U.S. Nuclear Regulatory Commission Plan for Monitoring Disposal Actions Taken by the U.S. Department of Energy at the Savannah River Site F-Area and H-Area Tank Farm Facilities in Accordance With the National Defense Authorization Act for Fiscal Year 2005

October 2015

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety
and Safeguards

Washington, DC 20555-0001

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ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Is Reasonably Achievable
Am	Americium
ASR	Alkali Silica Reaction
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
CNWRA®	Center for Nuclear Waste Regulatory Analyses
Cs	Cesium
CY	Calendar Year
DOE	United States Department of Energy
DOD	U.S. Department of Defense
DO	Dissolved Oxygen
EDS	Energy Dispersive Spectroscopy
EPA	United States Environmental Protection Agency
EXAFS	Extended X-Ray Absorption Fine Structure
FEPs	Features, Events, and Processes
FFA	Federal Facility Agreement
FTF	F-Tank Farm or F-Area Tank Farm
FY	Fiscal Year
GA	Gordon Aquifer
GCL	Geosynthetic Clay Liner
GCP	General Closure Plan
GSA	General Separations Area
HDPE	High Density Polyethylene
HLW	High-Level Waste
HRR	Highly Radioactive Radionuclide
HTF	H-Tank Farm or H-Area Tank Farm
K_ds	Distribution Coefficients
LAZ	Lower Aquifer Zone
LLW	Low-Level (Radioactive) Waste
MA	Monitoring Areas
Nb	Niobium
MEP	Maximum Extent Practical
MFs	Monitoring Factors
NDAA	Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005
NEA	Nuclear Energy Agency
Np	Neptunium
NRC	United States Nuclear Regulatory Commission
OOV	Onsite Observation Visit
OU	Operable Unit
PA	Performance Assessment
PO	Performance Objective
POC	Point of Compliance
Pu	Plutonium

ACRONYMS AND ABBREVIATIONS (continued)

Ra	Radium
RAI	Request for Additional Information
RPP	Radiation Protection Program
SCDHEC	South Carolina Department of Health and Environmental Control
SEM	Scanning Electron Microscopy
Sr	Strontium
SRS	Savannah River Site
Tc	Technetium
TER	Technical Evaluation Report
Th	Thorium
TRR	Technical Review Report
U	Uranium
UCL	Upper Confidence Level
UAZ	Upper Aquifer Zone
UTRA	Upper Three Rivers Aquifer
WD	Waste Determination
WIR	Waste Incidental to Reprocessing
XANES	X-Ray Absorption Near Edge Structure
XRD	X-Ray Diffraction
Zr	Zirconium

DEFINITIONS

As Low As (Is) Reasonably Achievable (ALARA): From 10 Code of Federal Regulations (CFR) 20.1003—Making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to the state of technology, the economics of improvements in relation to benefits to public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Closed Monitoring Factor: State of a monitoring factor after U.S. Nuclear Regulatory Commission (NRC) staff determines and documents that the monitoring factor is no longer applicable or the technical issue or uncertainty has been resolved.

Disposal: The isolation of radioactive wastes from the biosphere.

Follow-Up Action: Items identified during monitoring that require additional effort by the U.S. Department of Energy (DOE) to resolve. Examples include DOE providing answers to questions generated during technical reviews or DOE providing results of a particular experiment once it becomes available. Follow-up actions are generally less risk significant than Open Issues. Follow-up actions can become Open Issues if the follow-up action is related to a technical issue that is later found to be risk significant, or if insufficient progress is being made on addressing what is thought to be a risk-significant technical issue.

High-Level Radioactive Waste (HLW): (i) irradiated reactor fuel; (ii) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing reactor fuel; and (iii) solids into which such liquids have been converted.

Highly Radioactive Radionuclides (also called Key Radionuclides): Those radionuclides that contribute most significantly to risk to the public, workers, and the environment. In the context of the Ronald Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA), NRC staff considers the term “highly radioactive radionuclides” to be equivalent to the term “Key Radionuclides” used in the manual for DOE Order 435.1 (DOE M 435.1-1), the West Valley Policy Statement, and in some NRC reviews of DOE waste determinations. In the context of an NRC review of a DOE waste determination conducted under the NDAA, “Highly Radioactive Radionuclides” are not (in general) limited to radionuclides with high specific activity.

