March 31, 2006

Mr. Mark A. Gilbertson
Deputy Assistant Secretary
Environmental Cleanup and Acceleration, EM-20
Office of Environmental Management
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION ON THE DRAFT SECTION 3116 DETERMINATION FOR CLOSURE OF TANK 19 AND TANK 18 AT THE SAVANNAH RIVER SITE

Dear Mr. Gilbertson:

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the “Draft Section 3116 Determination for Closure of Tank 19 and Tank 18 at the Savannah River Site,” dated September 30, 2005, and associated documentation. We have enclosed a request for additional information (RAI), which is a list of comments for which the NRC staff requires responses from the U.S. Department of Energy (DOE) before we can complete our review. As we continue our review of DOE documents and responses, we may develop additional comments for which we will require DOE response.

As I have discussed with you previously, although the draft Section 3116 determination for Tank 19 and 18 was submitted in September 2005, our staff did not begin its review until December 2005, after completion of a separate review for DOE’s previously submitted draft Section 3116 determination for salt waste disposal at the Savannah River Site. In order to meet the current schedule, in which we are endeavoring to complete our review by August 31, 2006, we need to receive your responses to the RAI on or before May 31, 2006. If it would be useful to DOE, my staff is willing to meet with your staff to discuss our RAI or your responses. If you have any questions, please contact me at 301-415-6717 or Anna Bradford, senior project manager on my staff, at 301-415-5228.

Sincerely,

/RA/

Scott C. Flanders, Deputy Director
Division of Waste Management
and Environmental Protection
Office of Nuclear Material Safety
and Safeguards

Enclosure: Request for Additional Information

March 31, 2006

Mr. Mark A. Gilbertson
Deputy Assistant Secretary
Environmental Cleanup and Acceleration, EM-20
Office of Environmental Management
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION ON THE DRAFT SECTION 3116 DETERMINATION FOR CLOSURE OF TANK 19 AND TANK 18 AT THE SAVANNAH RIVER SITE

Dear Mr. Gilbertson:

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the "Draft Section 3116 Determination for Closure of Tank 19 and Tank 18 at the Savannah River Site," dated September 30, 2005, and associated documentation. We have enclosed a request for additional information (RAI), which is a list of comments for which the NRC staff requires responses from the U.S. Department of Energy (DOE) before we can complete our review. As we continue our review of DOE documents and responses, we may develop additional comments for which we will require DOE response.

As I have discussed with you previously, although the draft Section 3116 determination for Tank 19 and 18 was submitted in September 2005, our staff did not begin its review until December 2005, after completion of a separate review for DOE's previously submitted draft Section 3116 determination for salt waste disposal at the Savannah River Site. In order to meet the current schedule, in which we are endeavoring to complete our review by August 31, 2006, we need to receive your responses to the RAI on or before May 31, 2006. If it would be useful to DOE, my staff is willing to meet with your staff to discuss our RAI or your responses. If you have any questions, please contact me at 301-415-6717 or Anna Bradford, senior project manager on my staff, at 301-415-5228.

Sincerely,

/RA/

Scott C. Flanders, Deputy Director
Division of Waste Management
and Environmental Protection
Office of Nuclear Material Safety
and Safeguards

Enclosure: Request for Additional Information

DISTRIBUTION: EPAD r/f C. Barr X. Yin E. Jensen, OGC H. Arlt
M. O'Shaughnessy C. McKenney

ML060800295

OFFICE	DWMEP	DWMEP	DWMEP	DWMEP	DWMEP	DWMEP
NAME	K. Pinkston	A. Ridge	D. Esh	A. Bradford	R. Whited	S. Flanders
DATE	3 /23/06	3 /23 /06	3 /29/06	3 /29/06	3 /31/06	3/31/06

OFFICIAL RECORD COPY

Request for Additional Information for the Draft Section 3116 Determination for Closure of Tank 19 and Tank 18 at the Savannah River Site

INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the "Draft Section 3116 Determination for Closure of Tank 19 and Tank 18 at the Savannah River Site," [1] dated September 30, 2005, and associated documentation. Listed below are comments for which the NRC staff requires responses from the U.S. Department of Energy (DOE) before we can complete our assessment of whether the criteria of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) can be met. The comments are separated into major topical areas to facilitate DOE's responses. The path forward provided for each comment is a recommended approach to resolution; however, the NRC staff understands that there may be more than one method for adequately addressing the technical issues raised in the comments.

GENERAL

1. Comment: Page 15 of the draft waste determination states that Section 3116 of the NDAA specifies that the waste "must meet certain concentration limits and performance objectives for low-level waste (LLW) (3316(a)(3))". However in this draft waste determination, DOE has not determined the class of the waste residuals remaining in the tanks. Therefore, it is incorrect to imply that this waste will meet the Class C concentration limits specified in 3116(a)(3). In addition, the NDAA allows for waste to be disposed of that does not meet the Class C concentration limits.

Path Forward: Once DOE has determined the class of the waste to be left in the tanks (see Comment 18), determine whether the correct part of Section 3116 is being applied and cited in the waste determination.

2. Comment: Page 133 of the draft waste determination states that "The intruder analysis considers that active Federal institutional control over the disposal facility will be maintained at least 100 years after closure". This is not consistent with NRC's approach.

Path Forward: Correct the text of the draft waste determination accordingly. Also see Comment 19.

REMOVAL OF HIGHLY RADIOACTIVE RADIONUCLIDES TO THE MAXIMUM EXTENT PRACTICAL

3. Comment: Conclusions about the utility of additional cleaning on a cost per averted dose basis are sensitive to assumptions used in the performance assessment and may be significantly different after performance assessment issues are resolved. Additional information is needed to evaluate how uncertainties in the performance assessment are considered in the decision to stop waste removal activities.

Basis: Dose results used in the cost benefit analysis presented to support the cessation of waste removal from Tanks 18 and 19 are based on questionable assumptions. For example, in the Risk Benefit Evaluation of Residual Heel Removal in Tanks 19 and 18 [2] DOE calculates that the least expensive option for removing more waste from Tank 18 would cost $10,200,000 and reduce the 50-year public receptor dose by a total of 0.02 mSv (2 mrem) (50 years of exposure at 0.0004 mSv/yr [0.04 mrem/yr]), or $510,000,000 per mSv ($5,100,000 per mrem) averted. However, DOE calculates that a receptor that obtained drinking water from a well 100 m (328 ft) from the tank farm that is drilled into the Barnwell aquifer (see Comments 19 and 20) would receive a peak annual Np-237 dose of 0.23 mSv (23 mrem) [3], or 11.5 mSv (1.15 rem) in a 50-year exposure period. Thus, if the Barnwell aquifer could be used as a source of drinking water, the cost per averted dose would be reduced to $887,000 per mSv ($8,870 per mrem) averted based on DOE's dose calculations. In addition to receptor location, other performance assessment assumptions could have a significant effect on the calculated dose. Although several supporting documents identify the predicted high cost per averted dose as a basis for stopping waste removal activities [e.g., 4, 5], it is not clear how uncertainties in the performance assessment were included in decisions to stop waste removal activities from Tanks 18 and 19.

The NRC staff notes that the NDAA criterion requires that the waste has had "highly radioactive radionuclides removed to the maximum extent practical." The staff believes that, in the case of residual waste that will remain in tanks, the intent of requiring removal of highly radioactive radionuclides to the maximum extent practical could be met by reducing the volume of residual waste in the tanks to the maximum extent practical. This is because, in many cases, it may be very difficult to selectively remove certain radionuclides from the waste remaining in the tanks due to technological, operational, or economic constraints. However, this general approach of evaluating the removal of waste from the tanks does not eliminate the need to consider whether technologies exist that may be appropriate for removing selected highly radioactive radionuclides from the waste.

Path Forward: Explain how uncertainties in performance assessment calculations are included in DOE's evaluation of the practicality of continuing waste removal. This information is needed to assess the process DOE uses to determine that tank waste removal is complete. The response should specifically address references to cost per averted dose in documents used to support the decision to stop waste removal activities from Tanks 18 and 19.

Because the doses predicted by the site performance assessment affect the evaluation of the benefits of additional waste removal, the analysis of the costs and benefits of removing additional waste from Tanks 18 and 19 should be updated to reflect any changes in the doses predicted by the performance assessment resulting from comments in this Request for Additional Information.

4. Comment: The basis provided to demonstrate that waste has been removed to the maximum extent practical includes several statements about which additional information is needed.

Basis: The draft waste determination presents many reasons why the technologies used to retrieve waste from Tanks 18 and 19 were the most practical selections and why adequate waste removal has been achieved. However, the reasons provided do not comprise a clear and technically defensible basis as to why the criterion has been satisfied. For example:

- The draft waste determination cites Federal Facility Agreement (FFA) regulatory commitments as being a factor in tank removal technology selection. It is not clear that the FFA is a barrier to waste retrieval, or that the State of South Carolina would prefer to have more waste left in the tanks even if technology is available to remove it, solely to achieve a specific deadline for tank closure.

- In Tank 19, most of the residual waste is in the center of the tank because the pumps are near the tank walls. In Tank 18, most of the residual waste is at the periphery of the tank. Access restrictions are cited (e.g., the physical configuration of the tank) as a primary limitation to further waste removal; however, some of the reasons cited appear to conflict with other information provided, specifically:

  - Line of sight is provided as being very limited, but extensive video mapping was performed of residual waste volumes.

  - The creation of new tank openings is stated as resulting in the risk of tank top collapse, but new openings were created for tank sampling.

  - The center riser is stated as having only two small openings installed, but the center riser is large. It is not clear how replacement of the small openings with a larger opening within the center riser of Tank 19 would result in mechanical stability concerns.

- Radiation exposure to workers is cited as a primary consideration during technology selection. It is not clear why worker exposure would present a significant obstacle to additional waste removal, because Section 7.2.4 of the draft waste determination presents detailed information as to how the Savannah River Site (SRS) has successfully managed the risk to workers during past operations.

Path Forward: Provide additional information addressing each of the items listed above.

5. Comment: Additional information is needed to provide confidence in DOE's heel removal technology selection process.

Basis: During initial technology selection for removal of waste from Tank 18, DOE identified that one of the risks of using the Advanced Design Mixer Pump (ADMP) was that the last stages of heel removal may require too much water or time to complete [6]. Thus the technology selection committee recommended that, if the ADMP was selected as the Tank 18 cleaning technology, DOE should prepare to use a secondary system, such as sluicers or a robotic suction system, to complete heel removal after use of the ADMP [6]. Consistent with the predictions of the technology selection committee, the need to avoid addition of water to the tank farm was identified as a primary reason that additional cleaning cycles in Tank 18 would be technically impractical [1, 5]. However, DOE has also concluded that it would not be practical to implement additional cleaning techniques [1, 5]. Thus it appears that the potential need to implement a secondary system to complete heel removal was not adequately considered in the decision to use the ADMP for Tank 18 heel removal.

Path Forward: Explain whether the potential need to implement a secondary system to complete heel removal, as identified by the technology selection committee [6], was considered in the selection of the ADMP for Tank 18 heel removal. If it was not believed that a secondary system would be required, explain why the prediction of the technology selection committee was believed to be incorrect. If the possible need to implement a secondary system to complete heel removal was considered when the ADMP was selected, explain why implementation of a secondary system to complete heel removal is no longer considered practical.

6. Comment: Although various waste removal technologies were discussed in Appendix C of the draft waste determination, it is not clear how the information presented in Appendix C was used to support the evaluation of technologies available for the removal of waste from Tanks 18 and 19. The discussion of potential waste removal in the draft waste determination appears to be based on the technology selections performed for Tanks 18 [6] and 19 [7] in 2001 and 1998, rather than the information presented in Appendix C. In addition, the reasons for eliminating certain technologies from the initial technology evaluations require additional explanation.

Basis: SRS has cooperated with other DOE sites to identify technologies available for cleaning tanks as part of the Tanks Focus Area initiative. Several technology reports referenced in Appendix C of the draft waste determination, which describes technologies that may be applicable to additional waste removal at SRS, were written by the Tanks Focus Area group. This type of cooperation should facilitate the application of the best applicable technologies for waste removal within realistic schedule constraints.

However, it appears that the technologies described in Appendix C of the waste determination were not considered in the evaluation of whether it may

be practical to remove additional waste from Tanks 18 and 19. Instead, the Risk Benefit Evaluation of Residual Heel Removal in Tanks 19 and 18 [2] indicates that representative technologies for evaluation were based on the technology selections performed for Tank 18 [6] and 19 [7] in 2001 and 1998. Thus it is not clear that DOE-SRS has critically examined technology applied at other DOE sites and whether any of those technologies could result in better waste retrieval for Tanks 18 and 19. Instead, several promising technologies were described in Appendix C, but no discussion was provided explaining why they could not be used to perform additional waste removal from Tanks 18 and 19. For example, a Russian Pulsating Mixer pump was described in Appendix C as a technology with promise, having been used at Oak Ridge National Laboratories, and it was noted that this pump provides "excellent scouring action, low cost, mechanical simplicity, and ability to operate in much lower liquid levels" than centrifugal mixing pumps [1]. No drawbacks to its use were noted in Appendix C of the draft waste determination, but the technology was not discussed in the main text of the draft waste determination or the risk benefit analysis DOE used to support the conclusion that it would be impractical to remove additional waste from Tanks 18 or 19 [2].

In addition, it is not clear that the evaluation of the technologies considered in the draft waste determination was updated to reflect recent developments. For example, based on the results of the 1998 study [7], the text of the draft waste determination indicates that vacuum conveyance systems have low technical maturity [1]; however, a vacuum conveyance system has been successfully employed at Hanford [8]. Similarly, the use of oxalic acid was determined to be impractical because of concerns about system integration impacts and authorization basis impacts, but no discussion was provided about work that has been completed in recent years to prepare for the use of oxalic acid for tank cleaning at SRS (see Comment 11). In general, it appears that although several new technologies were identified in Appendix C of the draft waste determination, neither the information presented in Appendix C nor the current status of the technologies originally evaluated in 1998 and 2001 were considered in the evaluation of the practicality of removing additional waste from Tanks 18 and 19.

Path Forward: Provide a critical evaluation of technology development for tank waste retrieval at SRS and other DOE sites since the 1998 technology evaluation [7] was performed, and address the applicability of those technologies to further waste retrieval at SRS for Tanks 18 and 19. The evaluation should address promising technologies described in Appendix C as well as vacuum removal technologies. The evaluation should provide a quantitative basis for the inapplicability of those technologies.

7. Comment: Additional information is needed that describes DOE's efforts to develop technologies to remove zeolite from Tanks 18 and 19.

Basis: In the High-Level Waste Tank Closure Final Environmental Impact Statement (EIS) [9] DOE assumed that, of the 51 high-level waste (HLW) tanks at SRS,

13 would have 3790 L (1,000 gal) of waste remaining after cleaning, 37 would have only 379 L (100 gal) remaining after cleaning, and Tank 17, which had been closed at the time, would contain 8330 L (2,200 gal) of waste. The volumes of waste remaining in Tanks 18 and 19 are 6.7 and 16.9 times greater than the predicted value of 3790 L (1,000 gal). The primary reasons given to explain why waste removal from Tanks 18 and 19 was more difficult than originally predicted were unexpected difficulties associated with removing aged zeolite from the tanks [1].

However, 11 tanks at SRS contain zeolite, and six contain significantly more than 3790 L (1,000 gal) of zeolite [10]. Information on the development of technologies to address the difficulties associated with removal of aged zeolite from HLW tanks is necessary to determine the applicability of these technologies to removal of waste from Tanks 18 and 19.

Path Forward: Describe current technologies and ongoing efforts to develop technologies that address the difficulties associated with removing aged zeolite from HLW tanks, including the tendency of aged zeolite to form hardened slabs and the tendency of aged zeolite to settle rapidly, and specific actions that can be taken with respect to Tanks 18 and 19.

8. Comment: Figures 2-34 through 2-36 of the draft waste determination do not provide a clear basis for stopping waste removal from Tank 18. The statistical bases for the trend lines are not provided.

