen for an intact saltstone monolith. Residual oxygen would be consistent with field conditions at the SDF as would the

transport of gas and liquid-phase oxygen to the fractured vaults and saltstone. In addition, the saltstone grout has been shown to be fractured which would increase the surface area-to-volume ratio, thereby increasing the oxidation of saltstone.

NRC staff recognizes that research is ongoing and that the results presented in Figure 1 below are based on a modeled system. However, this model is parameterized from experimental results conducted with a saltstone simulant whereas the shrinking core model utilized in the PA is less empirical. Additionally, some key parameters of the shrinking core model, such as the Tc K_d are based on a formulation that is drastically different than saltstone (see SP-15).

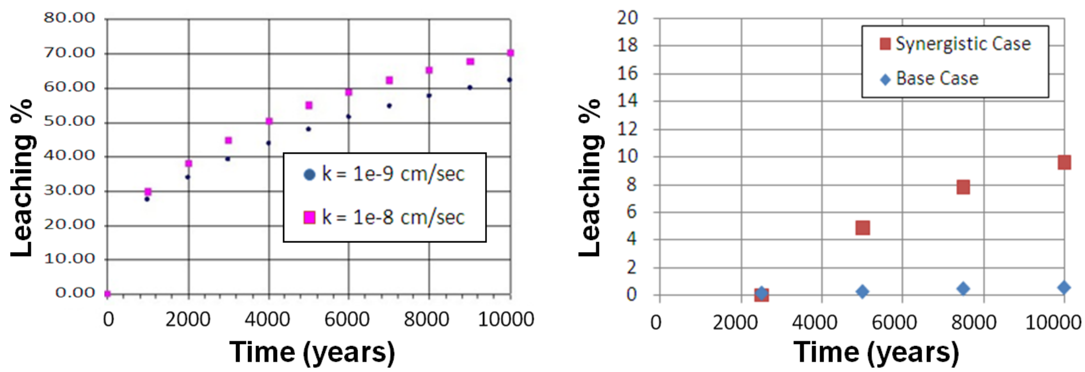

Figure 1: Tc-99 release over the 10,000-year compliance period based on results (a) WSRC-STI-2007-00056 and (b) the 2009 PA model results

Path Forward: The PA should be consistent with relevant research or justification should be provided discussing why it was excluded. Provide any additional references on Tc-99 leaching from saltstone that have not already been provided to the NRC.

Vault Performance

VP-1 **Comment:** Additional analysis is needed to assess the applicability of the degradation mechanisms responsible for the observed fracturing of Vaults1 and 4 walls and the degradation mechanisms described in SRS-REG-2007-00041 to the FDCs and to other parts of Vaults 1 and 4.

NRC Response: The DOE response is adequate at this time; the NRC staff is continuing to review several of the references that were provided by the DOE.

VP-2 **Comment:** Additional basis is required for neglecting disposal unit degradation mechanisms other than sulfate attack.

DOE Response Discussion: The DOE response contained two main elements: sensitivity analyses and ongoing research. A sensitivity case was provided with what DOE believes is pessimistic assumptions that demonstrated the doses would remain marginally below 25 mrem/yr. The DOE response did not address the NRC requests

to address corrosion cracking or to provide analog information as technical basis (e.g. model support).

The response is mostly complete, but as previously indicated issues or uncertainties should be reflected in the base case and not in an alternative analysis case. For example, the analysis presented shows that the dose could approach 25 mrem/yr. Combined with any other issue that moderately increases the dose independently from this analysis, the performance objective could be exceeded. The original NRC comment provided many technical considerations that should result in modifications to the base case, based on DOE's currently available supporting information.

Path Forward: Update the base-case model to reflect the potential effects of applicable degradation mechanisms and their uncertainties based on currently available information.

Provide justification for neglecting other forms of degradation of disposal unit cementitious materials, including alkali silica reaction, corrosion cracking, and other relevant forms of degradation. The justification should address Vaults 1 and 4 floors and roofs as well as FDC walls, roofs, and floors.

If maintenance of an alkaline pH near steel components of the disposal units is relied upon to demonstrate steel passivity, the model generating predicted pH values should account for local effects near steel components (e.g., pH depression by carbonation in fractures near steel components) or address why such phenomena can be neglected.

A summary of observed reinforcement corrosion of concrete at SRS should be provided. Provide information to demonstrate that modeling of engineered systems in this application is consistent with observed performance of analogous systems at SRS.

VP-3 **Comment:** The effect of modeling disposal unit floors as completely reducing for the entire performance period, and beyond 20,000 years, should be analyzed.

DOE Response Discussion: The DOE response stated that the exposed surfaces of the vault concrete floor begin oxidizing at time zero. The chemical transition times for the various cementitious materials were presented in Table 4.2-17 of the PA, as computed in PORFLOW except for the shrinking core simulations. The shrinking core model explicitly simulated the oxidation of saltstone and the vault concrete for Tc-99 simulations.

The shrinking core model represents a uniform oxidation front with an unreacted core. Rapid transport of redox-sensitive radioelements (e.g., Tc-99) through the oxidized region would occur followed by immobilization once the radionuclide reached the core. However, a fracture in the vault floors would quickly result in a non-reducing fast pathway. It is not clear that DOE has conducted adequate characterization of the floor to support the assumption that the floor is not fractured (initially or at any future time) in the base case. Based on the demonstrated floor

performance of Vault 2 (due to cracking near anchor bolts) during recent hydrotesting, it is also not clear that the assumption of no fractures in the floors of Vaults 1 and 4 in the base case is realistic as Vaults 1 and 4 floors also contain anchor bolts. NRC staff understands that Vaults 1 and 4 floors are 24 inches thick versus 8 inches thick for the Vault 2 design which may affect the potential for fracturing at the anchor bolt sites.