Indeterminate: With respect to NRC staff’s monitoring responsibilities under the NDAA, an NRC staff finding that it has insufficient information to adequately assess compliance of DOE disposal actions with the Performance Objectives (POs) in 10 CFR Part 61, Subpart C. Additional information is forthcoming from DOE within a reasonable timeframe to allow NRC staff to assess compliance with the POs.

Monitoring Area (MA): General features (or aspects) of the disposal facility or action that NRC has determined to be important to assessing compliance with the POs in 10 CFR Part 61, Subpart C. MAs are further divided into more specific monitoring factors (MFs).

Monitoring Factor: Specific features (or aspects) of the disposal facility or action that NRC has determined to be important to assessing compliance with the POs in 10 CFR Part 61, Subpart C. NRC typically identifies MFs through the review of a DOE waste determination, Performance

Assessment (PA), information DOE generates during monitoring (e.g., technical reports on laboratory or field experiments), or other information collected during monitoring (e.g., during NRC onsite observation visits). MFs are a subset of MAs and tracked as open or closed.

Onsite: Areas of the DOE site where monitoring activities will be carried out. This may include areas that have some relationship to, but are outside the physical boundaries of, a particular Waste Incidental to Reprocessing (WIR)-related facility.

Onsite Observation: A formal, preannounced site visit to a DOE WIR-related facility by NRC staff for purposes of observing DOE facilities, activities, processes, or experiments related to compliance with 10 CFR Part 61, Subpart C POs.

Open Issue: A concern that NRC staff identifies during monitoring activities, which requires additional information from DOE to address. Examples include a MF that DOE has not taken sufficient action to address or instances where data collected by DOE are not consistent with assumptions (e.g., conceptual model assumptions, mathematical assumptions, or parameter values) that DOE made in the PA. Open Issues are generally more risk significant than Follow-up Actions. An Open Issue could lead to a finding that DOE disposal actions are not in compliance with the POs in 10 CFR Part 61, Subpart C.

Operations: The actions taken by DOE while carrying out waste disposal actions through the end of the institutional control period, including PA development (analytical modeling), waste removal, grouting, stabilization, observation, maintenance, or other similar activities.

Performance Assessment: A type of systematic (risk) analysis that addresses (i) what can happen, (ii) how likely it is to happen, (iii) the resulting impacts of that happening, and (iv) how those impacts compare to specifically defined standards.

Performance Objectives: One of five 10 CFR Part 61, Subpart C, requirements for Low-Level Waste (LLW) disposal facilities: (i) general requirement (10 CFR 61.40), (ii) protection of the general population from releases of radioactivity (10 CFR 61.41), (iii) protection of individuals from inadvertent intrusion (10 CFR 61.42), (iv) protection of individuals during operations (10 CFR 61.43), and (v) stability of the disposal site after closure (10 CFR 61.44).

Recommendations: NRC suggestions made during the Savannah River Site tank farm consultation phase that DOE might consider to further enhance its approach for management of incidental waste. Recommendations are typically made during the consultation phase. A crosswalk-walk between the F-Area Tank Farm facility and H-Area Tank Farm facility recommendations made during the consultation phase to MFs described in this plan is provided in Table A–1.

Technical Review: NRC technical staff review of reports, studies, analyses, experiments, and other information prepared by DOE, South Carolina Department of Health and Environmental Control, or other stakeholders that is important to NRC staff's assessment of compliance of DOE disposal actions with the POs in 10 CFR Part 61, Subpart C.

Waste Determination (or Non-High-Level Waste Determination): DOE documentation required by Section 3116 of the NDAA that demonstrates that a specific waste stream is not HLW.

Worker: DOE or contractor staffs who carry out operational activities at the land disposal facility.

EXECUTIVE SUMMARY

The Ronald Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) authorizes the U.S. Department of Energy (DOE) in consultation with the U.S. Nuclear Regulatory Commission (NRC) to determine whether certain radioactive waste related to reprocessing of spent nuclear fuel is not high-level waste (HLW), provided certain criteria are met. The NDAA applies specifically to DOE facilities in South Carolina and Idaho and not to similar DOE facilities located in other states. The NDAA also requires NRC to coordinate with the covered state (i.e., South Carolina or Idaho) to monitor DOE disposal actions to assess compliance with the Performance Objectives (POs) for Low-Level Waste (LLW) in Title 10 *Code of Federal Regulations* (10 CFR) Part 61, Subpart C. These POs include (i) general requirement (10 CFR 61.40), (ii) protection of the general population from releases of radioactivity (10 CFR 61.41), (iii) protection of individuals from inadvertent intrusion (10 CFR 61.42), (iv) protection of individuals during operations (10 CFR 61.43), and (v) stability of the disposal site after closure (10 CFR 61.44). This monitoring plan details the NRC's path forward to assessing DOE disposal action compliance with each of these POs for residual waste remaining in the HLW tanks at the Savannah River Site (SRS) near Aiken, South Carolina, at the time of facility closure.