Basis: The data in Figure 2-34 of the draft waste determination do not show diminishing returns, as implied in the text of the draft waste determination. The removal rate appears to be roughly 11,400 L (3000 gal) of solids per cycle, while only 16,300 L (4300 gal) of solids currently remain in Tank 18. Figure 2-36 shows that approximately 150 L (40 gal) of solids were removed per hour of operation during the last three removal cycles, and the total time of ADMP operation has been roughly 1000 hours. Therefore it is unclear why the ADMP could not be run for 100 more hours, or 10% longer, to remove the majority of the solids remaining in the tank. Although the computational fluid dynamics model used to predict ADMP performance was used to support the conclusion that the ADMP was not performing as expected, it is not clear that the model results indicated that one or two additional cleaning cycles would remove significantly less waste than the six cycles that had been performed [5].

Support has been provided for the conclusion that altering the ADMP intake screen would not significantly improve performance [5] and it was determined that pump behavior was more indicative of gradual air build-up in the pump casing or a gradual loss of slurry density than obstruction of the inlet or pump cavitation [11]. Although observed waste foaming was believed to be a likely cause of the gradual build up of air in the ADMP, it appears that loss of slurry density due to waste foaming was not investigated further because it was determined that a solution could not be implemented in time to meet project schedule requirements [11].

Path Forward: Provide the basis for stopping waste retrieval from Tank 18, specifically addressing the use of two more transfer cycles. The total cost of performing the waste retrieval operations for transfers 4, 5 and 6 should be provided and compared to the estimated cost of performing two more transfers with the in-place ADMP and transfer pumps. The ADMP history indicates the final waste retrieval operation from Tank 18 was completed during the week of June 12, 2003 [11]. Provide any written documentation generated at the time that addresses why additional cleaning cycles were not performed, including whether there were any programmatic or contractual milestones associated with tank heel removal. Provide a breakdown of the specific types of waste remaining in Tank 18 (e.g., liquid, mobile solids, insoluble solids, and zeolite) and their removal efficiencies from bulk waste retrieval to heel removal.

9. Comment: Figures 2-23 and 2-24 of the draft waste determination do not provide a clear basis for stopping waste removal from Tank 19. The statistical bases for the trend lines in Figures 2-23 and 2-24 of the draft waste determination are not provided.

Basis: The data suggest that a continuous application of a single operation or technology has not been performed, thereby invalidating the generation of a trendline through the last half of the data. The data suggest that significant solids removal was achieved by the first nine transfers, followed by more moderate removal until transfers 37-41, which removed much smaller volumes of solids from Tank 19. However, the volume of solids removed during the last five transfers increased to an average of approximately 980 L (260 gal) per transfer. The detailed information about each cleaning cycle presented in Appendix A of the Tank 19 Waste Removal Equipment Technology Evaluation [12] is helpful but does not provide sufficient information about changes made in the cleaning process as it progressed to explain variations in the data shown in Figures 2-23 and 2-24 of the draft waste determination. For example, it is not clear when hydrolancing took place or why the remaining heel volume shown in Figure 2-24 of the draft waste determination increases around transfer cycle number 37. In addition, the cycle-by-cycle information in the Tank 19 Waste Removal Equipment Technology Evaluation [12] appears to indicate that there were 47 cleaning cycles, while the text of the waste determination indicates that there were 46 cleaning cycles and Figure 2-23 only shows 45 data points.

Path Forward: Provide a basis for the trend lines shown in Figures 2-23 and 2-24 of the draft waste determination. Provide a detailed comparison of transfer cycle number with date of operation and any changes in the operations performed (i.e., indicate the times at which process modifications or additional waste processes such as hydrolancing took place). Explain why the last five transfers removed a volume of solids that was approximately seven times greater than the average volume of solids removed by the previous five transfers. Correct Figure 2-23 of the draft waste determination to reflect data from all of the transfer cycles or explain why the number of data points shown in Figure 2-23 does not correspond to the number of cleaning cycles.

10. Comment: Additional information is necessary to understand the basis for stopping waste removal from Tank 19.

Basis: Figure 2-23 of the waste determination indicates that the rate of waste retrieval from Tank 19 increased significantly after the thirty-ninth cleaning cycle, and that the last five cycles removed over 760 L (200 gal) of waste per cycle. It is not clear why it would be expected that additional removal cycles would not also remove approximately 760 L (200 gal) of solid waste per cycle and remove nearly all of the solid waste remaining in the tank in approximately 70 additional cycles.

The Tank 19 Waste Removal Equipment Technology Evaluation [12] indicates that the cleaning campaign was stopped in June 2001 because of changes in removal efficiency, discussed with respect to Figure 2-23 above, and failure of the BIBO® transfer pump. However, the Technically and Economically Practical Endpoint Summary for Tank 19 [4] indicates that replacing the BIBO® transfer pump, the failed SW Flygt mixer, and another mixer that may possibly fail, as well as performing another 70 waste retrieval cycles, would cost $2.1 million. If all of the waste could be removed from the tank, the marginal cost (including equipment replacements) would have been only $33 per L ($124 per gal) of waste, as compared to the average cost of $167 per L ($631 per gal) of waste removed during Tank 19 heel removal [4]. If it is assumed that only half of the waste could be removed by the same number of additional cleaning cycles, the cost would be only $66 per L ($248 per gal) of waste. Thus it is unclear why failure of the BIBO® pump would provide sufficient justification for the cessation of waste removal from Tank 19.

The Tank 19 Heel Removal Systems Engineering Evaluation [7] indicates that the goal of Phase I bulk heel removal for Tank 19 was to remove all but 7570 L (2,000 gal) of waste from the tank, and that the goal of Phase II of heel removal for Tank 19 was to remove all but "the calculated volume that can be declared incidental waste". Thus it appears that a recalculation of how much waste could be declared "incidental to reprocessing" was performed when the cleaning goal was changed from less than 7570 L (2000 gal) of waste to the current volume of 63,970 L (16,900 gal) of waste.

Path Forward: Provide the basis for stopping waste retrieval from Tank 19, specifically addressing the basis for concluding that the removal efficiency in additional cycles would not be similar to the removal efficiency in the last five cleaning cycles. Explain whether the failure of the BIBO® pump was a significant factor in the decision to cease waste removal activities from Tank 19, specifically addressing the marginal costs of replacing the pump. Please provide any written documentation generated when cleaning was stopped that address the recalculation of how much waste could be declared to be "waste incidental to reprocessing" and whether there were any programmatic or contractual milestones associated with tank heel removal. Provide a breakdown of the specific types of waste remaining in Tank 19 (e.g., liquid, mobile solids, insoluble solids, and zeolite) and their removal efficiencies

from bulk waste retrieval to heel removal.

11. Comment: More information about the efforts required to update the safety basis to include cleaning with oxalic acid, and the efforts to develop a hazards analysis for using oxalic acid is needed to evaluate the practicality of cleaning Tanks 18 and 19 with oxalic acid.

Basis: The Risk Benefit Evaluation of Residual Heel Removal in Tanks 19 and 18 [2] indicates that the safety basis would need to be updated to allow the use of oxalic acid to remove additional waste from Tanks 18 and 19. DOE estimates that updating the safety analysis to include oxalic acid cleaning would represent a significant fraction of the delay (8 of 20 months) and cost ($3 million) associated with implementing oxalic acid cleaning in Tanks 18 and 19 [2]. However, neither the draft waste determination nor the risk benefit analysis addressed the significant amount of work that has already been done at SRS to plan for the use of oxalic acid to clean waste tanks or the probability that oxalic acid would be used to clean other tanks at SRS.

It would seem that information gained from cleaning Tanks 16 H and 24 H could be used to support revision of the current safety basis to allow Tank 18 or 19 to be cleaned with oxalic acid. For example, the Risk Benefit Evaluation of Residual Heel Removal in Tanks 19 and 18 [2] indicates that a necessary step in revising the authorization basis would be corrosion testing. It is unclear why the necessary corrosion testing would not already have been done to support cleaning Tank 16 H and 24 H, or why information gathered during the oxalic acid cleaning of Tank 24 H, which was also a Type IV tank, could not support conclusions about whether corrosion would be a concern during cleaning of Tanks 18 and 19. Similarly, the Technically and Economically Practical Endpoint Summary for Further Waste Removal Activities in Tank 18 [5] indicates that a hazards analysis for the use of oxalic acid to clean Tank 18 was already in progress as of November 2003, but the status of this hazards analysis was not discussed in the draft waste determination or risk benefit analysis [2].

Furthermore, it appears that DOE may use oxalic acid to clean several other tanks at SRS. The Tank 19 Heel Removal Systems Engineering Evaluation [7] states "It is recognized that some form of chemical cleaning may ultimately be needed in Tank 19 and will definitely be needed in tanks with higher source terms." More recently, DOE indicated that oxalic acid cleaning may be required for heel removal from SRS waste tanks and prepared a preferred flowsheet describing oxalic acid downstream effects and disposition options [13]. Thus it seems that: (1) a significant amount of work already has been performed to implement oxalic acid cleaning at SRS; and (2) because DOE appears to anticipate that oxalic acid cleaning will be necessary at several other tanks at SRS, it would be inappropriate to assign the entire cost for updating the safety authorization for chemical cleaning to Tanks 18 and 19.

DOE has hypothesized that part of the reason that cleaning with oxalic acid

did not remove more zeolite from Tank 24 H and was not more effective in removing Cs from the zeolite was that the majority of the solids were in a "hard, immovable mass" [14]. However, in the Characterization of Tank 19 Residual Waste [15], DOE estimates that 92% of the solids in Tank 19 had been mobilized during heel removal. Therefore it seems that oxalic acid cleaning of Tank 19 could be more effective than oxalic acid cleaning of Tank 24H was.

Supporting documentation [2] indicates that the Heel Removal and Annulus Cleaning Technology Development Suspension plan [16] may contain some of the required information.

Path Forward: Describe the extent to which previous experience cleaning Tanks 16 H and 24 H with oxalic acid could be used in the updating of the safety basis necessary to allow the use of oxalic acid to clean Tanks 18 and 19. Provide the status of the hazards analysis for using oxalic acid that was referenced in the Technically and Economically Practical Endpoint Summary for Further Waste Removal Activities in Tank 18 [5]. Discuss the impact on the Risk Benefit Evaluation of Residual Heel Removal in Tanks 19 and 18 [2] of amortizing the cost and time necessary to develop the safety basis for using oxalic acid among the tanks that are expected to require chemical cleaning [7, 13] and compare the projected cost and effectiveness of using oxalic acid to the cost and effectiveness of the cleaning cycles that were performed for Tank 19. Provide the Heel Removal and Annulus Cleaning Technology Development Suspension plan [16].

12. Comment: Additional information about aerosolization concerns is needed to explain why the PITBULL® pump cannot be used to remove waste from Tank 19.

Basis: The Tank 19 Waste Removal Equipment Technology Evaluation [12] indicates that the PITBULL® pump was installed in the Northeast Riser of Tank 19, but the pump was not and cannot be used because it could cause aerosolization of the waste and overwhelm the HEPA filters. It is not clear why the PITBULL® pump was installed, when it was determined that it could cause problematic aerosolization of waste, and what options are available to overcome the aerosolization problem. The Technology Evaluation indicates that some of the necessary information may be contained in calculation S-CLC-F-00323 (a full reference was not provided).

Path Forward: Provide information about the costs associated with implementing technology to limit the impacts of aerosolization of the waste if the PITBULL® pump is used. Explain what new information became available after the selection and installation of the PITBULL® pump that indicated that the pump could not be used because of aerosolization concerns. Provide S-CLC-F-00323.

13. Comment: The considerations for further waste removal provide a ratio of worker risk to potential future exposure to the public, and the cost to public dose averted. These metrics are not appropriate for a variety of reasons.

Basis: Risk to a worker is an assumed risk (i.e., someone can choose to work or not work around radiation), whereas risk to the public is a risk that is imposed by an action that the public receptor may assume no or minimal benefit from and may not be aware of. Substantially different limits are applied to these risks and these risks are not directly comparable. More importantly, the cost to averted public dose ratio should be provided on a site and/or national basis for DOE in order to have the appropriate context. If DOE were to use this type of approach, it should be done consistently across the complex to make decisions about clean-up programs or other activities. While the absolute values are useful, the relative values compared to other DOE programs or decisions would provide much better basis for decision making. It appears that the costs per tank are large but they are not large in comparison to many other DOE programs, nor are they particularly large compared to total system costs within the tank waste management and retrieval system at SRS.

Path Forward: Eliminate the comparison between worker risk and public risk, or provide the appropriate text to address the problems with comparing the two. Provide relative comparisons of the cost to averted dose for tank closure to other DOE programs at SRS, and to tank cleaning actions at other DOE sites.

INVENTORY AND SAMPLING

14. Comment: DOE developed statistically-based sampling plans to determine the inventory in Tanks 18 and 19. The number of samples and location of the samples were based on the assumption that the tank contents were well-mixed [3]. It is not clear that this assumption has been validated from the information provided.

Basis: The basis that the contents of Tank 19 were well-mixed is based on comparison of three solid samples, visual observation of the similarity of solid samples, the more than 3000 hours of mixing, and visual observation of the tank contents. Figure 2-30 of the draft waste determination shows the heel map following bulk sludge removal, which when compared to the map after heel retrieval contains a large portion in the center of the tank that could represent undisturbed material (see Figure 2-41). Some fraction of the zeolite has formed hardened slabs, creating the potential for encapsulation of solids that would not be well-mixed. It is not clear whether the system was well-mixed, or whether the mixing process could have simply been circulating a mobile fraction of material over an immobile fraction in the center of the tank.

DOE estimates that 92% of the solids in Tank 19 have been mixed [15]. However, the Tank 19 Heel, Supernate, and Possible Unmoved Heel Mounds Volume Calculation indicates that this number included only the solids present in three mounds of solids above the final liquid level, and does not include solids present under the liquid level in areas outside of the three mounds [17]. Because the aged zeolite was observed to form hardened

slabs and to settle faster than sludge, it appears that the calculation of the unmixed solids could have neglected hardened slabs of zeolite on the bottom of the tank under the final liquid level.

For Tank 18, a fraction of the tank was recognized as not well-mixed, and additional samples were taken from this location. The average of the samples from the additional location are significantly higher in some radionuclides and have a substantially different ratio of iron to silicon, suggesting the immobile insoluble fraction has the potential to contain a large fraction of the activity of long-lived radionuclides.

Path Forward: Provide details of the solid samples, including cross-sectional views that show the depth and quantity of material removed at each sample location for Tanks 18 and 19. Show the known location of any hardened material in the tanks and the locations where the presence of immobile solids cannot be eliminated, and the location of solid samples in relation to each. An alternative would be to increase the estimated inventory in the tanks to take into account the uncertainty in the characterization.

15. Comment: Inventory estimates are developed through a combination of sampling, process knowledge, and special calculation. Justification that process knowledge and special calculation can provide reliable predictions is not provided.

Basis: Tables 2-3 and 2-4 of the draft waste determination provide the estimated residual inventory for Tanks 18 and 19. There are values in the tables that are not intuitive, and the Waste Characterization System (WCS) is not amenable to independent verification without recourse to the developers. For example:

- The sampled values for uranium isotopes range from a factor of four to 30 less in Tank 19 compared to Tank 18; however, the WCS generated value for U-232 is nearly identical.
- The Cm-244 value in Tank 19 generated with the WCS is roughly five orders of magnitude less than the value for Tank 18, even though the other Cm isotopes are comparable.
- The Pu-244 value (from special calculation) in Tank 19 is roughly four times higher than the value for Tank 18; however, all the sampled isotopes of Pu are less in Tank 19 than Tank 18.
- The Characterization of Tank 19 Residual Waste [15] indicates that, prior to sampling, the concentration of Cs-137 in Tank 19 solids was underpredicted by factor of approximately 200. The underprediction is discussed and attributed to partitioning of Cs-137 onto zeolite. However, it is not clear that Cs-137 is the only radionuclide that is likely to partition onto the zeolite, and the possible underprediction of the concentration of unsampled radionuclides in Tank 19 solids due to partitioning onto zeolite is not discussed.
- The Characterization of Tank 19 Residual Waste [15] indicates that, prior to sampling the concentration of Pu-242 in the Tank 19 solids was

underpredicted by approximately a factor of 10. No reason for the underprediction is discussed, and no assessment of the possibility that unsampled radionuclides could be underpredicted by a similar factor due to similar processes is provided.