Path Forward: Vault floor fractures should be included in the base case or provide a technical basis for not including this feature in the base case in light of limited vault floor characterization and the performance of the FDCs.

VP-4 **Comment:** The effects of the potential inventory in Vaults 1 and 4 floors on radionuclide release should be analyzed.

NRC Response: The response is adequate. NRC staff agrees that the potential initial inventory in the floor is likely to be relatively small and not risk-significant.

VP-5 **Comment (New):** The uncertainty in the performance of the vaults is not adequately represented in the PA and the PORFLOW model.

Basis: Recent hydrostatic tests for Vault 2, Cells 2A and 2B have demonstrated the complexities and uncertainties regarding the hydraulic integrity of engineered barriers. Discrete engineering features that can drive system performance are not captured within the PA. Features such as material interfaces, the vault liner coating, and anchor bolts led to unanticipated vault performance (SRR-CWDA-2010-00099). DOE has taken steps to eliminate the issues regarding these features; however, the unanticipated leak test results are indicative of optimistic performance assumptions regarding the hydraulic properties of the FDCs, as well as Vaults 1 and 4. The long-term performance of these engineered barriers has uncertainty that is not adequately represented in the PA.

The discrete features that have driven the performance of Cells 2A and 2B in the hydrotests are not currently incorporated into the PORFLOW analysis. Accordingly, the model would be inadequate with respect to the representation of these failures. The PORFLOW model does not include the potential for discrete failures beneath the anchor bolts, flawed liner coatings, or the discrete material interfaces.

Based on conversations with SRR staff, the recent FDC leaks are not considered significant to the performance of these vaults and they do not significantly impact the conclusions of the PA; the presence of engineered barriers such as the shotcrete and the HDPE-GCL around the FDCs provide a defense in depth. Due to the additional reliance on these engineered barriers and very limited performance data for the relatively unique applications of these barriers, additional model support would provide necessary confidence. Additionally, it is not clear that the HDPE/GCL was a completely redundant barrier i.e., the expected flow and transport through the HDPE/GCL may be correlated to the performance of FDCs.

Path Forward: Provide a technical basis demonstrating that recent events and

discrete features will have a negligible impact on the dose results. This may include demonstration that barriers in addition to the FDC vaults will provide compensatory performance, such that the conclusions of the PA are not affected by (i) the observed performance of the FDCs to date and (ii) reasonably expected future performance.

Alternatively, reevaluate the expected performance of Vaults 1, 2, and 4 in light of evidence demonstrating the significance of discrete features. Reevaluation of vault performance may indicate that these discrete features should be incorporated into PA models.

VP-6 **Comment (New):** The bypassing of flow through Vaults 1 and 4 walls may not have a physical basis.

Basis: In Section 5.6.3.1, DOE discussed the result of water preferentially flowing through the vault walls and around the saltstone wasteform, which is due to the hydraulic model parameters for the Saltstone vaults and wasteform. The hydraulic conductivity of the walls for Vaults 1 and 4 for all cases in the PA is 4 orders of magnitude greater than that of the backfill or native soil. Although degrading the vault walls is locally conservative, globally the result is non-conservative. If there is not a physical basis for the walls to hydraulically degrade to the extent discussed in the PA, then the flow through the saltstone wasteform would be underestimated.

Path Forward: Provide additional support for the assumed hydraulic conductivity of the degraded Vaults 1 and 4 walls that result in the modeled bypassing of flow around the saltstone wasteform.

<u>Far Field Transport (FFT)</u>

FFT-1 **Comment:** Additional justification is required for the uncertainty ranges used for K_d values in site soils.

DOE Response Discussion: The DOE stated that the selection of the uncertainty distributions used for the K_d values were based on >730 K_d measurements of 8 radionuclides taken from 27 samples collected from the E-Area vadose and aquifer zones, as discussed in WSRC-STI-2008-00285. The provided reference indicated that the 27 depth-discrete samples were collected from a single borehole from E-Area. Variability in the distributions was attributed to general geochemical/geological differences in the site soils. The resulting data was used to estimate the statistical range and distribution of the K_d values for the studied radionuclides. Using these 8 radionuclides as analogues, the distribution coefficient variability was applied to >50 radionuclides.

WSRC-STI-2008-00285 evaluated the vertical variability of K_d values for 8 different radionuclides; however, lateral variability and radionuclide-specific chemistry may also affect K_d variability. Section 3.1.4.2 discusses the complexity and variability of the local geology and soils and it is not clear that a single borehole from E-Area would be representative of the soils at Z-Area. In addition, it is not clear that the

variability in K_d values for 8 radionuclides would adequately capture the variability of all 50+ radionuclides.

Path Forward: Depending on the extent to which DOE will rely on the GoldSim model, provide additional basis regarding the ability of K_d measurements on sediment samples from a borehole at E-Area for 8 radionuclides to bound the potential variability of >50 radionuclides at Z-Area.

FFT-2 **Comment:** It is unclear whether any site-specific K_d value measurements have been performed for the sorption of radium to soil.

NRC Response: The answer to this RAI is adequate, but NRC staff would appreciate receiving the document described in the response to this comment (SRR-CWDA-2010-00057) if it has been issued. If the measured K_d value is significantly different than the one assumed in the PA, the new value should be used in a revised base case.

FFT-3 **Comment:** Additional justification is needed for the K_d of selenium in vadose and backfill soils.