In fiscal years 2010 and 2013, DOE issued draft Waste Determinations that concluded that stabilized waste residuals in F-Area Tank Farm facility (FTF) and H-Area Tank Farm facility (HTF) tanks and auxiliary components, as well as the tanks and auxiliary components themselves, could meet NDAA criteria for Waste Incidental to Reprocessing at the time of closure and as such could be managed as LLW. As required by the NDAA, DOE consulted with NRC regarding DOE's conclusions in its draft waste determinations for the tank farms. Results of a multiyear consultative review culminated in NRC staff's issuance of a Technical Evaluation Report (TER) in October 2011 (ML112371751) for FTF, and later in June 2014 for HTF (ML14094A496). As DOE is in the early stages of tank farm closure, information regarding final waste distributions and factors influencing facility performance is incomplete. This type of information is necessary to enable NRC staff to adequately assess compliance of the DOE disposal actions with the POs in 10 CFR Part 61, Subpart C. Therefore, rather than reaching conclusions regarding DOE's ability to meet the POs in 10 CFR Part 61, Subpart C, NRC staff instead provided a series of comments and recommendations in its TERs with respect to the type of additional information NRC staff needed to have reasonable assurance that the POs could be met (ML112371751, ML14094A496). If NRC staff's comments and recommendations are addressed by DOE, NRC staff expects that NRC will be in a better position to assess compliance with the POs. NRC staff rationalized that sufficient time was available for DOE to implement many of the recommendations as tank farm closure progresses.

DOE issued a final waste determination in March 2012 (DOE/SRS–WD–2012–001) for FTF; DOE commenced grouting of Tanks 18F and 19F in April 2012 and Tanks 5F and 6F in August 2013. NRC has issued nine Technical Review Reports (TRRs) and conducted five On-site Observations (OOVs) since it began monitoring FTF in April 2012. Monitoring activities focused on (i) closure of FTF Tanks 5F, 6F, 18F, and 19F, including review of grouting documentation and observation of grouting operations, and (ii) review of inventory and revised risk estimates for Tanks 5F, 6F, 18F, and 19F and the entire FTF through special analyses. NRC staff also reviewed updated waste release experiment and modeling reports; documentation of features, events, and processes applicable to the site; and environmental monitoring data. Most of the findings in the FTF TRRs were applicable to and discussed in the HTF TER. The technical issues identified in the TRRs performed for FTF to date, as well as technical issues unique to HTF that are documented in staff's HTF TER (ML14094A496), have been considered in revising the FTF monitoring plan to encompass both FTF and HTF (see Tables A–1 and B–1). Thus, the U.S. Nuclear Regulatory Commission Plan for Monitoring Disposal Actions Taken by the U.S. Department of Energy at the Savannah River Site F-Area Tank Farm Facility in Accordance With the National Defense Authorization Act for Fiscal Year 2005, January 2013 (FTF monitoring plan) (ML12212A192) is being replaced by this combined SRS Tank Farm Monitoring Plan.

DOE issued a final waste determination in December 2014 (DOE/SRS–WD–2014–001) for HTF but had not yet completed closure of any single HTF tank at that time. Tanks 12H and 16H have been cleaned and are the first HTF tanks scheduled for grouting. The Tank 16H closure module was approved by the South Carolina Department of Health and Environmental Control (SC DHEC) in the spring 2015, and DOE commenced grouting of the tank shortly thereafter. DOE also prepared a Special Analysis and Final Removal Report for Tank 16H in the spring 2015. DOE issued the Tank 12H closure module for public comment in spring 2015 and plans to supplement the closure module after final characterization is complete.