In some cases, estimators such as fission yields are used to estimate the concentrations of radionuclides that are not measured. However, it is not clear why this would be a reliable estimator if tank inventories are accumulated over many years as a result of different operations, and the sampled radionuclide and estimated radionuclide have different chemical behavior in the tank environment.

Table 3-5 of the Performance Objectives Demonstration Document (PODD) provides detailed estimates on a tank by tank basis. The following observations are made:

- Tanks 17 and 19 are estimated (based on sampling) to contain the two highest Tc-99 concentrations in the tank farm. It is unlikely that the Tc-99 inventory in all of the F Tank Farm tanks that have not been sampled is lower than these sampled values, unless there is a reason to expect that Tanks 17 and 19 contain the waste with the highest Tc-99 concentrations in the tank farm. Thus, it seems that the Tc-99 inventories in the other tanks in the tank farm have been underestimated.
- The sampled Tank 18 value for Np-237 is by far the highest value of all tanks. DOE acknowledges that part of the reason for the high Np-237 in Tank 18 is the introduction of laboratory waste that was not tracked with the WCS [18]. The result demonstrates that untracked waste can have a significant impact on estimates generated with the WCS.
- The total inventory of Np-237 in Tanks 17-20 is roughly three times higher than the predicted inventory in Tanks 1-8. However, the concentration of Np-237 in Tanks 17-20 is roughly 30 times lower than the predicted concentration in Tanks 1-8. This suggests that either DOE has assumed roughly 100 times better waste removal for Tanks 1-8 than for Tanks 17-20 when generating the inventory and the overall risk from the F Tank Farm or the concentrations are inaccurate.
- There is zero estimated tritium in Tanks 1-8 and Tanks 25-28, 33-34, and 44-47, although the sampled tank group (Tanks 17-20) has measured tritium.
- The concentration of I-129 is lowest for the tank group of 17-20, as estimated with the WCS, compared to the other tank groups. It is not clear why I-129 concentrations are so much lower for Tanks 17-20 than the other tanks.

These items are identified because they cause concern that the unsampled radionuclides in Tanks 18 and 19 may have a high degree of uncertainty that is not accounted for and that the current inventory of the F Tank Farm presented in the PODD may not be sufficiently accurate for decision making.

Path Forward: Describe any studies that have been done to assess the reliability of

predictions of inventory based on WCS data. Provide an explanation of the differences between the WCS generated values and the sampled values, and assess the possibility that unsampled radionuclides could be underpredicted, specifically addressing processes believed to lead to the underprediction of some of the sampled radionuclides. Provide uncertainty estimates for the inventories based on process knowledge and special calculations presented in Tables 3-2 and 3-4 of the PODD. Uncertainties in radionuclide inventories, especially that of Cm-244, should be considered in the comparison of waste concentrations to Class C concentration limits.

16. Comment: It is not clear how sample uncertainty was treated in developing the Tank 18 and 19 inventories. It is not clear that the inventory values are consistent with the reported sample measurement data and the described analysis approach. It is not clear that the south mound in Tank 18 has been adequately characterized.

Basis: Table 3-1 of the PODD provides several results that are represented as an upper bound, some of which were apparently used to calculate an average solid concentration and some of which were not. In a number of cases, the average of all solid samples is equal to the only measurement that is not presented as an upper bound (e.g., for Sr-90, Np-237). It is not possible to calculate a 95% Upper Confidence Limit (UCL) from one measurement. If the UCL is also considering measurement uncertainty, then the true uncertainty in the inventory of radionuclides for which a UCL was based on one reported measurement has not been adequately addressed.

The results in Table 3-2 of the PODD could not be verified given the information in Table 3-1 and the description of waste residuals.

The south mound sample for Tank 18 has roughly 10 times less Cs-137, 2.5 times more Np-237, and 2.5 times more Am-241 than the average of the five other solid samples. Page 104 of the PODD indicates that Sample FTF-230 was taken from the exposed 11-inch high south mound, and that this portion of the mound was defined as consisting of all areas in the south mound with solids height greater than four inches. Given this, and Figure 3-8, it can be estimated that as much as 75% of the south mound, or over half of the solids in Tank 18, are effectively unsampled and the inventory is potentially underestimated significantly considering the difference in the FTF-230 sample and the other solid samples.

Path Forward: Describe the development of the UCLs in the Tank 18 and 19 data. Provide the calculations for the values in Tables 3-1 and 3-2. Provide an assessment of the unsampled volume in Tank 18, and revise the base case inventory used in the performance assessment conservatively accounting for uncertainty or perform more sampling to limit uncertainty in the inventory data.

17. Comment: The draft waste determination states that failed and abandoned equipment left in the tanks result in tank access limitations; however, an estimate of the

activity associated with this equipment is not provided, specifically the interior void spaces that apparently have not been sampled.

Basis: The pill boxes of Tank 18 are contaminated, resulting in higher than normal radiation levels. In Tank 18, an abandoned transfer pump, two abandoned mixer pumps, an abandoned evaporator feed jet, and gravity drain line are installed in five of six perimeter risers.

Path Forward: Provide the void volume of the equipment and the characterization information for the waste inside the failed or abandoned equipment for Tanks 18 and 19. Provide a discussion of any openings in the equipment and whether it was isolated hydraulically prior to being abandoned. Provide a basis for the quantity of waste inside the equipment.

CONCENTRATION AVERAGING

18. Comment: The draft waste determination states that DOE is not deciding whether the waste does or does not exceed Class C concentration limits because there is no clearly applicable NRC guidance on applying the concentration limits in 10 CFR 61.55 to situations like Tank 18 and Tank 19. NRC draft interim guidance for concentration averaging for these types of situations was published in the Federal Register on December 16, 2005 [19].

Basis: DOE presented calculations to estimate waste classification, although the actual class was not stated. Consideration was given to a broad range of things including, but not limited to, airborne particulate waste inside the tank. The approach suggested by DOE is not consistent with the NRC draft interim guidance issued in December 2005. The DOE approach is that stabilization of the system would result in stabilization of the waste, which is correct. However, 10 CFR Part 61 allows for concentration averaging to determine waste classification with respect to stabilization of the waste and not stabilization of the total disposal system. The concentration limits in the classification tables of 10 CFR 61.55 were developed considering the commercial disposal of low-level waste, and different types of dilution or mixing effects have already been considered in the calculation. Therefore, excessive averaging could result in improper waste classification. Additional discussion is presented in the Federal Register Notice [19].

Path Forward: Provide waste classifications that are consistent with the NRC draft interim guidance for the waste in Tanks 18 and 19, or provide an appropriate basis for using an alternative approach that is consistent with the intent of 10 CFR Part 61. Do not consider contaminated air, exterior tank walls, concrete walls, or concrete domes in the calculations.

RECEPTOR DESCRIPTION

19. Comment: DOE's approach to demonstrating compliance with 10 CFR 61.41 for Tanks 18 and 19 is not consistent with NRC's approach.

Basis: 10 CFR 61.44, "Stability of the Disposal Site after Closure," states: "The disposal facility must be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required." The stability performance objective is consistent with a premise of 10 CFR Part 61 that the facility must be sited, designed, used, operated, and closed with the intention of providing permanent disposal. A disposal facility should not require long-term maintenance and care. Stability is particularly important considering the statement in 10 CFR 61.59(b) that "institutional controls must not be relied upon for more than 100 years following transfer of control of the disposal site to the owner."

DOE's approach to protecting the public is driven by the assumption that long-term control of the site will be provided in perpetuity. The public receptor is defined as residing and carrying out most activities on the far side of a stream more than 1800 m (6000 ft) from the tank farm facility. 10 CFR Part 61 explicitly defines 100 years as the active institutional control period. At the time of development of 10 CFR Part 61, it was envisioned that low-level waste would decay to activities that would not pose a significant risk to an inadvertent intruder in a maximum of 500 years and that there would not be significant quantities of long-lived isotopes that would pose unacceptable long-term risks to the public. In developing 10 CFR Part 61, the NRC considered longer periods of institutional control in development of the draft EIS [20]. Assumptions about the persistence of institutional controls in the international community were considered and a series of public meetings were conducted to get input from stakeholders. The consensus among the stakeholders was that it is not appropriate to assume institutional controls will last for more than a few hundred years. Material that requires institutional control for much longer than 100 years in order to demonstrate compliance with the performance objectives would generally be determined to not be suitable for near surface disposal as low-level waste. The philosophy is that the engineered and natural system should be able to afford protection to the public, without total reliance on societal control of the site. It is NRC's understanding that other DOE sites (e.g., Idaho, Hanford, West Valley) do not assume control of the site in perpetuity when evaluating tank closure.

In general, compliance with 10 CFR 61.41 in the period after active institutional controls have ended should be evaluated by assessing the dose to a member of the general public that is located at the point of maximum exposure outside of the disposal site. This receptor should be assumed to engage in residential, agricultural, or other activities that are consistent with regional practices. The disposal site includes a buffer area around the disposal area, where the disposal area circumscribes the disposal units [21]. An appropriate buffer zone is expected to extend approximately 100 m (330 ft) from the disposal area. In the case of a tank farm, the tanks are expected to be regarded as disposal units. Thus an appropriate buffer zone is expected to extend 100 m (330 ft) from the line circumscribing the tanks in a

single tank farm, or to a similar distance that is supported by a technical justification. A receptor engaging in activities on the disposal site, rather than outside the buffer zone, in the period after active institutional controls have ended is regarded as an inadvertent intruder and doses to this receptor should be evaluated to demonstrate compliance with 10 CFR 61.42.

Although DOE states that a location across Fourmile Branch from the tanks is the location at which a residential receptor could receive the highest dose [3], this result depends on questionable assumptions made in the performance assessment (e.g., see Comment 20). Resolution of Comment 20 is necessary before appropriate locations for a member of the public receptor can be evaluated.

Path Forward: After resolution of other technical comments that may impact the performance assessment results, provide a revised analysis with the public receptor located off site during the 100 year active institutional control period and at the boundary of the disposal site (i.e., approximately 100 m [330 ft] from the tanks in F Tank Farm) after the end of the institutional control period.

20. Comment: Dose calculations provided to demonstrate consistency with 10 CFR 61.41 assumed a public receptor would live in the area of Fourmile Branch, approximately 1,830 m (6,000 ft) from Tanks 18 and 19 [3]. Dose calculations to demonstrate consistency with 10 CFR 61.41 should assume a public receptor is located at the point of highest projected dose outside of the disposal site (see Comment 19). Assumptions about the use of water from the Upper Three Runs aquifer have a significant effect on the location at which the public receptor is expected to receive the highest dose from material released from Tanks 18 and 19, and require additional support.

Basis: DOE justifies placing a public receptor downstream of the point where the Upper Three Runs aquifer discharges to Fourmile Branch based on the arguments that: (1) institutional control would preclude receptors from locating near the release point for the 10,000-year performance assessment period; (2) the Upper Three Runs aquifer cannot reliably support household water use; and (3) the best practice for well drillers in the area would be to complete a water supply borehole in the underlying Congaree aquifer, which DOE indicates receives little recharge from the Upper Three Runs aquifer.

Use of institutional control is addressed in Comment 19.

DOE based its conclusion that the point of highest dose to a member of the public would be across Fourmile Branch on the conclusion that the Upper Three Runs aquifer (including the Water Table and Barnwell-McBean aquifers and the tan clay confining zones in the nomenclature of the PODD [3]) could not support domestic water use and that it would be best practice for local well drillers to complete boreholes within the Congaree aquifer. The following evidence suggests that the Upper Three Runs aquifer can support at least domestic water demands:

(1) Infiltration rates used in the performance assessment are 40 cm/yr (15.7 in/yr) [3]. The per-capita water use coefficient for self-supplied domestic water in South Carolina is 284 L/d (75 gal/d) [22], or 1140 L/d (300 gal/d) for a household of four. DOE calculations [23] suggest that the effective drawdown radius after 30 minutes is about 19 m (62 ft) for a well pumping at 11 L/min (3 gal/min) in the Upper Three Runs aquifer. Mean annual recharge within the calculated effective radius is about 1210 L/d (325 gal/d), which will more than supply household needs.

(2) A multiwell pumping test in the vicinity of the F-Tank Seepage Basins, screened in the lower zone of the Upper Three Runs aquifer, was able to sustain a 47 L/m (12.5 gal/min) pumping rate for 1,895 minutes (31.6 hours) and recover within 25 hours [24]. This corresponds to 79 days of water supply drawn in less than 32 hours with no adverse effects. The average distance from the F-Tank Seepage Basins to the modeled performance assessment 100-m well location is less than 500 m (1640 ft).

(3) The DOE calculations [23] suggest that pumping a borehole screened in the entire Upper Three Run aquifer can yield 23 L/min (6 gal/min) for 30 minutes (average daily requirements for a household of four are met at this rate in 50 minutes) and will produce a drawdown of less than 3.5 percent of the aquifer thickness with the lowest conductivity considered. The same document suggests that, as an upper bound estimate, the aquifer with the same adverse conductivity could support pumping rates of 13,665 L/d (3,610 gal/d) at a steady rate through gravity drainage without recharge, far in excess of household needs. Note that the most adverse aquifer conductivity considered, 0.91 m/d (3 ft/d), is smaller than the conductivities used in the performance assessment, (4.9 m/d [16 ft/d] and 6.1 m/d [20 ft/d] for the upper and lower zone, respectively) and more than three times smaller than the conductivity estimated from the multiwell pumping test (3.0 m/d [10 ft/d]). Gravity drainage is proportional to aquifer conductivity, implying that the upper bound from this methodology should be several times larger.

Path Forward: Provide additional support for the conclusion that the Upper Three Runs aquifer could not be used to support domestic water use, addressing each of the specific points listed in the Basis of this comment. Discussion of pumping data should include a discussion of the age and condition of the wells.

21. Comment: Additional information is needed to support the estimate that 4% of contaminated water leaching from Tanks 18 and 19 will travel to the Congaree aquifer.

Basis: The dose to a receptor drinking water taken from the Congaree aquifer increases with the fraction of contaminated water that flows to the aquifer. Although it is stated that 4% of infiltrating water in the area of Tanks 18 and 19 reaches the Congaree aquifer [3], neither the basis nor the expected uncertainty for that value is provided. References describing the integrated hydrogeological modeling of the General Separations Area (GSA) [25] indicate that flow in the Congaree aquifer (referred to as the Gordon aquifer in the cited reference) appears to be influenced significantly by recharge from the overlying aquifers.

Path Forward: Provide data taken from the site to support the conclusion that approximately 4% of contaminated water from Tanks 18 and 19 will flow to the Congaree aquifer. Provide the expected range of uncertainty and variability in the fraction of infiltrating water flowing to the Congaree aquifer with a technical basis. Address the consistency of the 4% value with the vertical hydraulic conductivity assigned to the green clay layer in the performance assessment calculations.

22. Comment: The performance assessment calculates the dose to a receptor taking drinking water from Fourmile Branch, but does not address the possibility of underflow.

Basis: The performance assessment assumed that all contaminated water is discharged into nearby streams, which provide a large amount of dilution for exposure pathways such as drinking water consumption. Direct consumption of groundwater would likely result in larger drinking water doses than from consumption of stream water for the “offsite” receptor. Underflow of water from the aquifer that is not discharged to the stream could result in higher drinking water doses for the DOE offsite receptor, if credible.