DOE Response Discussion: The DOE stated that a K_d for selenium of 1,000 mL/g is representative of a low pH soil and a low pH soil is considered appropriate as measurements ranged from 5.3 to 5.7 in the Z-Area background well, ZBG-1 (SRNS-TR-2009-00452). The impact of alkaline buffering on the selenium K_d values was evaluated in the probabilistic GoldSim model by using a minimum value of 250 mL/g, to account for the leaching of young-age cement. In addition, DOE ran a bounding sensitivity case using the Case A GoldSim model with both backfill and vadose zone soil K_d values for selenium set equal to zero. The effect on peak dose was less than 3% for Sector B within 20,000 years. DOE stated that the bounding sensitivity analysis provides confidence that lowering the selenium sorption onto soils has a negligible impact on dose results.

Although 3% represents a small absolute increase in dose, it represents a large relative increase in the dose derived from Se-79. According to SRNS-TR-2009-00452, the pH range of 5.3-5.7 appears to be too narrow for the Z-Area. Three wells within the Z-Area demonstrated pH values in excess of 5.7 and as high as 7. ZBG-1 represents the background well for the site; however part of NRC staff's concern is the variability across the site, including the potential impact of the cementitious materials in the SDF. In addition, the sensitivity case provided by DOE does not provide confidence as the conservatism of these sensitivity cases is unclear.

Path Forward: Depending on the extent to which DOE will rely on the GoldSim model, the selenium K_d values for soil should account for site variability in current conditions as well as reasonably expected future conditions.

SRNS-TR-2009-00452, Z-Area Groundwater Monitoring Report for 2009, Savannah River Site, Aiken, SC, December 29, 2009.

Provide reference Kaplan, D. I., and S. M. Serkiz, 2006. *WSRC-RP-2006-00005, Influence of Dissolved Organic Carbon and pH on Anion Sorption to Sediment*, Washington Savannah River Company, Aiken, SC.

FFT-4 **Comment (New):** The PA should discuss the implications of calcareous zones within the far field transport model.

Basis: The presence of calcareous zones may require alternative flow conceptualization and modeling. Depending on the extent of these zones within the lower Upper Three Runs (UTR) aquifer, a dual porosity and dual permeability model may better represent flow through a porous matrix and open conduits. The presence of open conduits may (i) lead to preferential flow pathways through the subsurface, (ii) influence the location of the point of maximum exposure or compliance point, (iii) lead to decreased natural attenuation (sorption) to subsurface materials due to a decreased solids to pore water ratio, and (iv) lead to reduced K_d values for key radionuclides (e.g., Pu) due to elevated concentrations of carbonate, or non-equilibrium sorption due to the fast transport rates.

Path Forward:

1) Provide a technical basis for neglecting potential open flow conduits within the calcareous zone of the lower UTR aquifer.
2) Provide support for the treatment of the calcareous zones as porous media in transport modeling in light of the fact that decreased solids and presence of high carbonate concentrations can lead to significantly higher mobility for key risk drivers such as Pu.
3) Provide the report, Mueser, Rutledge Consulting Engineers (1986) Saltstone disposal, Z-Area SRP, cited in WSRC-TR-99-4083, “Significance of Soft Zone Sediments at the SRS” that may contain additional information to evaluate the scope and magnitude of calcareous zones in the Z Area subsurface.

<u>Air Pathway</u>

AP-1 **Comment:** The dose from the radon pathway was not included in the dose assessment of the air pathway (Section 4.5 of the PA).

NRC Response: The DOE response is adequate.

AP-2 **Comment:** The calculations used for the air pathway dose may not have adequately evaluated the dose from this pathway. The materials were assumed to remain constant over the simulation period and degradation of the wasteform and vault does not seem to have been considered. Also, the sensitivity of the calculated land surface flux rates of radionuclides to the assumed moisture content in the cover was also not evaluated.

NRC Response: The DOE response is adequate.

<u>Inadvertent Intrusion</u>

II-1 **Comment:** Key assumptions about the potential pathways of exposure of an inadvertent intruder appear to underestimate dose.

DOE Response Discussion: In the analysis described in the PA, the intruder analysis was performed at a location of one (1) meter from the boundary of the SDF, which is one meter from some of the FDCs. In response to the NRC comment that the dose at one meter from Vault 4 may be higher, DOE provided a revised analysis that includes the dose at a distance of one meter from Vault 4. NRC staff finds that this portion of the response was acceptable (with the caveat that NRC staff does not agree with the use of Case A [see II-2]).

NRC staff also commented that the one-meter concentrations used in the intruder analysis were based on a 15.2 m (50 ft) grid that began at a distance of one meter from the disposal cells. NRC staff did not believe that it was appropriate to average the concentrations over this large a grid because the concentration of radionuclides that decay relatively quickly and are transported slowly may be very different over the 15.2 m (50 ft) cell. The new calculation for Vault 4 provided by DOE conservatively assumes that the concentration at one meter is equal to the concentration calculated under Vault 4. This response is acceptable to the NRC, but the NRC staff would like additional clarification on the Darcy Velocity assumed in this calculation.

The calculated dose at a distance of one meter from the FDCs was not evaluated in a similar manner and is still based on the concentration averaged over the 15.2 m (50 ft) grid. NRC staff needs an assessment of the dose at one meter from the FDCs to evaluate if the performance objectives can be met.

Additionally, as discussed in more detail in B-2, NRC staff does not agree with the exclusion of the poultry and egg pathway from the dose assessment and NRC staff believes that this should be included in the dose assessment for the intruder.

Path Forward: Provide an evaluation of the effect of the grid size assumption for the FDC. Consider the effect of including the poultry and egg pathway on the intruder (see B-2).

Provide a clarification on the Darcy Velocity assumed in the intruder calculation for Vault 4.

II-2 **Comment:** The basis for the use of Case A to calculate the intruder dose is not provided. Additionally, the methodology used for determining the key radionuclides for the intruder uncertainty/sensitivity analysis may have resulted in radionuclides that are risk significant to the intruder being excluded from this analysis. As a consequence, the results of the uncertainty/sensitivity analysis may not capture the true uncertainty in the intruder dose.