In accordance with the NDAA, NRC will assess FTF and HTF compliance with the POs in 10 CFR Part 61, Subpart C. A Performance Assessment (PA) is typically used to demonstrate compliance with two of the four POs: 10 CFR 61.41, “Protection of the General Population from Releases of Radioactivity,” and 61.42, “Protection of Individuals From Inadvertent Intrusion,” which are assessed using dose-based criteria. A PA is a type of systematic risk analysis that addresses (i) what can happen, (ii) how likely it is to happen, (iii) what the resulting impacts are, and (iv) how the impacts compare to specifically defined standards. Considering the long time period over which long-lived radionuclides pose a hazard to human health, a robust PA is needed to establish that the POs will be met for releases from the Tank Farms that may occur many hundreds or thousands of years in the future. NRC considers sufficient PA model support, coupled with observation of disposal actions that are carried out in conformance with detailed closure plans, necessary for NRC to have reasonable assurance that the POs can be met. Many key features of DOE’s disposal facility design are important to the compliance demonstration for the Tank Farms, as documented in the PAs for the Tank Farms. These key features are the focus of NRC staff’s monitoring efforts.

NRC’s monitoring plan focuses on the most risk-significant aspects of DOE disposal actions. These risk-significant aspects were binned under eight monitoring areas (MA). The first six MAs relate to protection of the general public and intruder protection. NRC staff developed MA 1, “Residual Waste Inventory,” to ensure that the final postcleaning inventory developed for the tank farms is consistent with assumptions made in DOE’s final waste determination and PA, or that the final waste inventory at the time of closure does not lead to a finding of noncompliance with the POs. NRC will also perform monitoring activities related to engineered and natural features of the disposal facility that are also found to be important to meeting the POs. NRC staff developed MA 2, “Waste Release,” to ensure that releases of key radionuclides remain below levels that would lead to an exceedance of the POs during the compliance period. NRC staff developed MA 3, “Cementitious Material Performance,” to ensure that cementitious materials act as effective barriers to fluid flow for some period of time, mitigate or attenuate releases of radioactivity from the tanks, and otherwise perform consistently with DOE PA assumptions, and that the impact of any deviations in assumed performance is evaluated. NRC staff developed MA 4, “Natural System Performance,” to ensure the hydrogeological system acts as an effective natural barrier to attenuate key radionuclide releases as assumed in DOE’s PA models. Additionally, under MA 4, NRC staff will review environmental data collected by DOE as an additional assurance that the Tank Farms are operating as predicted by DOE models. NRC staff developed MA 5, “Closure Cap Performance,” to evaluate key features of the closure cap identified in NRC staff's review. All of these MAs are directly related to the facilities' long-term ability to limit or mitigate releases of constituents from the Tank Farms and are considered important to assessing compliance with the POs. Items of lower risk significance or longer term activities are addressed in MA 6, "PA Maintenance." PA maintenance is also necessary to ensure that a mechanism is in place to consider new and significant information that may be collected in the future that might significantly alter results presented in DOE's PA.

While DOE relies on a PA to demonstrate compliance with POs related to general public and intruder protection, evaluation of compliance with 10 CFR 61.43, "Protection of Individuals During Operations," can be more directly assessed through observation of DOE closure activities. NRC plans to perform a graded review of DOE's radiological protection program while observing DOE's most risk-significant closure activities (e.g., tank cleaning, sampling, and grout placement activities) to assess compliance with 10 CFR 61.43. For example, NRC staff will review radiation records and environmental data or reports and possibly conduct interviews during closure activities to assess compliance with 10 CFR 61.43. NRC staff's assessment of compliance with 10 CFR 61.43 is addressed under MA 7, "Protection of Individuals During Operations."

Finally, monitoring activities to assess compliance with 10 CFR 61.44, "Stability of the Disposal Site After Closure," partially overlap those activities developed to support assessment of compliance with 10 CFR 61.41 and 61.42. NRC considers unique factors affecting stability of the disposal site not already discussed under 10 CFR 61.41 and 61.42 under MA 8, "Site Stability."

To prepare this monitoring plan, NRC staff, in consultation with SCDHEC, began by comprehensively considering all of its previous comments and recommendations on each Tank Farm PA and waste determination review and crosswalked each of the items to one of the eight MAs described previously that NRC considers important to DOE's compliance demonstration.[1] This crosswalk is provided in Appendix A. As such, this monitoring plan will serve as the starting point from which NRC staff will assess compliance with the POs in 10 CFR Part 61, Subpart C, in fulfillment of its monitoring responsibilities under the NDAA. As discussed in the preceding paragraphs, the eight MAs are as follows:

- MA 1, "Inventory"
- MA 2, "Waste Release"
- MA 3, "Cementitious Material Performance"
- MA 4, "Natural System Performance"
- MA 5, "Closure Cap Performance"
- MA 6, "PA Maintenance"
- MA 7, "Protection of Individuals During Operations"
- MA 8, "Site Stability"

MAs are supported by a number of Monitoring Factors (MFs). While MAs are mainly used to bin technical topics, MFs are smaller, specific items that NRC staff will monitor in fulfillment of its

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[1]NRC recognizes that some of its previous review comments and recommendations are less risk significant or may require longer time periods to address than others. Lower risk or long-term activities are binned into MA 6, "PA Maintenance."