Path Forward: Provide measurements supporting the assumption that all of the flow in the aquifers discharges to the streams, or demonstrate that the current hypothetical receptor receives a higher dose than someone who uses groundwater from an offsite location, assuming underflow has occurred.

23. Comment: Additional and clarifying information regarding receptor locations is needed.

Basis: Many of the figures in the PODD and draft waste determination that show the receptor locations, such as Figures 4-3 and 4-7 of the PODD, do not accurately indicate the location of the receptor when they are exposed to the various contaminated media. For example, Figure 4-7 shows the receptor receiving a dose from incidental ingestion of soil and direct radiation from the soil on the seepline side of the creek. However, the concentrations used to calculate these doses are based on the concentrations in the sediment in the stream calculated at the end of the stream transport leg. In addition, page 128 of the PODD indicates that the receptor is located just downstream of the point on the groundwater discharge, but this distance is not clearly specified within the main text of the PODD. It would be helpful for the value of this parameter to be stated more transparently in the description of

receptor location. The Multimedia Environmental Pollutant Assessment System (MEPAS) modeling uses a value of 101 (330 ft) m for the "Distance Downstream from Center of Source" parameter.

Path Forward: Clarify how many unique receptor locations were used for calculating doses, pinpoint all receptor locations on a single map, and summarize the characteristics of each receptor at each location. In summarizing receptor locations and characteristics, indicate where the seepline receptor engages in various activities that lead to exposure to radionuclides, as well as which contaminated media the receptor is exposed to in various locations and which transport calculations were used in computing the relevant media concentrations. In correcting Figures 4-3 and 4-7, include any differences in distance downstream from the seepline location. Indicate any differences between the seepline and outcrop locations and which media concentrations were used at which locations.

24. Comment: Modeling of receptors exposed to water from the Congaree aquifer requires clarification.

Basis: The text of the PODD [3] and draft waste determination [1] state that the Congaree aquifer is modeled as flowing to Upper Three Runs, rather than Fourmile Branch. However, the parameters used in MEPAS for the flow velocity, depth of flow, and width of flow for the surface water environment are exactly the same for the analyses of the Congaree aquifer as they are for the other two aquifers.

The distance between a well located 100 m (330 ft) downgradient of the tank farm from Tanks 18 and 19 in the Congaree aquifer appears to be based on the location of a well 100 m (330 ft) downgradient of the tank farm in the Upper Three Runs aquifer. Because the Congaree aquifer flows in the opposite direction of the Upper Three Runs aquifer, and Tanks 18 and 19 are much nearer to the edge of the tank farm that is downgradient in the Congaree than they are to the edge of the tank farm that is downgradient in the Upper Three Runs Aquifer, the distance used in the MEPAS modeling to calculate the dose to a receptor drinking from a well drilled into the Congaree aquifer that is 100 m (330 ft) from the tank farm appears to be significantly too long (e.g., approximately 300 m [980 ft] instead of approximately 100 m [330 ft]). The additional distance included in the calculation could lead to a significant underestimate of dose to a receptor drinking from the Congaree aquifer because of the additional dispersion that will occur during transport in the MEPAS calculations.

Path Forward: Clarify whether the Congaree aquifer was modeled as flowing to Upper Three Runs or to Fourmile Branch. After other issues that affect dose results from the performance assessment are resolved, calculate the dose to a member of the public receptor obtaining drinking water from a well in the Congaree aquifer that is at the edge of the buffer zone in the direction that is downgradient of the tanks in the Congaree aquifer. The size of an appropriate buffer zone is discussed in Comment 19.

25. Comment: The PODD [3] states that Tanks 18 and 19 are located close to the groundwater divide and that contaminated plumes are likely to travel toward Upper Three Runs in addition to Fourmile Branch [3]. It is not clear from this statement how much of the contaminated plumes are expected to travel in each direction.

Basis: Tanks 18 and 19 are located near the edge of the tank farm on the side of the tank farm closest to Upper Three Runs. The location of a well 100 m (330 ft) from the edge of the tank farm in the direction of flow towards this stream is much closer than a well located 100 m (330 ft) from the other side of the tank farm (i.e., in the direction of flow towards Fourmile Branch). Though the groundwater flow in the Congaree Aquifer may have been modeled as flowing in the direction of Upper Three Runs (see Comment 24), the flow in the Water Table and Barnwell-McBean aquifers was modeled as flowing towards Fourmile Branch. It is important to know how much water will be flowing in each direction in each aquifer because the dose received by consuming water from a well 100 m (330 ft) from the tank farm in the direction of flow towards Upper Three Runs could be higher than the amounts presented in PODD Tables 4-15 to 4-26. The information about how much of the plume is expected to travel in each direction is also useful for the assessment of the conservatism that all of the contaminated infiltration water flows in the same direction.

Path Forward: Provide any available information about the relative amounts of contaminated infiltration water associated with the tanks that flow towards Fourmile Branch and Upper Three Runs in each of the aquifers.

26. Comment: The clay layers in the performance assessment are modeled as continuous layers of low vertical conductivity. It is not clear if there is adequate characterization at the F Tank Farm to justify this assumption.

Basis: The clay layers act as substantial transport barriers in the performance assessment due to the low vertical hydraulic conductivity (0.14 cm/yr [0.0046 ft/yr] for the green clay layer, 52 cm/yr [1.7 ft/yr] for the tan clay layer) compared to the aquifer soils. Page 47 of the PODD describing the potentially affected aquifers states that the Gordon confining unit (i.e., the green clay layer) is not continuous but is a series of superimposed lenses of green and gray clay that thicken, thin, and pinch out abruptly. Page 50 of the PODD indicates the tan clay layer may be 0 m (0 ft) thick within the GSA. The MEPAS modeling may have oversimplified the geology and not adequately taken into account geologic variability and uncertainty.

Path Forward: Provide a plan view map showing wells that generated characterization information for the green and tan clay layers nearest to the Tanks 18 and 19. If characterization information does not support the assumed continuity of the layers, update the base case performance assessment results to represent the potential for fast pathways through non-continuous clay layers. The presence of fast pathways may require a more complex simulation of vertical

transport than the one-dimensional simulation of vertical transport as currently implemented with MEPAS.

27. Comment: Additional information is required to enable NRC staff to verify the inadvertent intruder calculations. The intruder analysis presented in the PODD [3] is inconsistent with the scope of the waste determination. The persistence of the intruder barrier and depth of the waste during the performance period must be demonstrated.

Basis: The intruder scenario for this waste determination should be based on waste in Tanks 18 and 19 rather than inventory in the piping and ancillary equipment because DOE has indicated that this waste determination pertains only to Tanks 18 and 19 and does not include the transfer lines [3].

The intruder analysis assumes that a well-driller will not be able to drill through the intruder grout layer in the tanks at any point during the 10,000 year performance period. Although it is stated that this conclusion is based on regional practices, no data is provided to support the assertion. A drilled well is not the only type of well that could be installed. A number of natural materials have compressive strengths that approach or exceed that of the intruder grout although they are commonly found at some depth. No data or analysis is provided to support the long-term mechanical properties of the intruder grout. Although it appears to be unlikely that an average resident would be able to drill through the intruder barrier soon after closure, the long-term mechanical properties of the intruder barrier are less certain. In analysis for the EIS for 10 CFR Part 61, Class C waste was defined for the most part as decaying to an acceptable level for the inadvertent intruder at 500 years.

Because, in general, more waste is expected to be exhumed in the construction of a residence than in the drilling of a well, and because the waste would be expected to be mixed with less uncontaminated soil after exhumation, the intruder-construction/resident scenario would be expected to pose a much larger risk than the intruder-well driller scenario. The intruder analysis assumes that the depth to waste is greater than 3 m (9.8 ft), thereby eliminating the intruder-construction/resident scenario from consideration. Although the depth of the tank residuals is provided as the primary reason that an intruder would not contact tank waste while constructing a residence [3], the depth of the tanks during the entire performance period is not clear because the closure cap has not been designed [3] and the waste determination indicates that installation of a low-permeability cover is optional [1]. Diagrams showing the current and future depth of the tanks below the land surface are not provided. Although most of the waste is expected to be located at the bottom of the tanks after closure, DOE has indicated that there is contamination at the tops of the tanks. In particular, DOE has indicated that waste removal efforts were limited by contamination of two pill boxes on top of Tank 19 [3].

The Automated Intruder Analysis Application and associated input and output

files have not been provided.

Path Forward: Provide intruder scenarios that are more relevant to the scope of the draft waste determination (i.e., relevant to waste released from Tanks 18 and 19 rather than piping and ancillary equipment, which DOE has stated are not within the scope of the Tank 18 and 19 waste determination [3]). It is expected that an inadvertent intruder could have access to any point on the disposal site (see Comment 19) and would place a well at the point at which the maximum dose would be received (e.g., at 1 m [3.3 ft] from Tank 18 or Tank 19). Assumptions about aquifer use should be supported (see Comment 20) and could be different for different intruder scenarios (e.g., a residential intruder as compared to an agricultural intruder). Provide the concentrations calculated for the intruder scenario in the various media, including the water concentration in each aquifer and the concentration in soil that is brought to the surface in the course of drilling the well. Provide an analysis of the dose to an inadvertent intruder who drills through the barriers and tank at the time of hydraulic failure (i.e., 500 years after closure).

Provide data to justify the long-term properties of the intruder grout and that regional practices would prohibit drilling through the equivalent of a natural sedimentary rock. Provide a description of natural resources in the region (e.g., that an intruder would be expected to drill for). Provide diagrams showing the depth to tanks after closure, and a description of the contamination of the tops of the tanks that a residential intruder could contact during the construction of a residence.

Provide the Automated Intruder Analysis Application and associated input and output files (in electronic form) used in the draft waste determination.

28. Comment: Mechanical aspects of the closure concept are not adequately addressed.

Basis: The closure concept employs an intruder barrier type grout to reduce the likelihood of direct contact with the waste. The plans for verifying the compressive strength of material after emplacement are not provided. The reducing grout is provided as being designed with a compressive strength of greater than 340 kPa (50 psi). It has not been demonstrated that the compressive forces imposed on the reducing grout, intruder grout, and concrete basemat from the overlying materials will not exceed the design values at facility closure. The vault and carbon steel tank would not be expected to provide significant mechanical support more than 100 years after closure, due to deterioration.

Table 2-5 of the draft waste determination indicates the intruder barrier grout will contain slag and fly ash, which is not consistent with descriptions in the text or Table 2-6 of the draft waste determination.

Path Forward: Provide estimates of the mechanical forces imposed on the various components of the closure system, and compare those to the design values. If necessary, demonstrate how the performance assessment has

incorporated the impacts into the calculations. Provide the plans for verifying the compressive strength of the as-emplaced intruder barrier.

29. Comment: Additional information is needed to support assumptions made regarding the agricultural practices of an inadvertent intruder.

Basis: The assumed area (1000 m^2 [0.25 acres]) for spreading of drill cuttings references the draft EIS for 10 CFR Part 61. In the draft EIS for 10 CFR Part 61, this area was for a generic analysis, and the primary consideration was for the intruder construction scenario where a much larger volume of material was being exhumed than in the intruder drilling scenario. The larger area would be needed to reasonably distribute the large volume of material removed during the excavation process for the house. Applying an arbitrarily large area results in increased dilution of the intruder results. An area of 1000 m^2 (0.25 acres) represents a very large garden for a residential receptor.

In addition, it is unclear why the base-case agricultural intruder analysis did not include a pathway in which contaminated water is used to irrigate a garden [3].

Path Forward: Provide support for the assumptions that: (1) drill cuttings would be spread over a 1000 m^2 (0.25 acres) area; and (2) contaminated water would not be used to irrigate a garden. Alternately, revise the base-case agricultural intruder scenario to include irrigation of a garden with contaminated water and a garden size that is consistent with the area over which drill cuttings are expected to be spread, considering regional practices for spreading drill cuttings. It is expected that an inadvertent intruder could have access to any point on the disposal site (see Comment 19) and would place a well at the point at which the maximum dose would be received from contamination resulting from Tank 18 or Tank 19 (e.g., at 1 m [3.3 ft] from Tank 18 or Tank 19).

NEAR FIELD RELEASE

30. Comment: The PODD indicates that DOE plans to use a single pour point to place grout in Tanks 18 and 19, although DOE had previously indicated that using a single grout pour location could have the undesirable effect of moving all of the waste to the edge of the tanks, closer to the accessible environment [26]. In addition, more information is needed about options available to increase mixing of waste and grout.

Basis: DOE used multiple grout pour locations to close Tanks 17 and 20 to avoid moving waste to the sides of the tanks, making it more accessible to release to the environment [26]. Since that time, DOE has indicated that the maximum amount of oxidation of the waste form is expected to occur at the edges of the bottom of the tanks [3]. DOE also has indicated that most of the waste in Tanks 18 and 19 is relatively well-mixed and mobile [3]. Thus it appears that the use of a single grout pour point in the center of the tanks

could cause waste to be moved to the outer edge of the tanks into the area where it is most accessible to the environment. Although the grout placement requirements for Tanks 18 and 19 indicate that improvements in grout pours are expected based on improvements in grout slurry properties and experience with Tanks 17 and 20, it does not address the potential that the grout will move the waste to the edges of the tanks [27].

Grout pours in Tanks 17 and 20 resulted in approximately 25 to 30% mixing of waste and grout [3]. It is unclear why more thorough mixing could not be achieved in Tanks 18 and 19 because the waste in the tanks is expected to be relatively mobile and well-mixed (except for an area in the south mound of Tank 18) [3]. Although DOE has indicated that they have not taken credit for mixing of waste and grout, the use of K_d values applicable to radionuclide sorption to concrete would be more applicable to waste that was mixed with grout than to waste that lies under a layer of grout (see Comment 37). Poor mixing of the grout and waste adds uncertainty to the performance assessment and may increase radionuclide release because radionuclides will not have significant opportunity to adsorb to concrete in the source before being released.

Path Forward: Explain whether pouring grout only from the center riser would be expected to move waste to the edge of the tank bottom, and, if so, what measures are being taken to prevent the concentration of waste in the areas of the tank most accessible to the environment. Alternately, provide an estimate, with a technical basis, of how much waste will be concentrated around the edges of the tanks and revise the performance assessment to account for the oxidation expected around the edges of the bottom of the tank. Describe options for increasing mixing of the tank heel waste with grout in Tanks 18 and Tank 19, including the costs of those options.

31. Comment: The performance assessment assumes the grouted tanks have the hydraulic properties of sand at 500 years after closure as a result of abrupt failure. It is not clear that this approach is necessarily conservative, especially for short-lived contaminants.

Basis: The tanks contain fairly large residual inventories of some radionuclides (e.g., Cs-137, Sr-90) that essentially decay in place in the performance assessment calculations primarily as a result of the assumed 500-year engineered barrier lifetime. The tank liners are made of a large amount of steel and the tanks contain abandoned steel equipment that can be susceptible to corrosion. Corrosion of the tank liners and abandoned equipment could cause cracking in the grouted waste form due to expansion of the steel as it corrodes. Both the cracking of the grout in the tanks and the loss of physical integrity of the tank liners could create fast pathways for infiltration to the waste. In addition, the grout can experience shrinkage over time which will open pathways between the grout and the tanks. These discrete pathways in the actual system are not represented in the current modeling and it is not clear that deterministic one-dimensional modeling approach bounds the impact or appropriately accounts for the uncertainty.

The 500-year time frame for engineered barrier lifetime requires support. That is, it must be demonstrated through design, testing, characterization, modeling, and monitoring that a 500-year lifetime can be achieved.

Most of the waste in Tank 18 is located at the periphery of the tank, where reinforcement corrosion and shrinkage separation may be most likely to occur (roughly 80% of the solid inventory occupies about 5% of the area near the boundary of the tank). In addition, if the bulk of the grout were to remain intact but hydraulic failure were to occur at the exterior, the infiltration to the top of the tank would effectively be shed and directed to the waste, which could result in higher release fractions to the saturated zone than currently estimated due to local increases in flow and saturation and a more rapid deterioration of the chemical benefits of the overlying grout, in particular for Tank 18 where most of the waste is near the walls.