DOE Response Discussion: The response to the RAI provided by DOE states "(t)he deterministic intruder analysis results are based on Case A because Case A represents the reasonably expected degradation configuration for the SDF disposal units". As stated in PA-8, the NRC staff believes that Case A is very optimistic and is not supported. NRC staff needs an intruder assessment that is based on a credible compliance case that includes all risk significant radionuclides to determine that compliance with the performance objectives of 10 CFR 61 can be met.

In the RAI response, DOE stated that the SDF PA Section 6.5 presents results that address the effects of uncertainty on the estimation of intruder dose and that the calculated mean dose to the intruder for all cases (Cases A through E) is less than 10 mrem/yr. NRC staff recognizes that the GoldSim uncertainty analysis considers the other, more realistic degradation cases. However, NRC staff has some concerns about the GoldSim modeling calculations (see PA-11), and it is not clear that the doses calculated using the GoldSim model are reasonable or meaningful.

Additionally, DOE stated in the RAI response that the potential dose to the intruder associated with the other cases can be inferred based on the dose results at 100 m presented in the SDF PA Section 5.6.6. NRC staff disagrees with this statement because radionuclides that are transported slowly and decay relatively quickly (e.g., Sr-90 and Cs-137) could cause a significant dose at a distance of one (1) meter, but it is unlikely that these radionuclides would travel quickly enough to reach 100 m before decaying. These radionuclides might not be modeled as being released quickly enough in Case A to be a problem at one (1) meter, but they could be released more quickly if more water enters the system than was predicted in that model.

Path Forward: Provide an assessment of the intruder dose based on a realistic and reasonable compliance case.

<u>Biosphere</u>

B-1 **Comment:** The basis for excluding biotic transfer factors from the uncertainty analysis is unclear.

DOE Response Discussion: The DOE response indicated that uncertainty in biotic transfer factors did not result in large changes to the total dose, therefore uncertainty in the transfer factors were not included in the probabilistic analysis. The absolute changes to dose as a result of biotic transfer factor uncertainty was small, however the relative changes were moderate to significant. The impact of biotic transfer factor uncertainty should be part of the base case assessment.

This comment has been expanded to include plant transfer factors and the conceptual approach for developing the values for the distributions and the expected values for the base case. Biotic transfer factors directly influence calculated doses and can have very broad ranges. In many instances, the DOE recommended values are equal to the minimum value of the distribution (for plant transfer factors, at almost

a three to one ratio compared to values set to the maximum of the distribution). In effect, the distribution is defined such that the actual value will not be lower than the most likely value and the actual value is expected to be higher. These types of distributions are inconsistent with real world data and lack a conceptual basis.

Part of the reason for the distributions appears to be the derivation process documented in WSRC-STI-2007-00004. The process is not supported. DOE had derived transfer factors then updated them with a variety of sources, but primarily from PNNL-13421. For many transfer factors, the updating was performed by calculating a geometric mean of the old and PNNL-13421 values. This approach has no basis, and can result in a significant underestimation of biotic pathway doses. For example, the soil to plant transfer factor for Ra (a key radionuclide) was reduced by a factor of 100 from the previous value using this approach. A footnote infers that the PNNL-13421 values are site-specific, but NRC review of the reference indicates that the values are not site-specific but simply represent a different compilation of values.

Transfer factors operate on the concentrations derived at the end of the calculation, and can have very broad ranges. Many have very few observations. For the most part, the variance in observed values represents real world variability. Use of a geometric mean can result in a high likelihood of the actual value exceeding the assumed value and exceeding it by a large margin. Without actual site-specific measurements, transfer factors have to be selected conservatively.

Path Forward: Provide technical basis for the expected value and distributions of transfer factors used in the analysis. The results should not be aggregated with a geometric mean transfer factor.

B-2 **Comment:** The animal product pathways included in the dose assessment are the beef, milk, and finfish pathways. A basis for excluding the other animal product pathways (e.g., consumption of poultry and eggs) from the dose assessment is not provided.

DOE Response Discussion: In the response to this comment, DOE states that the exposure pathway for poultry and eggs is not included in the SDF PA compliance model based on a survey of local practices within 50 miles of the SRS. WSRC-RP-91-17 cites a personal communication from T. Mathis who indicated that it is the local practice to source poultry feed from offsite. Based on this communication, DOE excluded poultry and eggs as an exposure pathway.

NRC staff believes that this study does not provide a sufficient technical basis to conclude that chicken feed is currently, or will in the future, be sourced from offsite. In addition, even if the poultry primarily consume commercial feed, the poultry may still consume other things (e.g. bugs and forage) which may contain site-derived radionuclides. Furthermore, the poultry would likely consume groundwater (extracted for domestic or agricultural purposes) from the site. For these reasons, the NRC staff does not believe it is appropriate to exclude the chicken and egg pathways from the PA.

Path Forward: Provide an evaluation of the dose to the member of the public and intruder from chicken and egg pathways.

B-3 **Comment:** The effects of radionuclide build-up in irrigated soils may be underestimated.

DOE Response Discussion: The DOE response indicated that use of a 30-year build-up time as compared to a 183-day build-up time for radionuclides in irrigated soils did not result in large changes to the total dose; therefore the effects did not need to be included in the base case.

Most releases from the SDF are expected to occur slowly over thousands of years. The 30-year buildup time may be exceeded for long-lived radionuclides, however NRC acknowledges that the assessment provided did not consider losses from erosion and leaching. Ambiguity could be reduced by including expected gain and loss processes to determine equilibrium build-up factors.

The absolute changes to dose as a result of increased build-up times were small; however the relative changes were significant. The impact of build-up time uncertainty should be part of the base case assessment.