NDAA responsibilities. MFs will help facilitate monitoring by providing specific activities for NRC staff to focus on. These MFs will be tracked as open or closed. If issues arise related to MFs, NRC staff may develop an "open issue" to document concerns related to the MF. In this way, NRC staff will have a mechanism to communicate to DOE, early in the process, the need for additional information, prior to NRC's issuance of a notification letter of concern or letter of noncompliance. NRC staff will note the status of each MF in the periodic monitoring compliance reports prepared for the Idaho National Laboratory and SRS (see NUREG–1911 NRC Periodic Compliance Monitoring Report for U.S. Department of Energy Non-High-Level Waste Disposal Actions, Rev. 3 [ML111890412]).

Because Congress directed NRC to monitor DOE disposal actions to assess compliance with the POs in 10 CFR Part 61, Subpart C, this monitoring plan is first organized by PO, with one chapter devoted entirely to each of the four POs. As indicated previously, NRC staff evaluates what MAs are important to DOE's demonstration of compliance with each PO—MAs are, therefore, listed directly beneath each PO and support NRC staff's assessment of Tank Farm facility compliance with the POs, as required by the NDAA. As stated previously, each MA supports one or more POs. If the MA supports multiple POs, the monitoring plan will indicate whether the MA and underlying factors are an exact duplicate of a previously listed MA and underlying set of factors (in which case the MA and factors will not be repeated) or whether there are unique aspects of the MA or underlying factors that pertain to just that PO (in which case only the unique aspects of the area and relevant factors will be discussed under the PO). Table ES–1 lists each MA and indicates the POs each MA supports.

Table ES–2 provides NRC staff's prioritization of each MF under MAs 1–5 developed to support assessment of compliance with the 10 CFR 61.41 PO. Many of these factors also support assessment of compliance with the 10 CFR 61.42 PO because an inadvertent intruder is also assumed to be exposed to Tank Farm waste through the groundwater pathway, similar to the pathways considered for evaluation of the 10 CFR 61.41 PO, although the compliance point is assumed to be onsite rather than offsite for the inadvertent intruder. Additionally, unique considerations may apply to assessing compliance with 10 CFR 61.42 because additional scenarios related to direct intrusion into the disposal facility are also considered in assessing compliance with the 10 CFR 61.42 PO. MA 6, "Performance Assessment Maintenance," MFs are not listed in Table ES–2, because PA Maintenance items are considered items of lower risk significance or longer term monitoring activities by default. Each of the MFs for MAs 1 through 8 is discussed in more detail in the chapters that follow.

This monitoring plan also provides information regarding the types of monitoring reports NRC plans to prepare to document its monitoring activities. For example, NRC plans to issue a report following each onsite observation and will summarize monitoring activities and changes to the status of its monitoring activities in periodic reports. If NRC concludes that actions taken by DOE are not in compliance with POs, NRC will notify DOE, the covered State, and Congress, as required by the NDAA. The types of notification letters related to a finding of noncompliance are listed in Section 1.9 of this document.

Table ES–1. List of Monitoring Areas and Associated Performance Objectives					
MA	**Monitoring Areas**	**10 CFR Subpart C Performance Objective**			
		61.41	**61.42**	**61.43**	**61.44**
1	Inventory	X	X		
2	Waste Release	X	X		
3	Cementitious Material Performance	X	X		
4	Natural System Performance	X	X		
5	Closure Cap Performance	X	X		
6	Performance Assessment Maintenance	X	X		
7	Protection of Individuals During Operations			X	
8	Site Stability	X*	X*		X

*Note: 10 CFR 61.44 PO related to site stability impacts DOE's ability to meet the 10 CFR 61.41 and 10 CFR 61.42 POs (i.e., site stability is important to meeting the POs for protection of general population from releases of radioactivity from the disposal facility and protection of individuals from inadvertent intrusion). Therefore, MA 8, "Site Stability," is important to demonstrating 10 CFR 61.41 and 10 CFR 61.42 POs are met, as well as demonstrating that the 10 CFR 61.44 PO is met.