Path Forward: Provide the thicknesses of grout over all steel in the closed system. Identify the points of exposure or minimal thicknesses of grout over the steel. Provide an assessment of shrinkage for Tanks 18 and 19, including specific observations from Tanks 17 and 20 if visual characterization of the tanks was performed during or after closure. Provide the laboratory data addressing the long-term shrinkage behavior of the grout. Provide the quantity and location within the closed system of aluminum and zinc associated with the tank system, supporting equipment, or abandoned equipment. Provide an assessment and comparison of the release rates when discrete features of the system are considered that result in higher flow, higher saturation, and more rapid chemical deterioration to the current values generated in the performance assessment.

32. Comment: The assumption that the source term can be modeled using unsaturated flow is not clearly demonstrated to be either likely or clearly conservative, particularly with regard to Tc-99.

Basis: In its performance assessment [3], DOE does not consider climate change, which could influence fluxes through the tanks and the position of the water table. DOE justifies neglecting future climate change based on calculations suggesting that release rates would be lower if releases occurred within the saturated zone [23], primarily with the rationale that the cross-sectional area exposed to flow is much smaller with horizontal saturated flows than with vertical unsaturated flows. DOE also assumes that the aqueous concentrations are the same in both cases (release in saturated versus unsaturated flow), thus tacitly asserting that the chemical environment of the waste (hence the retardation coefficient) would be identical in both cases.

The assertion that the chemical environment is identical regardless of the flow environment has not been demonstrated. DOE assumes that waters passing through highly reducing grout maintain a strongly reducing character when contacting the waste; however, calculations justifying this assumption are not presented. This assumption is used to justify large K_d values for the wasteform even though (1) the waste is not emplaced within reducing grout,

(2) no reducing grout lies between the waste and the external environment, and (3) the external environment consists of a partially saturated porous medium in which gaseous oxygen can readily diffuse. Even if the assumption of chemical protection were correct, should the water table rise sufficiently such that the waste would be inundated, water contacting the waste from horizontal flow would not pass through reducing grout and would not be afforded the same chemical benefits.

A lack of chemical protection would imply that the K_d values for the waste may be orders of magnitude smaller than those assumed by DOE, hence release rates could be orders of magnitude larger for saturated release than those calculated using the methods in Schepens, 1999 [23]. The largest vertical-to-horizontal flux ratio in Table 5 of Schepens, 1999 [23] is 73 to 1. Using the same calculations as Schepens, 1999 [23], except assuming that the wasteform K_d for Tc-99 is 1 mL/g in the horizontal (saturated) case (i.e., the same as the basemat) instead of 1,000 mL/g, implies that Tc-99 releases (hence peak doses) can be about 10 times larger in the horizontal release scenario than the vertical release scenario. Note that the Schepens, 1999 [23] calculation neglects lateral diffusion from the waste through the basemat, which may significantly increase release rates in the horizontal release scenario.

DOE [23] provided monitoring information on water levels in the vicinity of Tanks 18 and 19, indicating that water levels in monitoring wells adjacent to the tanks are typically 1.2 to 1.5 m (4 to 5 ft) below the tank bottoms. It is not clear that this is representative of the long-term environment of the tanks, however, for the following reasons:

- The water table elevation used to justify an extensive vadose zone may not be representative of postclosure conditions. Monitoring borehole FTF-12, located just outside the pit containing Tanks 17-20, typically has water table elevations 0.6 to 0.9 m (2 to 3 ft) higher than boreholes within the pit. Insofar as the pit is paved and dewatered so that local recharge is essentially zero, water elevations in the monitoring boreholes within the pit may be significantly lower than would be expected upon closure, and monitoring borehole FTF-12 may be more representative of postclosure conditions.

- A mildly wetter climate could cause a rise in water table that could result in inundation of the waste. The regional water table elevation results from a balance between regional recharge and lateral flow to discharge points. Since lateral flow gradients would be broadly unchanged if the recharge changed, lateral flow in the Upper Three Runs aquifer is roughly proportional to the water table elevation above the green clay confining unit (roughly 30 m [100 ft] in the vicinity of F Tank Farm). Thus, a long-term change in climate resulting in an increased recharge of just 2 percent would bring the water table elevation in FTF-12 above the bottom of both Tanks 18 and 19 on average.

Path Forward: Provide dose calculations using a realistic release model supported by experimental measurement or a clearly conservative release model. Alternatively, demonstrate that the current calculations and sensitivity analyses are realistic or conservative when taking into account the chemical environment of the waste. The assessment of the effect of water table fluctuation on the waste should take into account the changes in concrete pore water chemistry as a function of the number of pore volumes of water that have moved through the waste (e.g., Figure 2 of [28]) given the proposed cement content in the reducing grout [3] and the resulting effects on the sorption and solubility of radionuclides.

33. Comment: The depth to the water table is stated as being approximately 1.5 (5 ft) below Tanks 18 and 19; however, the uncertainty and variability in this value is not presented and the potential impacts of water table fluctuation are not addressed in the performance assessment. The current information does not support assuming the water table does not contact the basemat, tank bottoms, and waste throughout the 10,000 year analysis period because the analysis is incomplete.

Basis: The depth to the water table is important for a variety of reasons. A siting requirement for a low-level waste facility is that it not be located in the zone of water table fluctuation. This is because of potential increases in flux rates of contaminants to the saturated zone, and potential increased deterioration of engineered barriers in this zone such as a cement when exposed to cyclic wetting and drying. Whereas the analysis by DOE estimates a maximum of 8% of the reducing grout will be oxidized in 10,000 years, essentially all of the waste containing layer would be expected to oxidize in 10,000 years or less if exposed to water table fluctuation.

Limited information is presented to address the depth to water below Tanks 18 and 19. The PODD states that there is an approximate 1.5 m (5 ft) difference between the water table and the bottom of the tanks. In response to the NRC request for additional information on the closure of Tanks 17 and 20, DOE provided additional information on water levels for the F Tank Farm [23]. The vadose zone thickness is estimated to be 1.49 m (4.89 ft) and 1.28 m (4.21 ft), under Tanks 18 and 19, respectively. Based on data from 1986 to 1996 the average water table fluctuation at the F-Area is estimated to be +/- 1.3 m (4.4 ft) based on a 95% confidence interval. Figure 4 [23] shows that on two occasions during the 1986 to 1996 period, the water level in the wells closest to Tanks 18 and 19 exceeded the level of the tank bottom. The data from 1986 to 1996 includes the effect of yearly and seasonal variation; however, the analysis approach is incomplete and the conclusions are not supported by the analysis.

The measurement period for the water-level data is limited. The precipitation over this period ranged from approximately 120 to 140 cm (46 to 55 in) per year, and the 31 year average is 126.3 cm (49.73 in). In 1971, there were over 160 cm (64 in) of precipitation and in 1964 there were over 180 cm (73 in) of precipitation. The calculation of the confidence interval from the water

level data may not appropriately represent the variability and uncertainty in the data. The water level data should have seasonal and yearly variability. The calculation of the confidence intervals appears to have calculated an average fluctuation that does not appropriately represent the uncertainty and variability in the seasonal values. For example, if there were 24 measurements for a particular well, it would be expected that there may be only six measurements per season in the time series. By combining all of the data without justification, a higher degree of confidence in the variability than is actually known is presented. In addition, a wet season that has a higher seasonal average would need to have less fluctuation in order for the water level to rise to the level of the tank bottoms. Finally, because the time series only represents 1986 to 1996, it is certain that the observed water level changes do not span the projected water level variation for the 10,000 year analysis period. A statistical projection that also considers extreme events that could result in rapid increase in local recharge rates, such as hurricanes and tropical storms, would need to be performed.

Path Forward: Provide all water level data collected for the F Tank Farm, preferably in electronic form. Provide detailed information on the depth to water at Tanks 18 and 19 including a plan view map showing the closest wells, their time histories of water levels, when they were installed, and how it was ensured they have not been clogged with siltation or other processes that would impact their water level. Provide a statistical projection of water levels at the F Tank Farm with and without the consideration of extreme events such as hurricanes and tropical storms. Provide an assessment of the impacts naturally induced climate change would have on water levels at Tanks 18 and 19 over the next 10,000 years. Provide an assessment of the risk to an inadvertent intruder and member of the public (see Comment 19) assuming the tank bottoms are in the water table, oxidizing conditions prevail, and the grout has hydraulic and chemical properties appropriate for degraded conditions. Provide an assessment of the potential pulse of material that could be released depending on the timing of water table fluctuation at Tanks 18 and 19.

34. Comment: Additional information about the effects of radiation and heat generated by the residual waste in Tanks 18 and 19 on the durability of the grout is needed to assess the predicted physical degradation of the grout.

Basis: Documented tests of various grout formulations used to support the selection of the proposed formula for the reducing grout [29] indicates that curing temperature was a factor in choosing a reducing grout formula to minimize the potential for thermal and shrinkage cracking. However, the potential effects of the thermal properties of the waste itself on grout thermal and shrinkage cracking were not addressed. Because the waste is expected to remain relatively unmixed and to be localized at the bottom of the tank, it seems that the waste could cause thermal gradients in the grout that could have an effect on waste cracking and degradation. Similarly, the potential for radiological damage to the grout was not addressed in the waste determination or PODD.

Path Forward: Provide a basis for concluding that the radiological and thermal properties of the residual waste in Tank 18 and 19 will not enhance degradation of the grouted waste, or assess predicted effects on grout integrity and radionuclide release.

35. Comment: Additional information and clarification of information presented in Table 7-4 of the draft waste determination is needed.

Basis: Table 7-4 of the draft waste determination indicates that the grout was assumed to fail hydraulically and chemically at 500 years, which does not appear to be consistent with what was actually done in the modeling of Tanks 18 and 19 (or Tanks 17 and 20). The modeling of Tanks 18 and 19 assumed the tanks failed hydraulically at 500 years but that the chemical properties persisted for the analysis period of 10,000 years.

The table indicates that the carbon steel liners are expected to remain essentially intact for 700 years but no reference for that estimate is provided. A reference is needed to enable assessment of any conservatism associated with not including the liner in the performance assessment.

Path Forward: Correct the table or clarify the information. Provide a reference for the estimate that the carbon steel tanks will remain intact for 700 years.

36. Comment: Justification for the assumed immobilization of the free liquid fraction of the residual waste in Tanks 18 and 19 by the reducing grout is not sufficient.

Basis: The stabilization approach for Tanks 18 and 19 involves addition of reducing grout to stabilize the residual waste. Tank 18 is estimated to contain 9080 L (2400 gal) of free liquid and Tank 19 is estimated to contain 6800 L (1800 gal) of free liquid. Although the results of tests indicated that the selected grout formulation had 0% bleed water [29], demonstration of binding of free liquid was not provided. 10 CFR Part 61 does not allow for disposal of any free liquids as low-level waste, because liquids can be easily dispersed into the environment. The fractional release rate associated with the free fraction may represent a substantial risk.

Path Forward: Provide the data demonstrating that the free liquid is bound with the grout selection and emplacement techniques, such as leaching test results for the grout blend selected for Tanks 18 and 19 closure. These test results would ideally be from large-scale samples that have been produced with conditions similar to actual waste emplacement conditions and procedures. Starting with the correct proportions of simulated solid and liquid waste residuals in a steel vessel, grout would be poured in a process similar to tank closure. The resulting column would be characterized and leach tested, with specific information about retention of the free liquid fraction developed. An alternative approach would be to compare the fractional release rates estimated in the performance assessment calculations with the potential fractional release rates from the free liquid fraction to show the performance

assessment values bound the impacts (e.g., for H-3, I-129, Cs-137, Sr-90, Tc-99, Np-237, Pu-isotopes, U-isotopes).

37. Comment: DOE has not provided a justification for the use of distribution coefficients (K_d values) developed for cementitious materials in the source term release model.

Basis: The tank residual materials are those that remain after extensive cleaning operations. DOE has indicated that it expects relatively little mixing between the waste and grout [3]. It is likely that residual waste will form a distinct layer sandwiched between overlying grout and the steel tank bottom. The release model presented in the PODD [3] employs K_d values developed for modeling transport through cementitious materials. However, if the residual waste does not mix with the grout but underlies it, then most of the waste inventory will not come into direct contact with the reducing grout. Therefore, the basis for using cementitious material K_d values is not clear.

At the January 25, 2006, meeting between NRC and DOE, DOE indicated that the basis for using K_d values applicable to reducing grout to represent release of radionuclides from the waste even though the waste is not expected to mix extensively with grout was that the chemical conditions of the water contacting the waste were expected to be dominated by the effects of the reducing grout. However, this response appears to discount the role of sorption sites in the cementitious material. As indicated in the reference from which most of DOE's K_d values for grouted waste were taken [28], concrete composition has relatively small effect on the sorption of many radionuclides to concrete as long as the pore water pH remains above 12.5 because the dominant sorbing substrate is the cement itself. Thus, even if the waste were expected to mix with the reducing grout thoroughly, the basis for using K_d values developed to describe radionuclide sorption to ordinary concrete is not clear because of the relatively low cement content of the proposed reducing grout (i.e., approximately 2% by weight for the proposed reducing grout [3] as compared to over 10% by weight for ordinary concrete). In addition, the potential effects of grout additives, such as sodium thiosulfate, Advaflow, and Kelco-Crete, on the mobility of radionuclides in the cement is unknown.

DOE uses K_d values from Bradbury and Sarott [28] for most of its radionuclides in the grout, including Tc and Np. The cited reference describes three "Regions" of concrete chemical degradation as a function of pH [28]. DOE uses K_d values consistent with Regions I and II for most radionuclides in grouted waste, which would be relevant to radionuclides in concrete with a pore water pH above 12.4 [28]. However, as a chemical requirement the PODD indicates that the grout must maintain the pH of infiltration water above 9.5 [3], which would correspond to lower "Region III" K_d values. Although the PODD states that previous reducing grout analysis indicates that the pH is greater than 12 for tank closure grouts [3], the cited reference analyzed grouts with cement fractions ranging from 28% to 33% cement by weight [30], which would be expected to have significantly higher

alkalinity pore waters than the proposed reducing grout because the proposed reducing grout will contain only approximately 2% cement by weight [3] and the cement fraction of concrete typically controls pore water pH and alkalinity.

Path Forward: Provide a technical basis for using K_d values developed to describe sorption of radionuclides in ordinary concrete to describe release of radionuclides from the grouted tanks, given that DOE expects relatively little mixing between the waste and grout and that radionuclides are not expected to come into contact with cementitious materials until they reach the concrete basemat. The response should address differences between the proposed grout formulation and the concrete for which any literature K_d values that are used in the performance assessment were developed, including the possible effects of the grout additives as well as the relatively low cement fraction of the grout. If it is determined that there is sufficient technical basis to justify the use of K_d values developed to represent radionuclide mobility in ordinary concrete to represent radionuclide release from residual waste in Tanks 18 and 19 that will not be mixed with grout to a significant extent, the applicability of Bradbury and Sarott Region I and II values as compared to Region III values should be addressed specifically. Provide any studies that have been done to measure the pore water pH of the proposed reducing grout. Provide any studies that have been done to measure leaching of radionuclides from samples of solids taken from the tanks that were not mixed with grout.

38. Comment: Insufficient basis has been provided to support DOE's conclusion that the chemical performance of the reducing grout will not deteriorate during the performance period.

Basis: The report DOE used as a basis for its source term K_d values provides a diagram showing the expected decrease in concrete pH as a function of water flow through the concrete and the amount of anhydrous cement in the concrete [28]. Because of the low cement content of the proposed reducing grout, the progression to the lower K_d values applicable to aged concrete, designated as "Region III" values in the reference document, from the "Region I" values that DOE used for most radionuclides in its performance assessment would be expected to be more rapid for the reducing grout proposed by DOE than for ordinary concrete. Thus, even if the grout were expected to mix thoroughly with the waste, it seems that Region III K_d values would be more appropriate than Region I and II K_d values to describe radionuclides release from the source term for a significant fraction of the performance period.