Path Forward: Include build-up of radionuclides during multiple years of irrigation in the base case PA model.

B-4 **Comment (New):** The soil to plant transfer factors may be too low due to the elimination of the leafy plant component.

Basis: WSRC-STI-2007-00004 uses soil to plant transfer factors for non-vegetative portions of food crops because local productivity of non-leafy vegetables is expected to be considerably greater than that of leafy vegetables (based on WSRC-RP-91-17). However, the transfer factors for leafy vegetables can be considerably larger than non-leafy vegetables for key radionuclides. For example, the reference most used as a source of transfer factors in the current analysis (PNNL-13421) has a factor of 210 for leafy vegetables and a value of 0.24 for non-leafy vegetables for Tc. At a 13% leafy vegetable fraction, the vegetable pathway dose from Tc would be over 100 times larger with the leafy and non-leafy components calculated separately and then combined compared to assigning all vegetables as non-leafy. In addition, the WSRC-RP-91-17 reference may have underrepresented garden production data due to limited survey response.

Path Forward: Include the leafy vegetable pathway explicitly in the plant pathway dose calculation. Consider using EPA or NRC references for garden productivity data.

B-5 **Comment (New):** The drinking water ingestion rate of 337 L/yr is inconsistent with an average member of the critical group definition.

Basis: The drinking water ingestion rate is calculated by taking the mean per capita total water ingestion of 1233 mL/day and multiplying by the 75% value from community water. However, this is weighting the critical group member's consumption rate by the type of group the critical group member is in. Given the current site usage and definition of the receptor as a resident farmer, the drinking water consumption rate should be a minimum of 87% of the total water ingestion rate (subtract out the bottled water fraction). Consideration should also be given to adjusting the values for a receptor engaging in a more labor-intensive lifestyles than average in a climate that is warmer than average.

Path Forward: Modify the drinking water consumption rates to be consistent with the defined receptor and scenario.

ALARA analysis

A-1 **Comment:** Social, economic, and public policy considerations do not appear to have been considered in an analysis of maintaining doses "As Low As is Reasonably Achievable" (ALARA).

DOE Response Discussion: The response to this RAI states that "the estimated dose pathways evaluated in the PA are well below the performance objectives; therefore, a qualitative assessment of disposal alternatives is justified." NRC staff agrees with the concept that a less detailed ALARA is required when the predicted doses are low, but NRC staff would like to note that an assessment that includes the concerns raised in other RAIs (e.g., PA-11, PA-13, IN-1, etc.) may result in a higher calculated dose. In addition, the response to this RAI did not include a discussion on the processes that are being used to minimize the inventory that is disposed of at the SDF. A discussion on maintaining the worker dose at levels that are ALARA was also not included.

Path Forward: Provide additional information on the methodology used to minimize the inventory of radionuclides that are sent to the SDF. Also, provide more details on the controls that exist to minimize the dose to the workers.

Clarifying Questions

As mentioned in the Structure of Comments section of this RAI, the staff found the remaining clarifying comment responses, not referred to in the section below, to be acceptable. In addition to referring to one Clarifying Comment from RAI-2009-01, the staff has added new clarifying comments in RAI-2009-02.

C-4 **Comment:** Clarify the basis for the selenium K_d of 150 mL/g for old oxidizing conditions. It is not clear from the PA, or the supporting report WSRC-STI-2007-00640, how the value was selected. Clarify whether the evaluation considered the presence in solution of the selenium as selenate, which is potentially less sorptive than selenite.

DOE Response Discussion: The DOE discussed site-specific batch experiments that showed selenium K_d values ranging from 29.7 to 78.5 mL/g. These experiments were discounted in favor of literature values due to the aqueous selenium concentrations being near the detection limits. The basis for the selenium K_d of 150 mL/g for old oxidizing conditions relied on the values reported in "Sorption of Selenite and Selenate to Cement Materials" (Baur and Johnson 2003). DOE stated that selenite is expected to convert to selenate under old oxidizing conditions and that the K_d values for selenate from the report by Baur and Johnson (2003) were between 180 and 380 mL/g. DOE further stated that as cementitious materials degrade, the selenium sorption constants (K_d = 1041 mL/g) approach that of the sediment. Selenium sorption was stated as being very high due to the ubiquitous presence of iron oxides and low pH of the sediment.

The K_d values of 180 and 380 mL/g reported in "Sorption of Selenite and Selenate to Cement Materials" were for selenite, not selenate. Baur and Johnson (2003) reported no significant update of selenate with calcium-silicate-hydrate (C-S-H) and only limited sorption with ettringite. Furthermore, it is not clear why the sorption coefficient for selenium would approach that of sediment as cementitious materials degrade. The chemistry of degraded cementitious material would not be expected to have the same chemical properties as sediment (high iron content and low pH), which is responsible for the high sorption coefficient for selenium.

Path Forward: Provide support for the selenium K_d of 150 mL/g for old oxidizing conditions or revise the base case K_d value.

C-8 **Comment:** For benchmarking cases B-E (Sections 5.6.2.3.5 though 5.6.2.3.8), the PA compares the doses predicted based on the PORFLOW model and post-benchmarking GoldSim model resulting from "all modeled radionuclides". Clarify whether the term "all modeled radionuclides" in this context refers to the original list of radionuclides included in the PORFLOW model or a smaller list of radionuclides modeled during the benchmarking effort.

DOE Response Discussion: The response to this clarifying comment only addressed the radionuclides included in the Case A PORFLOW and the GoldSim calculations. The radionuclides included in the PORFLOW calculations for Cases B-E were not discussed.

Path Forward: Provide a list of the radionuclides provided in the PORFLOW calculations for Case B, Case C, Case D, and Case E.