CFR = *Code of Federal Regulations*, PO = Performance Objective, DOE = U.S. Department of Energy, MA = Monitoring Areas

Table ES–2. NRC Prioritization of Monitoring Factors That Support 10 CFR 61.41 and 61.42				
MA 1 Inventory	**MA 2 Waste Release**	**MA 3 Cementitious Material Performance**	**MA 4 Natural System Performance**	**MA 5 Closure Cap**
1.1— Final Inventory and Risk Estimates*	2.1— Solubility-Limiting Phases/Limits and Validation†	3.1— Hydraulic Performance of Concrete Vault and Annulus (As it Relates to Steel Liner Corrosion and Waste Release)‡	4.1— Natural Attenuation of Key Radionuclides†	5.1— Long-Term Hydraulic Performance§
1.2— Residual Waste Sampling*	2.2— Chemical Transition Times‡‖	3.2— Groundwater Conditioning via Reducing Grout‡‖	4.2— Calcareous Zone Characterization*	5.2— Long-Term Erosion Protection Design§
1.3— Residual Waste Volume*		3.3— Shrinkage and Cracking of Reducing Grout*	4-3— Environmental Monitoring*	5.3— Closure Cap Functions That Maintain Doses ALARA§
1.4— Ancillary Equipment Inventory§		3.4— Grout Performance*		
1.5— Waste Removal (As It Impacts ALARA)§		3.5— Vault and Annulus Sorption‡		
		3.6— Waste Stabilization (As It Impacts ALARA)§		

‖In the FTF PA, certain HRRs such as technetium and plutonium, which are initially assumed to be in a low solubility state, are eventually assumed to be released at risk-significant solubilities that could exceed the performance objectives over long periods of time. Therefore, chemical transition times to a higher solubility, which are related to the extent of groundwater conditioning afforded by the reducing grout, are important to the compliance demonstration in the FTF PA. In contrast, chemical transitions to a higher, risk-significant solubility only occur in alternative cases in the HTF PA. Therefore, chemical transition times are less important to DOE's compliance demonstration in the HTF PA.

NRC = U.S. Nuclear Regulatory Commission, MA = Monitoring Areas, ALARA = As Low As Is Reasonably Achievable, DOE = U.S. Department of Energy, FTF = F-Area Tank Farm, PA = Performance Assessment, HRRs = Highly Radioactive Radionuclides, HTF = H-Area Tank Farm

§Lower Priority

*Medium Priority

†High Priority Recommended

‡High Priority Dependent or More Difficult *(The monitoring factors in orange‡ are risk significant to the DOE performance assessment, but the need for their implementation may be dependent on results of other monitoring factors. Because the monitoring factors in orange‡ are also expected to be more difficult to study or support, work on monitoring factors in red† are recommended first.)*

References

DOE/SRS–WD–2012–001, Rev. 0. "Basis for Section 3116 Determination for Closure of F-Tank Farm at Savannah River Site." Washington, DC: U.S. Department of Energy. 2012.

ML112371751. "Technical Evaluation Report for F-Area Tank Farm Facility, Savannah River Site, South Carolina—Final Report." Washington, DC: U.S. Nuclear Regulatory Commission. 2011.

ML14094A496. "Technical Evaluation Report for H-Area Tank Farm Facility, Savannah River Site, South Carolina—Final Report." Washington, DC: U.S. Nuclear Regulatory Commission. 2014.

ML12212A192. "U.S. Nuclear Regulatory Commission Plan for Monitoring Disposal Actions Taken by the U.S. Department of Energy at the Savannah River Site F-Area Tank Farm Facility in Accordance With the National Defense Authorization Act for Fiscal Year 2005." Washington DC: U.S. Nuclear Regulatory Commission. 2013.

SRS–WD–2014–001, Rev. 0. "Basis for Section 3116 Determination for Closure of H-Tank Farm at Savannah River Site." Washington, DC: U.S. Department of Energy. 2014.

1 MONITORING PROCESS

1.1 Background

The Savannah River Site (SRS) is an 803 square kilometer [310 square mile] facility developed in the 1950s as part of the country's growing weapons program. Many activities took place at the site, including the reprocessing of spent nuclear fuel in reinforced concrete buildings called canyons. Liquid waste from the reprocessing process was managed in 51 underground storage tanks contained in the F-Area Tank Farm (FTF) and H-Area Tank Farm (HTF) facilities. These tank farms are the subject of this monitoring plan.