In addition, it is not clear that redox conditions at the bottom of the tanks will be unaffected by potential aqueous or gaseous oxygen transport from below due to water table rise over time from climate change effects.

Path Forward: The response should address the expected change of pore water chemistry with time, taking into account the amount of water expected to pass through

the wasteform and the specific proposed grout formula [3]. The response should also address the potential for oxidizing conditions in the lowermost portions of the tanks.

39. Comment: It is unclear why several site-specific K_d values were not used in the performance assessment modeling.

Basis: In Table 4-6 of the PODD [3], a Tc-99 K_d of 1 mL/g is used for the clay subsurface units. In the performance assessment for the proposed saltstone disposal facility at the nearby Z-Area [31], a value of 0.1 mL/g was used, presumably for similar or identical clay units. The latter value was supported by site-specific data. Tc-99 is one of the two most important radionuclides in dose assessments for Tanks 18 and 19.

Similarly, site-specific measurements of actinide mobility in the F-Area at SRS appear to indicate that Am and Cm can be transported in dissolved form fairly readily at SRS [32], implying that it may not be appropriate to use the high K_d values used to represent Am and Cm mobility in the subsurface in the Tank 18 and 19 performance assessment.

Path Forward: Explain why certain site-specific information included in the saltstone performance assessment for Tc-99 transport in clay units was not included in the PODD [3]. Alternatively, demonstrate that the clay unit Tc-99 K_d value has a negligible effect on calculated dose. Explain why site-specific observations of Am and Cm mobility in the SRS F-Area are not reflected in the K_d values used in the Tank 18 and 19 performance assessment.

40. Comment: Leaching from grout would increase the pH of infiltrating groundwaters and could result in the migration of an alkaline plume below the grouted tanks. The presence of an alkaline plume could affect the transport of radionuclides from the grouted waste. These effects were not considered in the performance assessment.

Basis: Pore fluids in contact with fresh cementitious materials typically have a pH greater than 10 [33, 34]. The high pH and the low silica concentration associated with cement pore fluids could strongly alter the aluminosilicate minerals (e.g., clays) present in the underlying native soil. The sorption properties of radionuclides could be affected by changes in the properties of the soils and by changes in water chemistry and aqueous radionuclide speciation. These effects could influence the transport of contaminants from the grouted vaults.

Path Forward: Evaluate the potential importance of alkaline plume migration on the transport of radionuclides in the unsaturated zone under the grouted vaults or explain why it is not important.

41. Comment: The technical basis for uranium and plutonium grout K_d values based on solubility limits is not supported by references and has not been demonstrated to be reasonably conservative.

Basis: On page 147 of the PODD [3], DOE describes a solubility-based model for calculating grout release K_d values for uranium and plutonium. A reference is not provided for the key statement that, "Uranium and plutonium have previously been determined to have concentration limits in high pH environments such as grouted high-level waste tanks at the Savannah River Site (SRS), which are limited by the solubility (3×10^{-10} and 4.4×10^{-13} moles/liter, respectively) of these elements." Staff needs to review the basis for employing solubility control to calculate K_d values for the specific solubility limit values used, and for attendant assumptions about redox conditions, which affect uranium and plutonium solubility. The resulting K_d values (Table 4-7) are many orders of magnitude higher than any used for other actinides, and it is not clear why uranium and plutonium were treated differently.

Clarifying information resulting from the January 25, 2006, meeting with DOE [35], states that the technical basis for the solubility values for plutonium and uranium presented in Section 4.1.10 of the Tank 19 and Tank 18 PODD [3] was provided as Reference 9 in [3]. However, the text of the referenced document [36] indicates that the solubility limits are developed in Appendix E, and the version of the document supplied with the draft waste determination included only the main text of the document and does not include appendices. Available references indicate that the solubility limits for Pu and U in a cementitious environment may be much higher than the limits used as a basis for the effective K_d values used in the performance assessment model. For example, Ewert et al. (1992) [37] measured solubility limits for Pu and U in cement equilibrated waters with pH values ranging from 9 to 13 and reducing conditions to be approximately 1×10^{-10} M and 3×10^{-7} M, respectively. It is unclear why the solubilities of Pu and U in Tanks 18 and 19 would be expected to be significantly lower than the solubilities for Pu and U in high-pH, reducing conditions observed by Ewert et al. (1992) [37]. In a longer-term study, after 20 months leachate from a grout amended with Blast Furnace Slag and maintained in a reducing Ar/H_2 environment had a measured concentration of 9.7×10^{-10} M Pu-239/Pu-240 and a measured U concentration of 2.7×10^{-6} M [38].

Furthermore, it is not clear that solubility limits for U and Pu in ordinary concrete will accurately predict U and Pu solubility in the proposed reducing grout, because of the unknown effects of grout additives such as sodium thiosulfate, Advaflow, and Kelco-Crete, on U and Pu solubility.

A feature of a K_d-based release model is that the aqueous concentration of the radionuclide decreases as the source is depleted. Therefore, the uranium and plutonium K_d values will result in aqueous concentrations below a true calculated solubility limit as these elements are removed from the waste over time. DOE needs to provide a justification that such decrease in aqueous concentration, which is conceptually inconsistent with the solubility-based release model, does not significantly affect dose calculations (e.g., if release is slow enough that waste concentration decays negligibly).

In addition, effective K_d values calculated based on solubility limits depend on

the concentration of the radionuclide in the source. Although DOE states that no credit has been taken for mixing, effective K_d values decrease with decreasing source concentration. Therefore, it is non-conservative to neglect mixing of waste and grout in the calculation of an effective K_d from a solubility limit, and it would be more appropriate to assume the maximum amount of mixing expected between grout and waste when calculating an effective K_d from a solubility limit.

Path Forward: Provide a technical basis supporting the use of a solubility model for uranium and plutonium and provide references for the solubility limits used. Provide justification for using the referenced solubility limits, specifically addressing differences in the expected pore water chemistry of the concrete used in the referenced experiments and the proposed reducing grout, including the potential effects of grout additives. Provide support for the redox conditions assumed in the solubility model in light of uncertainties regarding maintenance of reducing conditions at the wasteform. Justify the use of a K_d model for uranium and plutonium, which results in decreasing aqueous concentrations over time in contradiction of the solubility conceptual model.

42. Comment: Additional justification is needed to support neglecting colloidal release of radionuclides from the grouted tanks.

Basis: In the performance assessment model, the concentrations of Pu and U are modeled as being solubility limited. However, colloidal transport can cause the release of Pu and U in excess of their solubility limits. The performance assessment model does not include the release of colloid-associated radionuclides from the waste form. Although it is recognized that two site-specific studies support the conclusion that there is very little colloidal transport of Pu at the F Tank Farm [32, 39], the concern remains that colloidal transport could enhance radionuclide release from a fractured waste form and that colloid-associated radionuclides could become dissolved (i.e., by dissolution or desorption) once released into the natural environment.

In general, pore waters of cementitious materials would be expected to have high ionic strengths that would destabilize colloids. However, because the reducing grout proposed by DOE is a novel formulation containing relatively little cement, it is not clear that the ionic strength of the pore water will remain high during the performance period, especially in cracks that may form fast pathways for the release of colloid-associated radionuclides. Similarly, it is not clear that a thin (18 cm [7 in]), fractured basemat will provide a sufficient chemical or physical barrier to limit colloidal release.

Path Forward: Provide support for the conclusion that the release of colloid-associated radionuclides from Tanks 18 and 19 will be negligible or provide a technical basis for bounding the colloid-associated release of Pu and U from Tanks 18 and 19 during the 10,000 year performance period.

43. Comment: Data providing measured laboratory- and field-values of hydraulic conductivity of the reducing grout and distribution coefficients and solubilities

of radionuclides in contact with water that has infiltrated through the proposed reducing grout are not provided.

Basis: The reducing grout is a novel formulation that may have unique properties that are not addressed in the performance assessment calculations. The reducing grout is expected to contain Portland cement, water, sand, slag, fly ash, sodium thiosulfate, a special viscosifying admixture, and a high range water reducer. The novel additives may have beneficial or adverse impacts on the hydraulic properties of the grout and its ability to modify infiltration chemically to retain radionuclides. Furthermore, because of its low cement formulation, the grout is expected to have different sorptive characteristics than ordinary concrete (also see Comment 37).

Path Forward: Provide laboratory and field values of hydraulic conductivity of the proposed reducing grout, as well as solubilities and distribution coefficients of highly radioactive radionuclides in contact with water that has infiltrated through the proposed reducing grout, or provide plans to generate the information.

44. Comment: Insufficient technical basis is provided to support the assumption that the reducing grout will cause infiltrating water to have low Eh as it moves through the grout.

Basis: The performance modeling for Tanks 18 and 19 does not assume the reducing grout mixes with the residual waste. Rather, the assumption is that infiltrating water will acquire a high pH and a low Eh from moving through the grout. This assumption is based in part on testing discussed in the report by Caldwell (1997) [30]. As discussed in Appendix A of the report, the Eh of deionized waters after reacting with crushed samples of reducing grout was measured. The 18 Eh values reported are all below -90 mV and are sufficiently reducing to cause reduction and precipitation of technetium(VII) as a technetium(IV) sulfide phase. However, a sufficient basis is not provided to support the assumption that infiltrating waters will continue to be reduced during the entire performance period. On the contrary, the results presented by Kaplan, et al. (2005) [40] suggest that the grout present along water flow pathways will not continue to reduce and that later infiltrating waters no longer will acquire a low Eh by reacting with the grout. Kaplan, et al. (2005) calculations show that the grout becomes oxidized where it comes into contact with infiltrating water carrying dissolved oxygen, mostly along the outer edge of the tank bottom (no crack scenario) or along the sides of the crack (one- or three-crack scenarios). Thus, the MEPAS calculations presented in the PODD [3], in which the K_d values for Tc-99 was kept constant at 1,000 mL/g, did not account for the oxidation of grout present along the water flow path and the potential effects of oxidized infiltrating waters on the release and transport of Tc-99.

Path Forward: Provide sufficient technical basis for the assumption that infiltrating waters will continue to be reduced throughout the MEPAS simulation time or discuss how the results of the sensitivity analyses sufficiently bound the potential effect of oxidized infiltrating waters on the release and transport of Tc-99.

45. Comment: Transport of all significant daughters may not be represented adequately in the performance assessment.

Basis: MEPAS assumes that daughters are transported at the same rate as the parent, which can lead to significant errors in dose calculations if the distribution coefficients of persistent and harmful daughter radionuclides are significantly lower than the distribution coefficients of the parents. For example, the distribution coefficient for Np-237 in the soil (5 mL/g) is substantially lower than the distribution coefficient for its parent (Am-241) in the soil (1900 mL/g) or its parent in the grout environment (Pu-241, which has essentially unlimited sorption in the grout in the current DOE approach).

Although this issue is not directly addressed in the PODD, a data validation report for performance assessment modeling for Tank 18 [41] indicates that the Np-237 inventory used in the MEPAS runs was increased to account for the ingrowth from the Am-241 that is originally present in Tank 18. However, no similar inventory adjustment appears to have been made for any other radionuclides, and it was not shown that Np-237 is the only daughter radionuclide of concern. It appears that the release of Pb-210, which would be expected to have a K_d of approximately 500 mL/g in a fresh cementitious environment and 50 mL/g in a degraded cementitious environment [28] may be under represented because its parent, U-234 is modeled with an extremely high K_d in both Tank 18 (5.98×10^8 mL/g) and Tank 19 (3.45×10^7 mL/g) [3]. In addition, the K_d values used to model Pb-210 are not included in Table 4-6 of the PODD.

Path Forward: Provide an evaluation of the potential impact of differences between the mobility of parent and daughter radionuclides on the dose predicted by the Tank 18 and 19 performance assessment. For any radionuclides for which the potential impact of differences in the mobility of parents and daughters is expected to have an impact on dose, provide calculations to bound the impact on dose or modify the performance assessment (e.g., by performing inventory adjustments or by setting the distribution coefficients of the parents and daughters equal and to the minimum in the decay chain) to predict the impact on dose. Provide the K_d values used to model Pb-210 in the performance assessment.

46. Comment: The possible effects of grout cracking on the oxidation of grout do not account for movement of oxygen in the gas phase and appear to have been underestimated.

Basis: The predicted oxidation of grout resulting from cracks in the grout depicted in Figures 2-33 through 2-35 of the PODD were based on the assumption that the cracks remain saturated with water, as indicated by DOE during the NRC and DOE meeting on January 25, 2006. However, no basis was provided for the assumption that cracks in the grout will remain saturated with water. Because oxygen will diffuse into the grout faster in the gas phase than in the liquid phase, the extent of oxidation of the grout during the performance period may have been underestimated significantly. Oxidation of grout is a

concern because of the large increase in the mobility of Tc in grout that occurs when the grout becomes oxidized.

Path Forward: Provide a basis for the assumption that cracks in the grout will remain saturated or update the predicted extent of oxidation of the grout to reflect diffusion of oxygen as a gas. Provide a basis for estimating or bounding the impact of grout oxidation during the 10,000-yr performance period on the release of Tc-99 from Tanks 18 and 19.

47. Comment: Modeling of a cracked basemat as a uniform layer of sand may overestimate the retardation of radionuclides in the degraded basemat.

Basis: In the performance assessment, the basemat was modeled as a layer of sand with K_d values that are applicable to concrete. This implementation provides a significant amount of retardation of radionuclides in the basemat in DOE's model. For example, the late run MEPAS files indicate the "centerline advective travel time" through the basemat for Pu and Np is 3666 years for Tanks 18 and 19 and 24,510 years for tanks with 119 cm (3.9 ft) thick basemats. In reality, radionuclide transport through the basemat is likely to be driven by fracture flow rather than by transport through the bulk material. There is not as much surface area for the radionuclides to sorb onto when the infiltrating water travels through fractures as there is when the water travels through pores in the basemat, and, therefore, not as much retardation is expected. Therefore, it is not clear that the implementation is appropriate or conservative.

Path Forward: Provide a basis for modeling the hydraulically failed basemat as layer of sand, specifically addressing the reduced surface area for sorption that would be expected in a fractured basemat as compared to a uniform layer of sand. If it is determined that modeling a cracked basemat as a layer of sand with K_d values applicable to concrete cannot be justified, provide an alternate model of the hydraulically failed basemat in the performance assessment model.

48. Comment: The analysis in the performance assessment takes substantial credit for the concrete basemats under the tanks without data to substantiate their integrity.

Basis: The performance assessment model assigns 4 cm/yr (1.6 in/yr) infiltration to the waste in the pre-failure time (e.g., before 500 years). However, although the radionuclide flux from the source is consistent with infiltration of 4 cm/yr (1.6 in/yr) of water through the waste, the assumed basemat integrity for the first 500 years after closure limits the releases to the underlying soil as if the infiltration rate assigned to the waste is only 0.3 cm/yr (see Comment 49). This could be of particular concern for contaminants such as Sr-90 that have a high specific activity and are not strongly sorbed onto the soil in the relatively thin or absent unsaturated zone.

The modeling is performed with the assumption that the basemats have

remained perfectly intact since installation roughly 50 years ago, and does not take into account the original geometry. The basemats for Tanks 18 and 19 are only 0.18 m thick (7 in) [3] and contain drainage slots of approximately 0.05 m (2 in) depth [42]. Because the basemats may be located in the zone of water table fluctuation (see Comments 32 and 33), and have experienced varying loads as a result of tank operations, it is unclear that the basemats currently are physically intact. Fracture flow through cracks can effectively eliminate the performance of a thin concrete slab with respect to being a barrier to radionuclide transport.

Furthermore, if water infiltrating through the tanks preferentially travels to the drainage slots, it appears that the appropriate thickness of the basemat in transport calculations is not the full 18 cm (7 in) basemat thickness but instead is the thickness under the drainage slots. Although the drainage slots represent a small fraction of the surface area of the basemat, they may have a significant effect on performance even if they do not enhance basemat degradation because water would be expected to preferentially migrate toward the drainage slots.