C-22 **Comment (New):** Figure 4.2-15 in the PA shows the vertical hydraulic conductivity of the lower lateral drainage layer reducing in time to approximately 4E-5 cm/s by 20,000 years. However, the PORFLOW model files indicate that the hydraulic conductivity is only reduced to 4.9E-3 cm/s for all cases. The flux out of the vaults is directly dependent on the infiltration rates. As indicated in IEC-8, the conservatism of the calculations for the hydraulic conductivity of these lateral drainage layers is not clear and according to the PORFLOW model files, it is not clear if these calculations

were implemented appropriately. Clarify why different hydraulic conductivity values were implemented in the PORFLOW model.

C-23 **Comment (New):** WSRC-STI-2008-00244 discussed the installation quality of the geomembrane as "Good"; however, the HELP model also requires the specification for the placement quality of the geomembrane. The Help model input data in Appendix J of WSRC-STI-2008-00244, listed the geomembrane placement quality as a "2". According to the "HELP User's Guide for Version 3" (Schroeder et al., 1994), an entry of 2, "assumes exceptional contact between geomembrane and adjacent soil that limits drainage rate (typically achievable only in the lab or small field lysimeters)." The basis for selecting the placement quality of the geomembrane should be provided.

References

[1] Baroghel-Bouny, V., Mainguy, M., Lassabatere, T., and Coussy, O. *Characterization and identification of equilibrium and transfer moisture properties for ordinary and high performance cementitious materials*, Cement and Concrete Research, Vol. 29, pp. 1225-1238. 1999.

[2] Baur, I. and Johnson, C.A., *Sorption of Selenite and Selenate to Cement Minerals*. Environmental Science and Technology. Vol. 37. pp. 3,442-3,447. 2003.

[3] Bayliss, S., Haworth, A., McCrohon, R., Moreton, A., Oliver, P., Pilkington, N., Smith, A., and J. Smith-Briggs. *Radioelement Behavior in a Cementitous Environment*. E-MRS Symposium on the Scientific Basis for Nuclear Waste Management. 1991.

[4] Berner U.R., *Modeling the incongruent dissolution of hydrated cement minerals*, Radiochimica Acta, V. 44/45, pp. 387-393, 1988.

[5] Bradbury, M. H., and Sarott, F. A., *Sorption Databases for the Cementitious Near-Field of a L/ILW Repository for Performance Assessment*, PSI Bericht 95-06, Paul Scherrer Institute, Labor für Entsorgung, Würenlingen and Villigen, Switzerland, March 1995.

[6] CBU-PIT-2005-00131, *Response to Request for Additional Information on the Draft Section 3116 Determination for Salt Waste Disposal at the Savannah River Site*. Westinghouse Savannah River Company, Aiken, SC, June 30, 2005. ML051920416.

[7] ESH-WPG-2006-00132, Liner, K., *Z-Area Industrial Solid Waste Landfill Vault Cracking (U)*, Savannah River Site, Aiken, SC, October 19, 2006. ML101590241.

[8] Fuhrmann, M., and A.L. Schwartzman. *Corrected K_d Values for Selenium*. Health Physics. 94(2):192, February 2008.

[9] Henocq, P., E. Samson, and J. Marchand, *Influence of alkali chloride on surface properties and solubility of C-S-H*, in: J. J. Beaudoin, J. M. Makar, L. Raki (Eds.), 12th International Congress on the Chemistry of Cement, Cement Association of Canada, Montreal, Canada, 2007.

[10] Huysmans, M. and Dassargues, A. *Review of the use of Péclet numbers to determine the relative importance of advection and diffusion in low permeability environments*. Hydrogeology Journal. Springer-Verlag, 2004.

[11] K-ESR-Z-00001, Li, W.T., *Saltstone Vault No. 2 Geotechnical Investigation Report*, Savannah River Site, Aiken, SC, Rev. 0, April, 2006. ML101590273.

[12] K-ESR-Z-00002, Williams, R.J., *Saltstone Disposal Cells No. 3 and 5 Geotechnical Investigation Report*, Savannah River Site, Aiken, SC, Rev. 0, July, 2009. ML102160523.

[13] LA-UR-01-4658, Nyhan, J.W., Koch, S.W., Balice, R.G., Loftin, S.R. *Estimation of Soil Erosion in Burnt Forest Areas of the Cerro Grande Fire in Los Alamos, New Mexico 2001*. ML102160532.

[14] Lukens, W.W., Bucher, J.J., Shuh, D.K., and N.M. Edelstein. *Evolution of Technetium Speciation in Reducing Grout*. Environmental Science and Technology. Vol 39. pp 8064-8070. 2005.

[15] LWO-CES-2006-00010, Miles W.C., *Savannah River Site Saltstone Disposal Facility Vaults 1 and 4 Overview*, Savannah River Site, Aiken, SC, October 19, 2006.

[16] Maltais Y., Marchand, J., et al. *Predicting the Durability of Portland Cement Systems in Aggressive Environments – Laboratory Validation Cement and Concrete Research* v. 34, p. 1579. 2004.

[17] NRC. *NUREG-1854, NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations, Draft Final Report for Interim Use*, U.S. Nuclear Regulatory Commission, Washington DC, August 2007. ML072360184

[18] NRC. *NRC Periodic Compliance Monitoring Report for U.S. Department of Energy Non-High-Level Waste Disposal Actions NUREG-1911, Rev. 1*. U.S. Nuclear Regulatory Commission. May 2008. ML091400501

[19] NRC. *Letter to T. Gutmann, DOE RE: NRC March 25-26, 2009 Onsite Observation Report for the SRS Saltstone Facility.* U.S. Nuclear Regulatory Commission. 2009a. ML091320439

[20] NRC. *August 2009 Summary of Meeting between NRC and DOE Regarding NRC Monitoring Activities at the SRS, Saltstone Facility.* U.S. Nuclear Regulatory Commission. 2009b. ML092650412

[21] NRC. *Letter to T. Gutmann, DOE RE: Request for Additional Information on the 2009 Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site*. March 31, 2010a. ML100820101.