The U.S. Department of Energy (DOE) is engaged in an expansive campaign to clean, stabilize, and close 49 of the 51 underground waste storage tanks at the FTF and HTF. DOE closed two FTF tanks (Tanks 17 and 20) in the 1990s prior to U.S. Nuclear Regulatory Commission (NRC) involvement pursuant to the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA). DOE cleanup activities also include supporting ancillary structures (i.e., evaporators, pump pits, pump tanks, diversion boxes, transfer valve boxes, and piping) used to process and transfer generated waste. The waste tanks and ancillary structures are several decades old. The original service life for these tanks was projected as 40 years; however, several of the aging waste tanks are approaching 60 years of service life. Given the inherent risks of exhuming the aging waste tanks and disposing them as high-level waste (HLW), DOE plans to clean, grout, and close the waste tanks and ancillary structures in place to reduce the risks to the workers, the public, and the environment.

In accordance with Section 3116 of the NDAA, on March 27, 2012 the Secretary of Energy, in consultation with NRC, made a determination that waste remaining within the tanks and ancillary facilities in FTF does not have to be considered or managed as HLW, requiring disposal in a geologic repository. Rather, the tank farm waste can be disposed of, in place, as Low-Level Waste (LLW).

NRC's consultation included the review of DOE's *Draft Basis for Section 3116 Determination for Closure of F-Tank Farm at the Savannah River Site*, which DOE submitted in September 2010. A detailed Site Performance Assessment (PA) accompanied the basis document (SRS–REG–2007–00002). During the review process, NRC staff held a number of technical exchange meetings with DOE and submitted a written Request for Additional Information (RAI) regarding certain aspects of the DOE basis document (ML103190402)[2]. DOE completed its response to NRC in the summer of 2011. NRC staff completed a Technical Evaluation Report (TER) in October 2011 (ML112371751). In its TER, NRC staff provided a number of recommendations to DOE that, if implemented, would allow NRC to assess compliance with the performance objectives (POs) in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 61, Subpart C, and increase the likelihood that the NRC would find that it had reasonable assurance that disposal actions at the FTF would be in compliance with the 10 CFR Part 61, Subpart C POs. DOE submitted additional information regarding several NRC TER recommendations prior to completing the final waste determination (DOE/SRS–WD–2012–001) and has plans to address other NRC recommendations, as indicated in its "Savannah River Site Liquid Waste Facilities

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[2] Accession numbers are provided for NRC documents and begin with the letters "ML." These accession numbers can be used to search for NRC documents in NRC's Agencywide Document Access and Management System (ADAMS) found at http://www.nrc.gov/reading-rm/adams.html.

Performance Assessment Maintenance Program, fiscal year 2012 Implementation Plan" (SRR–CWDA–2012–00020), as updated for fiscal year 2015 (SRR–CWDA–2014–00108).

NRC's consultation on the HTF began in February 2013 when DOE issued the *Draft Basis for Section 3116 Determination for Closure of H-Tank Farm at the Savannah River Site* for NRC review, as part of DOE's consultation with NRC under NDAA Section 3116 [DOE/SRS–WD–2013–001]. A detailed PA (SRR–CWDA–2010–00128) accompanied the draft basis document, providing much of the supporting information. Prior to submittal of requests for additional information, NRC exchanged information with DOE during a number of consultative telephone calls and public meetings held in early 2013. NRC submitted written RAIs in July 2013 (ML13196A135). DOE formally responded to the RAIs in November 2013 (SRR–CWDA–2013–00106). NRC had several follow-up clarifying questions regarding DOE's RAI responses. DOE responded to the clarifying questions in January 2014 (SRR–CWDA–2013–00144). On June 17, 2014, the NRC issued its *Technical Evaluation Report For H-Area Tank Farm Facility, Savannah River Site, South Carolina* [ML14094A496]. The TER presents NRC's consultative observations and recommendations. In the TER, NRC provided a number of recommendations to DOE, the implementation of which NRC believed was necessary for NRC to find reasonable assurance disposal actions at the HTF would meet the POs in 10 CFR Part 61, Subpart C. DOE completed its final waste determination or basis document for HTF in December 2014 (DOE/SRS–WD–2014–001). The DOE considered the NRC comments and recommendations in preparing the HTF 3116 Basis Document [SRR–CWDA–2014–00080].