Path Forward: Provide data to justify assumption that the basemats are intact, or assess the impact on dose of assuming that the basemats are currently cracked (i.e., that they do not limit water flux or provide for significant radionuclide retention [see Comment 47] for the first 500 years after closure). An appropriate assessment on the impact of basemat integrity on dose would be expected to address the impact to a member of the public as well as an inadvertent intruder. Provide the design information for the basemats, including the frequency and geometry of the drainage slots. Provide a description of reinforcement used in the basemats, if any, including the thickness of concrete covering the reinforcement. In addition, provide a discussion of the vaults that summarizes their construction, materials, design characteristics, and characterization of initial and current integrity. Describe the effect the drainage slots are expected to have on basemat integrity and performance.

FAR FIELD TRANSPORT

49. Comment: Additional clarification of the implementation of water fluxes in the performance assessment model is needed.

Basis: There appear to be some inconsistencies in the input values supplied to MEPAS. Internally to MEPAS, the calculated travel time through unsaturated legs appears to be based on a pore water velocity calculated by the smaller of the specified permeability and Darcy velocity values. The supplied permeability values are not necessarily consistent with the specified Darcy velocity in the inputs, and the Darcy velocities are not necessarily consistent with the applied seepage flux through the tank. For example, in Table C-13 [3] the permeability value (smaller than the applied flux) controls pore water velocity in medium 1 (the basemat), while the Darcy velocity (smaller than the

applied flux) controls pore water velocity in medium 2 (the vadose zone).

In addition, the annual flux of water through the source before hydraulic failure requires additional explanation. Figure 4-4 of the PODD indicates that 4 cm/yr of water flows through the source, but that its hydraulic conductivity is only 0.3 cm/yr. Furthermore, the hydraulic conductivity of the basemat before failure is only 0.3 cm/yr. Thus is it unclear where 3.7 cm/yr of water that flows through the source flows when it reaches the basemat. If the water flows around the basemat, it would represent faster pathways of radionuclide release.

Path Forward: Explain how water fluxes in various layers are calculated in the performance assessment model, specifically addressing the points in the Basis of this comment.

50. Comment: The performance assessment assumes an infiltration rate to the waste of 4 cm/yr prior to failure at 500 years, and a value of 40 cm/yr based on natural recharge estimates for SRS after failure. The post-failure value does not consider the actual geometry and current state of the tanks.

Basis: The soils surrounding the tanks were disturbed during construction of the tanks. Disturbed soils can have significantly higher hydraulic conductivities than undisturbed soils. The tanks are located in a depression that has large slopes of rip-rap material. DOE has not indicated that the rip-rap material will be removed upon tank closure and filling of the depressed area. The rip rap can act as a high conductivity pathway to effectively capture infiltration from a larger area and focus that infiltration in the vicinity of the closed tanks.

Path Forward: Provide the basis for assuming the hydraulic conductivity of disturbed soils will be the same as undisturbed soils. Provide the basis that the rip-rap layers will not result in substantially higher long-term infiltration to the tanks.

MODEL IMPLEMENTATION

51. Comment: The description of the performance assessment calculations presented in the PODD [3] is not sufficiently complete to allow staff to fully understand the conceptual models (from source to receptor) of each calculation executed, and the document does not provide a complete or integrated summary description of how each of these calculations were implemented from beginning to end (e.g., source to dose).

Basis: The PODD [3] describes the results of a variety of uniquely executed release, transport, and exposure calculations. This description indicates these calculations were implemented by executing the MEPAS 4.1 code, postprocessing code output with a separate FORTRAN program, and computing final dose results using spreadsheet software. This unique approach to implementing the calculations, such as using multiple code runs, adjustments to inventories, and substantial postprocessing of intermediate code outputs, requires additional explanation to ensure staff have the correct understanding of how the performance assessment was accomplished from

beginning to end. While individual parts of the performance assessment calculations are explained in detail, other parts are not described adequately. Additionally, it is important to have a more complete integrated summary of the entire modeling approach.

Areas for which additional explanation is needed include:

(1) The mechanics of the MEPAS calculations with regard to inventory adjustments explained on page 135 of the PODD [3], including why each inventory adjustment was made and why the code had to be run three times to implement the pre-grout and post-grout failure runs with the inventory adjustments.

(2) The algorithm used to calculate the inventory used in the early tank runs (i.e., run 2) from the MEPAS output from the pre-failure results (i.e., run 1). It is unclear how the outputs from the pre-failure MEPAS files were used to calculate the input to the early tank run (run 2) MEPAS files. Although the PODD (p. 135) indicates that the results of the pre-failure runs were used to determine the released inventory that reaches the aquifer in the first 500 years, because the pre-failure MEPAS files have a run time of 10,000 years the values for the activity that reaches the aquifer presented in the pre-failure .WLS files correspond to the radionuclides that reach the aquifer in 10,000 years rather than in the 500 year pre-failure period.

(3) The functions of the postprocessing FORTRAN program that is identified in box 2 of Figure A-3 of the PODD [3] and the spreadsheet shown in box 5 of the same figure, including which file types are consumed and produced by the FORTRAN program and the spreadsheet.

(4) How the water balance percentages (e.g., 31% of infiltration goes to the Water Table Aquifer, 65% to the Barnwell Aquifer, and 4% to the Congaree Aquifer) were included in the performance assessment. In the late source release MEPAS files for the transport of inventory from Tank 18 to the Congaree Aquifer (file FR05LCT8, page 10), the "mass passed this medium" parameter indicates that 58% of the Tc that is released from the source is transported through the green clay layer to the Congaree aquifer in 10,000 yrs. This is inconsistent with the assumption that only 4% of the contaminated infiltration water reaches the Congaree Aquifer.

(5) The method used to calculate the pathway dose conversion factor values presented in Table C-43 of the PODD [3].

(6) Which pathways are included in the calculation of dose in Tables 4-15 to 4-35 and the reason for excluding any pathways not

included in these calculations.

(7) The distances used from the tanks to the seepline receptor. At the meeting on January 25, 2006 it was stated that the "distance to the aquifer outcrop" values were used in the MEPAS modeling. However, the values used in the MEPAS modeling for the distances from the tanks to the aquifer outcrops (i.e., the "Centerline Downgradient Distance from Center of Source (X2)" parameter in MEPAS for the saturated zone layer for the adult receptor scenario) differ from the distances listed in Table 4-2 of the PODD [3]. The distances presented in Table 4-2 and the distances presented in the MEPAS Input/Output files are presented in the table below.

aquifer	Tank 18		Tank 19	
	distance in Table 4-2 (ft)	distance in MEPAS (ft)	distance in Table 4-2 (ft)	distance in MEPAS (ft)
Water Table	6213	6300 (1920 m)	6057	6168 (1880 m)
Barnwell-McBean	6077	6168 (1880 m)	5921	6037 (1840 m)
Congaree	5392	5479 (1670 m)	5236	5348 (1630 m)

Path Forward: Provide a traceable and integrated summary of the performance assessment calculations that identifies all transformations and adjustments to code inputs and results and provides additional clarification of the items described in the Basis of this comment to ensure the description of the performance assessment approach is complete. Include the necessary links between input and output files and results to clarify the overall computational approach. Provide the MEPAS files with which the pathway dose conversion factors (DCF) values were calculated.

Provide a map that shows the location of the wells located 1m (3.3 ft) from the tank farm, 100 m (330 ft) from the tank farm, and at the seepline, and the location of the seepline resident receptor in relation to Tanks 18 and 19. For the 1 m (3.3 ft) and 100 m (330 ft) well, indicate the location of these wells in the direction of groundwater flow for the Water Table, Barnwell-McBean, and Congaree Aquifers. Include on this map the boundary of the tank farm as well as the distances from the Tanks 18 and 19 to each of these receptor locations.

52. Comment: It is not clear that dispersion is being appropriately calculated and that the results do not represent significant numerical dispersion due to an insufficient evaluation of the sensitivity to time-stepping.

Basis: In the sensitivity analysis performed for the intruder well location with respect to drinking water, the dose to a receptor obtaining drinking water from a well located 100 m (330 ft) from the F Tank Farm (approximately 300 m [980 ft]

from the tanks) was only 26% of the dose to a receptor obtaining drinking water from a well located 1 m (3.3 ft) from the F Tank Farm (approximately 200 m [660 ft] from the tanks) [3, Table 5-14]. The increase in the exposure point from the source should not result in such a large decrease in dose, which would appear to be solely a result of dispersion. Because the dose is attributable to long-lived radionuclides, it does not appear that the difference is due to decay during transport. In Table 5-15 of the PODD, an increase in the well location from 1 m (3.3 ft) to 100 m (330 ft) from the tank farm (i.e., 200 m [660 ft] to 300 m [980 ft] from the source) results in a decrease in the maximum dose by a factor of five even though the time of the peak is the same (665 years).

Path Forward: Provide the sensitivity to time-stepping in the analysis to demonstrate there is not significant numerical dispersion. Provide a comparison to a separate calculation (such as separate groundwater calculation) to demonstrate that the MEPAS results are reasonable in the current application.

53. Comment: It is unclear what procedure was used to transform the concentrations of radionuclides presented as the results of the MEPAS modeling in the .eco files to the concentrations of radionuclides used in the calculation of dose.

Basis: The concentrations of Pa-233 and Ra-225 used to calculate dose in the results calculation files are different than the concentrations that were calculated by MEPAS and presented in the .eco files. For example, in the file FA05LBT8.eco, the concentration of Pa-233 has a value of up to 2.1×10^{-18} Ci/mL in Fourmile Branch and up to 7.0×10^{-15} Ci/mL in the 100 m (330 ft) well water and the concentration of Ra-225 has a value of up to 1.5×10^{-20} Ci/mL in Fourmile Branch and up to 2.7×10^{-17} Ci/mL in the 100 m (330 ft) well water. However, in the file "Barnwell McBean Alpha Calcs.xls" for Tank 18 on the "A calcs" tab the concentration of Pa-233 and Ra-225 is 0 Ci/mL for all time steps and all receptor locations.

Path Forward: Explain the procedure used to transform the concentrations of radionuclides listed in the .eco files to those used in the calculation of dose.

54. Comment: Additional information about radionuclide screening is needed.

Basis: Page 86 of the draft waste determination indicates that "the tank 19 and 18 groundwater analysis included all radionuclides identified in the residual material." Furthermore, page C-1 of the PODD indicates that the appendix does not include MEPAS files associated with radionuclides that contribute less than 0.01% of peak annual dose, which implies that radionuclide transport and dose were calculated for the screened radionuclides. However, page E-1 of the Tank Closure Modeling Input/Output Data Verification document [41] appears to indicate that radionuclides were screened prior to evaluation with MEPAS and that MEPAS runs were performed only for a small group of radionuclides (i.e., the radionuclides that are included in "List A" and "List B" in the PODD).

The MEPAS files provided for the radionuclides that were screened out and not included in the full MEPAS analysis (i.e., Appendix C [other radionuclides]) only pertain to Tank Group 3, and it is unclear whether radionuclide screening for Tanks 18 and 19 were based on the results of the screening analyses for Tank Group 3. Because the basemats under the tanks in Tank Group 3 are much thicker than the basemats for Tanks 18 and 19, and because DOE's performance assessment model predicts significant radionuclide retardation in the basemats, many radionuclides that DOE would predict would not be transported through the thicker Tank Group 3 basemats within 10,000 years in the model may have been screened out of the Tank 18 and 19 analyses inappropriately. In addition, some of the radionuclides in the tables of inventories for Tanks 18 and 19 (Table 3-2 and 3-4) are not listed in the MEPAS files NRC was given to document the screening analysis. Thus it is unclear how these radionuclides were screened from further analysis.

Path Forward: Describe the procedure used to screen radionuclides out of the groundwater analysis for Tanks 18 and 19.

55. Comment: The small effect on calculated dose when the Tc-99 grout K_d is changed from 1,000 to 1 mL/g and basemat and soil K_d values are set to 0 mL/g is unexpected and raises questions about the suitability of the MEPAS groundwater transport model for calculating dose.

Basis: Section 5 of the PODD [3] describes the results of the parameter sensitivity analyses applied to the MEPAS-based dose models. In one sensitivity case, a lowering of the grout Tc-99 K_d from 1,000 to 1 mL/g led to an increase in peak Tc-99 dose by only 32% (Table 5-4). When, in addition to this change, transport pathway Tc-99 K_d values were changed to 0 mL/g, the peak dose decreased from the base case by 4% (Table 5-5). As noted in the PODD [3], these results are non-intuitive. With no retardation in the basemat and soil, the Tc-99 peak should arrive sooner and be less attenuated by dispersion. More significantly, a lowering of the grout K_d by three orders of magnitude should result in source aqueous Tc-99 concentrations 1,000 times higher. Such a large increase in initial radionuclide concentration should be reflected in peak dose. The PODD explains this result as a function of the 70-year averaging period used by MEPAS. This explanation could be valid if all Tc-99 was released from the wasteform during the same 70-year period in both the base case and the low-K_d case. In such a case, the 70-year average dose would be the same because an equivalent mass of Tc-99 would have been delivered to the receptor location. However, this explanation is not intuitive (release rates for the two cases should differ substantially) and requires more careful explanation. More generally, NRC staff needs assurance that: (1) the MEPAS code is functioning correctly; (2) the use of a 70-year averaging period does not result in significant underestimation of peak doses; and (3) there is a logical explanation of results shown in Tables 5-4 and 5-5.

Path Forward: Provide a more detailed technical explanation for the lack of dose response in the Tc-99 K_d sensitivity analyses. The discussion should include support

for the high-K_d analysis results as well. If no changes are made to the MEPAS analyses, provide justification that the performance assessment provides a supportable prediction of potential receptor dose as a result of releases from the tanks.

56. Comment: Although animal and fish consumption contribute significantly to the all pathway dose results for Tanks 18 and 19, the input parameters used for animal and fish uptake in the exposure modeling are not provided.

Basis: Transfer coefficients and bioaccumulation factors are input parameters for exposure modeling that convert environmental media concentrations (e.g., surface water or groundwater) to concentrations in organisms from which contaminated animal based food products (e.g., milk, meat, and fish) are derived. Values for these parameters vary considerably in the literature [43], and can be important contributors to the magnitude of dose from specific exposure pathways. Table 4-12 in the PODD [3] indicates, for example, fish as a dominant pathway (68% of the peak dose for Tank 18), and Table 4-13 shows milk as a dominant pathway (47% of the peak dose for Tank 19). The importance (or lack thereof) of particular pathways is influenced by the selection of the transfer coefficients, so it is important to know the magnitude of selected values.

Path Forward: Provide a list of animal uptake factors used for modeling the milk, meat, and fish uptakes of significant elements released from Tanks 18 and 19 as part of the exposure calculations reported in the PODD [3]. References to source documents and the basis for selection of the set of values should also be provided.

57. Comment: The values used for the source term moisture content and bulk density parameters in MEPAS are inconsistent with the expected properties of grout.

Basis: The value listed for the source-term moisture content (AN5) in the MEPAS input/output files is 77.50%. This is much larger than the typical moisture content of grout. In addition, the source-term bulk density (R2) has a value of 1.00E+00 g/cm^3, which is less than the typical density of grout.

Path forward: Explain the basis for the water content and density values used in the MEPAS modeling.

58. Comment: Page 14 of the PODD [3] indicates code validation is described in Appendix A. Appendix A describes activities that check a subset of model inputs and outputs against the reported information; however, no information was found regarding code validation pertaining to the MEPAS 4.1 code.

Basis: Code validation is an important part of software quality assurance which adds confidence that complex calculations executed in the code are being implemented in accordance with software design requirements and functions. Although the PODD [3] refers to Appendix A for code validation information, no code validation information was found for the primary code (MEPAS 4.1) used for performance assessment calculations; therefore, clarification is

needed whether or not any code validation activities were conducted.