[22] NRC. *June 1, 2010 Summary of Teleconference between NRC Staff and DOE Concerning Saltstone Monitoring Activities*. June 29, 2010b. ML101790054.

[23] Or, D. and M. Tuller, *Flow in unsaturated fractured porous media: Hydraulic conductivity of rough surfaces*, Water Resources Research, v. 36, n. 5, 1165-1177.

[24] PNNL-13421, Staven, L. H., Rhoads, K., Napier, B. A., and D. L. Strenge. *A Compendium of Transfer Factors for Agricultural and Animal Products*. June 2003. ML101600004.

[25] PNNL-13895, Cantrell K.J., Serne, R.J., and Last, G.V. *Hanford Contaminant Distirbution Coefficient Database and Users Guide* June 2003. ML102160535.

[26] PNNL-17859, Ward, A.L., Berlin, G.T., Cammann, J.W., Leary, K.D., Link, S.O. *Test Plan to Assess Fire Effects on the Function of an Engineered Surface Barrier* September 2008.

[27] Pruess, K., Faybishenko, B., Bodvarsson, G. *Alternative concepts and approaches for modeling flow and transport in thick unsaturated zones of fractured rocks*. Journal of Contaminant Hydrology 38, 281-322, 1999.

[28] Rockhold, M. L., Fayer, M. J., and Heller, P. R. 1993. *Physical and Hydraulic Properties of Sediments and Engineered Materials Associated with Grouted Double-Shell Tank Waste Disposal at Hanford, PNL-8813*, Pacific Northwest Laboratory, Richland, Washington. September 1993.

[29] Samson, E. and J. Marchand, *Modeling the Effect of Temperature on Ionic Transport in Cementitious Materials*, Cement and Concrete Research, Vol. 37, pp. 455–468, 2007.

[30] Savage, B. M. and Janssen, D. J. 1997. *Soil Physics Principles Validated for Use in Predicting Unsaturated Moisture Movement in Portland Cement Concrete*, ACI Materials Journal, V. 94, No. 1, January-February 1997, pp. 63-70. 1997.

[31] Schroeder, P.R., Lloyd, C.M., Zappi, P.A., and Aziz, N.M., *The Hydrologic Evaluation of Landfill Performance (HELP) Model User's Guide for Version 3, EPA/600/R-94/168a, Office of Research and Development*, United States Environmental Protection Agency (EPA), Cincinnati, OH, September 1994.

[32] South Carolina DHEC. *SC DHEC Letter to SRR RE: Conceptual Approval of Disposal of Low-Level Containerized Waste A-Area SDF*. September 30, 2010. ML103340171.

[33] SRNL-ESB-2008-00017, Dixon, K. L., *Video Survey of Saltstone Vault 4, Cell G*, Savannah River Site, Aiken, SC, April 25, 2008. ML090150154.

[34] SRNL-STI-2008-00421 Rev. 0, Dixon, K. L., et al., *Hydraulic and Physical Properties of Saltstone Grouts and Vault Concretes*, Savannah River Site, Aiken, SC, November 2008. ML090150298.

[35] SRNL-STI-2009-00115, Rev. 1, Flach, G.P., Jordan, J.M., and Whiteside, T., *Numerical Flow and Transport Simulations Supporting the Saltstone Disposal Facility Performance Assessment*, Savannah River Site, Aiken, SC, June 17 2009. ML101600028.

[36] SRNL-STI-2009-00150 Rev 1, McDowell-Boyer, L., and Kaplan, D.I., *Distribution Coefficients (Kds), Kd Distributions, and Cellulose Degradation Production Correction Factors for the Composite Analysis*, Savannah River Site, Aiken, SC, April 7, 2009. ML101600030.

[37] SRNL-STI-2009-00636, Lilley, M. S., Powell, B. A., and Kaplan, D. I., *Iodine, Neptunium, Plutonium and Technetium Sorption to Saltstone and Cement Formulations Under Oxidizing and Reducing Conditions*, Savannah River National Laboratory, Aiken, SC, December 19, 2009. ML102160549.

[38] SRNL-TR-2008-00283, Denham, M.E, *Estimation of Eh and pH Transitions in Pore Fluids During Aging of Saltstone and Disposal Unit Concrete*, Savannah River National Laboratory, Aiken, SC, 2008. ML101600203.

[39] SRNL-TR-2009-00019, Kaplan, D.I., *Tc and Pu Distribution Coefficients, K_d Values, for the Saltstone Facility Performance Assessment*, Savannah River Site, Aiken, SC, January 16, 2009. ML101600279.

[40] SRNL-TR-2009-00052, Rev. 1, Taylor, G. A., *Saltstone Disposition Facility Stochastic Transport and Fate Model Benchmarking*, Savannah River Site, Aiken, SC, May, 2009. ML101600290.

[41] SRNS-STI-2008-00045, Kaplan, D.I., Roberts, K., Coates, J., Siegfried, M., and Serkiz, S., *Saltstone and Concrete Interactions with Radionuclides: Sorption (K_d), Desorption, and Reduction Capacity Measurements*, Savannah River Site, Aiken, SC, October 30, 2008. ML100550022.

[42] SRNS-STI-2008-00050, Rev. 1, Langton, C.A. *Evaluation of Sulfate Attack on Saltstone Vault Concrete and Saltstone—SIMCO Technologies, Inc. Part I: Final Report*, Savannah River National Laboratory, Aiken, SC, 2009. ML100550017.

[43] SRNS-TR-2009-00452, *Z-Area Groundwater Monitoring Report for 2009*, Savannah River Site, Aiken, SC, December 29, 2009. ML102160563.

[44] SRR-CWDA-2009-00009, *Technical Review Comment Sheet on NRC Review of – Hydraulic and Physical Properties of Saltstone Grouts and Vault Concretes*, Savannah River Site, Aiken, SC, 2009. ML092650422.

[45] SRR-CWDA-2009-00010, *Technical Review Comment Sheet on NRC Review of – Evaluation of Sulfate Attack on Saltstone Vault Concrete and Saltstone, Part I: Final Report*, Aiken, SC, 2009. ML100550041.

[46] SRR-CWDA-2009-00011, *Technical Review Comment Sheet on NRC Review of - Thermodynamic and Mass Balance Analysis of Expansive Phase Precipitation in Saltstone*, Savannah River Site, Aiken, SC, 2009. ML092650424.

[47] SRR-CWDA-2009-00017, *Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site*, October 29, 2009. ML102090664.

[48] SRR-CWDA-2010-00009, *NRC Salt Waste Monitoring Open Item Status*, Savannah River Site, Aiken, SC, February 9, 2010. ML092920074.

[49] SRR-CWDA-2010-00033, *Comment Response Matrix for NRC - Requests for Additional Information on the Saltstone Disposal Facility Performance Assessment*. July 23, 2010. ML102090664.

[50] SRR-CWDA-2010-00057, *Preliminary Ra and SR K_d Values of Subsurface SRS Sediments*. May 6, 2010. ML102160133

[51] SRR-CWDA-2010-00099, *NRC Staff Salt Disposal Unit (SDU) 2 Status*. July 28, 2010. ML102180250

[52] SRR-ESH-2010-00030, *Savannah River Site (SRR) Memorandum to Inform the South Carolina Dept. of Health and Environmental Control (SCDHEC) of Change in the Grout Sampling Strategy*. August 6, 2010. ML103340178.

[53] SRS-REG-2007-00041 Rev. 1, Rosenberger, K.H., *Unreviewed Disposal Question Evaluation: Evaluation of Liquid Weeping from Saltstone Vault 4 Exterior Walls*, Savannah River Site, Aiken, SC, April 2008. ML090120134.

[54] T-CLC-Z-00006, Peregory, W., *Saltstone Vault Structural Degradation Prediction*, Savannah River Site, Aiken, SC, Rev. 0, July 10, 2003.

[55] Vanapalli, S.K., Siller, W.S., Fredlund M.D. *The Meaning and Relevance of Residual State to Unsaturated Soils. 51st Canadian Geotechnical Conference*, Edmonton, Alberta, October 4-7, 1998.

[56] WSRC-RP-91-17, *Land and Water Use Characteristics in the Vicinity of the Savannah River Site*, Savannah River Site, Aiken, SC, March 1991. ML102210101.

[57] WSRC-RP-92-450, Strom, R.N. and D.S. Kaback, *Groundwater Geochemistry of the Savannah River Site and Vicinity (U)*, Savannah River Laboratory, Westinghouse Savannah River Company, Aiken, SC, 1992. ML102160585.

[58] WSRC-STI-2006-00198 Rev. 0, Phifer, M. A., et al., *Hydraulic Property Data Package for the E-Area and Z-Area Soils, Cementitious Materials, and Waste Zones*, Savannah River Site, Aiken, SC, September 2006. ML101600380.

[59] WSRC-STI-2007-00004, Rev. 4. Lee, P. L., et al., *Baseline Parameter Update for Human Health Input and Transfer Factors for Radiological Performance Assessments at the Savannah River Site*. June 13, 2008. ML101600382.

[60] WSRC-STI-2007-00056, Rev. 0. *International Program: Summary Report on the Properties of Cementitious Waste Forms*, Khlopin Radium Institute and the SRNL. March 2007.

[61] WSRC-STI-2007-00640, Kaplan, D.I., and Coates, J.M., *Partitioning of Dissolved Radionuclides to Concrete Under Scenarios Appropriate for Tank Closure Performance Assessments*, Savannah River Site, Aiken, SC, December 21, 2007. ML101600390.

[62] WSRC-STI-2007-00649 Rev. 0, Dixon, K., and Phifer, M. A., *Hydraulic and Physical Properties of MCU Saltstone*, Savannah River Site, Aiken, SC, March 31, 2008. ML101600392.

[63] WSRC-STI-2008-00236, Denham, M.E., *Thermodynamic and Mass Balance Analysis of Expansive Phase Precipitation in Saltstone*, Savannah River National Laboratory, Aiken, SC, May 2008. ML101600398.

[64] WSRC-STI-2008-00244, Jones, W.E., and Phifer, M.A., *Saltstone Disposal Facility Closure Cap Concept and Infiltration Estimates*, Savannah River Site, Aiken, SC, May 2008. ML083400069.

[65] WSRC-STI-2008-00285, Grogan, K.P., Fjeld, R. A., Kaplan, D.I., Shine, G.P., DeVol, T.Z., Coates, J., and Seaman, J., *Distribution of Sorption Coefficients (Kd Values) in the SRS Subsurface Environment*, Savannah River National Laboratory, Aiken, SC, June 30, 2008. ML102160599.

[66] WSRC-TR-2006-00004, Rev. 0. Kaplan, D. I., *Geochemical Data Package for Performance Assessment Calculations Related to Savannah River Site*. February 28, 2006. ML101600568.

[67] WSRC-TR-99-4083. *Significance of Soft Zone Sediments at the SRS*. Westinghouse Savannah River Company, Savannah River Site, Aiken, SC. September, 1999.

[68] X-CLC-Z-00027, Rev. 1. *Inventory Determination of PODD Radionuclides in Saltstone Vaults 1 and 4*, June 2009. ML102160640.