Path Forward: Clarify whether any code validation information or analyses were used to provide confidence that the MEPAS code used for performance assessment calculations was operating as intended. Include whether any activities were conducted to verify that the conceptual models and various permutations of the detailed release, transport, and dose calculations conducted for the performance assessment were correctly set up and run in the MEPAS code.

SENSITIVITY ANALYSES

59. Comment: Additional sensitivity analyses are needed to assess the potential doses attributable to Np-237 migration from Tanks 18 and 19.

Basis: Although Np was identified as the radionuclide contributing a significant dose from Tanks 18 and 19, site specific data supporting the choice of K_d values was not provided. Although literature values were used, no sensitivity analysis was performed to test the effects of uncertainties in the K_d values of Np in the grouted waste, concrete basemat, or site soils. In general, generic values of K_d are more uncertain than site-specific experimental values. For example, NUREG/CR-6377 [44] suggests a value of 2000 mL/g for the K_d of Np in oxidized concrete whereas Bradbury and Sarott suggests a K_d value of 5000 mL/g for both reducing and oxidizing conditions. Independent analyses suggest that the values provided in Bradbury and Sarott for degraded concrete (i.e., Region III values) may be more applicable to the state of the grouted waste and concrete basemat than the Region I and Region II values used in the performance assessment during a significant portion of the 10,000 year performance period (see Comment 38) and the effect of using these values on the predicted dose should be tested. Furthermore, because of the unique characteristics of the reducing grout that SRS plans to use to fill the tanks, there is uncertainty in the applicability of generic literature values to leaching from the grouted waste (see Comment 37).

Path Forward: Perform sensitivity analyses that evaluate the potential for more rapid release of Np from the wasteform, specifically addressing the points in the basis of this comment. These analyses should be combined with other uncertainty analyses and performed for appropriate receptor locations, as described in Comment 19. Assess the effects of the uncertainty in literature-based soil K_d values on the dose from Np from Tanks 18 and 19, or supply site-specific values with uncertainty estimates.

60. Comment: In general, the utility of sensitivity analysis is increased if the ranges over which a parameter is varied is based on the expected range of uncertainty or variability in the parameter value.

Basis: The sensitivity analysis presented in Section 5 of the PODD [3] give some indication of the dependence of model results on various parameters. However, the results would be more useful if the ranges of uncertainty in the tested parameters were discussed. For example, generic K_d values based on literature values may have associated uncertainties of several orders of

magnitude, whereas the uncertainty and variability of the expected amount of precipitation in a location over a 10,000 year period may be adequately represented by a much smaller range of values.

Path Forward: Compare the ranges of the dispersivity, inventory, water balance, and infiltration rate tested in Section 5 to the expected range of variability in these parameters.

61. Comment: The sensitivity and uncertainty analysis should be expanded to address the comments in this Request for Additional Information.

Basis: A number of issues are raised in this Request for Additional Information that may significantly change the performance assessment results. DOE has performed deterministic analyses of tank closure, but that does not obviate the need to consider the cumulative impact of the uncertainties on the results of the calculations. Particular areas of uncertainty identified in these requests for additional information include:

- Use of the upper aquifers for drinking water at the boundary of the disposal site after an institutional control period of 100 years (see Comments 19 and 20)
- Water table fluctuation on system degradation and release and transport (see Comment 32 and 33)
- Elimination of the basemat as a hydraulic and radionuclide transport barrier (see Comment 47)
- Revised inventory to address sampling limitations (see Comment 14 through 17)
- Use of Bradbury and Sarott Region III K_d values (see Comment 32, 37, and 38)
- Uncertainty in the value of the K_d for Np in the grouted waste, basemat, and site soils (see Comment 59)
- Uncertainty in the solubility limits for Pu and U and resulting uncertainty in the effective K_d values calculated based on the solubility limits (see Comment 41)

Path Forward: Perform an expanded sensitivity analysis for those the issues listed in the basis of this comment and any additional issues that DOE does not have adequate information to resolve at this time. Sensitivity analysis should include appropriate combinations of conditions and receptor locations.

CLARIFYING/REFERENCE REQUESTS

1. Comment: Plates from Aadland, et al. (1995) [24] are not provided in the supporting documentation. Please provide these plates for review.

2. Comment: Please provide the following references for review:

Flach, G.P. (1993) Groundwater model calibration and review of remedial

alternatives at the F & H Area Seepage Basins. WSRC-TR-93-384, Aiken, South Carolina: Westinghouse Savannah River Company. (The version supplied with the draft waste determination only has 5 pages).

Smits, A. D., M. K. Harris, K. L. Hawkins and G. P. Flach, 1997, Integrated hydrogeological modeling of the General Separations Area, Volume 1, Hydrogeologic framework (U), WSRC-TR-96-0399.

Newman, J.L., "Tank Closure Modeling Results for Tanks 19, 18, and FTF for August 2005 in Support of WD and PODD," CBU-PIT-2005-00211, Aiken, South Carolina: Westinghouse Savannah River Company, August 30, 2005.

3. Comment: The value used for basemat thickness in the MEPAS modeling (i.e., Thickness of Unsaturated Layer (H1) for modeling medium #1) for Tank Group 1 (Tanks 1-8) is equal to 3.4 ft. However, Table 4-1 of the PODD indicates that the basemat is 3.9 ft thick for these tanks. The opposite is true for Tank Group 3 (Tanks 25-28, 33-34, 44-47).

4. Comment: The inventory used in the pre-failure MEPAS files for piping and ancillary equipment (e.g., MEPAS input/output files FA05LBPA, FB05EBPA, FR05EBPA) is significantly less than the inventory listed in Table 3-7 for many radionuclides. The inventory used in the MEPAS files appears to be consistent with a 500-year decay period, which is unexpected for the pre-failure run files because the pre-failure simulations should begin at the time of closure. Although piping and ancillary equipment are not included in the scope of the current draft waste determination [3], clarification of the inventory differences is requested so that NRC staff may better understand the relationship between the information provided in the MEPAS files and the information presented in the PODD.

5. Comment: The titles of and text references to Figures 2-13 and 2-14 on pages 51 and 52 of the PODD appear to be reversed.

6. Comment: Page 99 of the PODD indicates that chemical cleaning has a potential dose savings of 0.045 mrem for a member of the public residing on the other side Fourmile Branch from the GSA. The expected value based on doses presented in the PODD is 0.45 mrem.

REFERENCES

[1] DOE, "Draft Section 3116 Determination for Closure of Tank 19 and Tank 18 at the Savannah River Site," DOE-WD-2005-002, Rev. 0, U.S. Department of Energy, Washington DC, September 2005.

[2] Gilbreath, K.D., "Risk Benefit Evaluation of Residual Heel Removal in Tanks 19 and 18," CBU-PIT-2005-00169, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, September 2005.

[3] Buice, J.M., R.K. Cauthen, R.R. Haddock, B.A. Martin, J.A. McNeil, J.L. Newman, and K.H. Rosenberger, "Performance Objective Demonstration Document (PODD) for the Closure of Tank 19 and Tank 18 Savannah River Site," CBU-PIT-2005-00106, Rev. 1, Aiken, South Carolina: Westinghouse Savannah River Company, September 2005.

[4] Martin, B., Hayes, C., and Adkins, B., Memorandum to S. Tibrea,"Technically and Economically Practical Endpoint Summary for Further Waste Removal Activities in Tank 19," HLW-WRE-2001-00035, Westinghouse Savannah River Company, Aiken, South Carolina, August, 2001.

[5] Chapman, N.F., Memorandum to K. A. Hauer, "Technically and Economically Practical Endpoint Summary for Further Waste Removal Activities in Tank 18," CBU-LTS-2003-00158, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, November 2003.

[6] Davis, N.R., "Tank 18 Waste Removal Systems Engineering Evaluation," WSRC-RP-2001-00024, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, May 2001.

[7] Davis, N.R., "Tank 19 Heel Removal Systems Engineering Evaluation, Evaluation Performed," PIT-MISC-0040, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, October 1998.

[8] Sams, T.L., "Stage II Retrieval Data Report for Single-Shell Tank 241-C-106," RPP-20577, Rev. 0, CH2M Hill Hanford Group, Inc., Richland, Washington, May 2004.

[9] DOE/EIS-0303, "High Level Waste Tank Closure Final Environmental Impact Statement," Savannah River Operations Office, Aiken, South Carolina, May 2002.

[10] Hamm, B.A., "Tank Farm Zeolite Historical Review and Current Inventory Assessment," CBU-PIT-2005-00099, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, June 2005.

[11] Augeri, M.J., "Advanced Design Mixer Pump History," WSRC-TR-2003-00472, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, August 2005.

[12] Adkins, B.J., "Technology Evaluation - Tank 19 Waste Removal Equipment," WSRC-TR-2000-00311, Rev. 1, Westinghouse Savannah River Company, Aikan, South Carolina, January 2002.

[13] Pike, J.A., et al., "Flowsheet for SRS Waste Tank Heel Removal Using Oxalic Acid," WSRC-TR-2004-00317, Rev. 0, November 2004.

[14] Fong, M.C., "Oxalic Cleaning of Tank 24H," DPST-85-782-TL, E.I. du Pont de Nemours and Company, Savannah River Plant, Aiken, South Carolina, September 1985.

[15] Thomas, J. L., "Characterization of Tank 19 Residual Waste," WSRC-TR-2002-00052, Rev. 3, Westinghouse Savannah River Company, Aiken, South Carolina, August 2005.

[16] Cantrell, J.R., "Heel Removal and Annulus Cleaning Technology Development Suspension Plan, CBU-FTF-2004-0094, November, 2004.

[17] Thomas, J. L., "Tank 19 Heel, Supernate, and Possible, Unmoved Heel Mounds Volume," G-CLC-F-00180, Rev. 1, Westinghouse Savannah River Company, Aiken, South Carolina, February 2002.

[18] National Academy of Sciences, "Committee inventory questions with answers by the Savannah River Site - Fact checked by the site," Accessed at: http://dels.nas.edu/nsrb/ctw/biblio.html on March 20, 2006.

[19] U.S. Nuclear Regulatory Commission, "Draft Interim Concentration Averaging Guidance for Waste Determinations," *Federal Register*, 70 FR 74846, December 2005.

[20] NUREG-0782, "Draft Environmental Impact Statement on 10 CFR Part 61 Licensing Requirements for Land Disposal of Radioactive Waste," United States Nuclear Regulatory Commission, Washington D.C., 1981.

[21] NUREG-0945, "Final Environmental Impact Statement on 10 CFR Part 61 Licensing Requirements for Land Disposal of Radioactive Waste," United States Nuclear Regulatory Commission, Washington D.C., 1982.

[22] Hutson, S.S., N.L. Barber, J.F. Kenny, K.S. Liney, D.S. Lumia, and M.A. Maupin, "Estimated Use of Water in the United States in 2000," U.S. Geological Survey Circular 1268, Available <http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf>, 2004.

[23] Schepens, R.J., "Response to U.S. Nuclear Regulatory Commission Additional Questions on SRS HLW Tank Closure," PB-99-0041, Aiken, South Carolina: U.S. Department of Energy, Savannah River Operations Office, April 1999.

[24] Aadland, R.K., J.A. Gellici, and P.A. Thayer, "Hydrogeologic Framework of West-Central South Carolina," PIT-MISC-0112, State of South Carolina Department of Natural Resources, Water Resources Division Report 5, South Carolina, 1995.

[25] Flach, G. P., M. K. Harris, "Integrated Hydrogeological Modeling of the General Separations Area, Volume 2, Groundwater Flow Model," WSRC-TR-96-0399, Rev. 1, April 1999.

[26] Caldwell, T.B., Langton, C. A., “Sludge Displacement Verification for Reducing Grout Report,” WSRC-TR-97-0101, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, April 1997.

[27] Langton, C. A., “Grout Placement requirements for Class C Tank Residual Waste Forms,” WSRC-RP-2005-01684, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina, April 2005.

[28] Bradbury, M. H., F. Sarott, “Sorption Database for the Cementitious Near-Field of a L/ILW Repository for Performance Assessment,” PIT-MISC-0075, ISSN 1019-0643, Paul Scherrer Institut, Switzerland, 1995.

[29] Langton, C.A. and N. Rajendran, "Laboratory and Field Testing of High Performance-Zero Bleed CLSM Mixes for Future Tank Closure Applications," WSRC-TR-98-271, Aiken, South Carolina: Westinghouse Savannah River Company, March 1998.

[30] Caldwell, T.B., "Tank Closure Reducing Grout," WSRC-TR-97-0102, Aiken, South Carolina: Westinghouse Savannah River Company, April 1997.

[31] Westinghouse Savanna River Company, “Response to Request for Additional Information on the Draft Section 3116 Determination for Salt Waste Disposal at the Savannah River Site,” CBU-PIT-2005-00131, Rev. 0. Aiken, South Carolina: Westinghouse Savannah River Company, 2005.

[32] Kaplan, D.I., P.M. Bertsch, D.C. Adriano and K.A. Orlandini. "Actinide association with groundwater colloids in a Coastal Plain aquifer." *Radiochimica Acta*. Vol. 66/67. pp. 181-187. 1994.

[33] Atkinson, A., N. Everitt, and R. Guppy. "Time Dependence of pH in a Cementitious Repository." Scientific Basis for Nuclear Waste Management XII. Symposium Proceedings 127. Pittsburgh, Pennsylvania: Materials Research Society. pp. 439-446. 1989.

[34] Glasser, F. and M. Atkins. "Cements in Radioactive Waste Disposal." MRS Bulletin. December. pp. 33-38. 1994.

[35] Westinghouse Savannah River Company, “Clarifying Information from January 25, 2006 Meeting with the Nuclear Regulatory Commission,” CBU-PIT-2006-00028, Rev. 0, Aiken, South Carolina, February 2006.

[36] Cook, J. R., et al., “Radiological Performance Assessment for the E-Area Vaults Disposal Facility,” WSRC-RP-94-218, Rev. 1, Westinghouse Savannah River Company, Aiken, South Carolina, April 1994.

[37] Ewart, F.T., Smith-Briggs, J.L., Thomason, H.P., and Williams, S.J. “The Solubility of Actinides in a Cementitious Near-Field Environment.” *Waste Management* v. 12, pp. 241-252, 1992.

[38] Biddle, P., Boult, K.A., Gale, M.D., Godfrey, J.G., Stone, N.S. Equilibrium Leach Testing of Low Level Waste. Part 2 Long-Term Tests on the Effects of Cementitious Grouts. United Kingdom Nirex Limited, Harwell, United Kingdom. 2002.

[39] Dai, M., Kelley, J. M. and Buesseler, K. O., 2002, Sources and Migration of Plutonium in Groundwater at the Savannah River Site, Environmental Science and Technology 36:3690-3699.

[40] Kaplan, D.I., Hang, T., and Aleman, S.E., “Estimated Duration of the Reduction Capacity Within a High-Level Waste Tank (U),” WSRC-RP-2005-01674, Aiken, South Carolina: Westinghouse Savannah River Company, August 2005.

[41] Martin, B.A., Chattin, J.C., and Gilbreath, K.D. “Tank Closure Modeling Input/Output Data Verification,” CBU-PIT-2005-00213, Rev. 1, Westinghouse Savannah River Company, Aiken, South Carolina, September, 2005.

[42] E.I. du Pont de Nemours and Company, “Additional Waste Storage Tanks Bottom Slab & Details,” W167482, Rev. 22, Savannah River Plant, Aiken, South Carolina, July 1958.

[43] International Atomic Energy Agency, "Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments," Technical Report Series No. 364, Vienna, Austria: International Atomic Energy Agency, 1994.

[44] Krupka, K.M., and Serne, R.J. “Effects on Radionuclide Concentrations by Cement/Ground-Water Interactions in Support of Performance Assessment of Low-Level Radioactive Waste Disposal Facilities,” NUREG/CR-6377, U.S. Nuclear Regulatory Commission, Washington, DC. April 1998.