NRC assumed its monitoring role, per the NDAA, once DOE issued its waste determination in March 2012 for the remaining tanks and ancillary structures at the FTF facility. NRC expanded its monitoring role to include HTF when DOE completed its final waste determination for HTF in December 2014. The NDAA provides a very specific responsibility for NRC to monitor disposal operations to ensure DOE disposal actions comply with the POs in 10 CFR Part 61, Subpart C. While NRC staff reviewed and provided comments on DOE's PA and waste determination for the entire FTF, NRC's TER (ML112371751) included a more detailed evaluation of the effectiveness of completed waste removal activities for Tanks 18F and 19F and provided recommendations related specifically to the closure of those two tanks that were further along in the closure process and for which DOE provided more detailed closure information. Between issuance of the final FTF waste determination and the final HTF waste determination, NRC also reviewed final inventories and risk estimates for FTF based on additional information collected on Tanks 5F and 6F that were grouted in 2013. Similarly, NRC's TER for HTF (ML14094A496) included a more detailed recommendation for Tanks 12H and 16H, which are further along in the closure process. This is important to note because the monitoring plan will include 49 tanks in the two tank farms, including 43 tanks for which little or no waste removal has occurred.

1.2 Objective

In accordance with Section 3116 of NDAA, after the Secretary of Energy has made a determination that some residual waste does not have to be managed as HLW, NRC is required to monitor subsequent disposal activities to assess compliance with the POs in 10 CFR Part 61, Subpart C. NRC must coordinate these monitoring activities with the South Carolina Department of Health and Environmental Control (SC DHEC), the primary site regulator.

This monitoring plan describes monitoring activities to be conducted in the context of their relationship with the ability for DOE to comply with the 10 CFR Part 61, Subpart C, POs. In most cases, compliance or potential noncompliance with the POs must be demonstrated through indicators of future performance. The monitoring plan identifies eight Monitoring Areas

(MAs) that NRC and SC DHEC find to be important to demonstrating compliance with the POs. DOE activities associated with disposal of tanks and associated waste will take decades to complete. NRC anticipates that implementation of this monitoring plan will take place concurrently with DOE closure activities. NRC staff activities related to the MAs will include the following:

- Technical reviews of DOE work products, experiments, and analyses tied to one or more MAs, including collection of environmental and radiological data.

- Periodic onsite (quarterly or less frequent) observations of aspects of DOE disposal activities and, as appropriate, related experiments.

NRC monitoring activities will be accomplished by NRC headquarters and regional personnel. In general, NRC staff will work in concert with SCDHEC personnel regarding accomplishment of monitoring tasks supportive of each organization's program.

1.3 Roles and Responsibilities

U.S. Department of Energy

The SRS Federal Facility Agreement (FFA) (WSRC–OS–94–42), a formal agreement between DOE, Region IV of the U.S. Environmental Protection Agency (EPA), and SCDHEC, specifies the order and time in which SRS waste tanks are closed. The organizations who are parties in the FFA have regulatory authority over certain activities at SRS. NRC is not a party to the FFA and does not have regulatory authority over waste disposal activities.

The FFA establishes that, among other things, the SRS waste tanks that do not meet secondary containment standards (older style tanks, specifically Types I, II and IV) must be removed from service according to the FFA schedule. The current FFA calls for operational closure of Tanks 18F and 19F (Type IV) by December 2012 and staggered operational closure of the other eight FTF (Type I) and twelve HTF (Type I, II, and IV) waste tanks (tank numbers not specified in the FFA) by September 2022 (WSRC–OS–94–42). Grouting of Tanks 18F and 19F was completed August 24, 2012 (SC DHEC and EPA concurred that tank closure was complete on September 19, 2012); and grouting of Tanks 5F and 6F was completed on December, 18, 2013 (SC DHEC concurred that tank closure was complete on January 22, 2014 [EPA concurred on January 23, 2014]). DOE addresses the closure of the remaining FTF and HTF tanks and ancillary structures in the SRS Liquid Waste System Plan (SRR–LWP–2009–00001).

DOE will pursue closure of the FTF and HTF and monitor its activities to ensure compliance with all requirements. DOE's relevant authority stems from the Atomic Energy Act of 1954, as amended, and applicable DOE Orders, manuals, and policies. DOE uses a documented process to review and resolve any disposal questions and develop any mitigation measures, as appropriate. Tank waste storage and removal operations are governed by an SCDHEC industrial wastewater construction permit (DHEC–01–25–1993). DOE will carry out removal from service and stabilization of the waste tanks and ancillary structures pursuant to a state-approved closure plan and the FTF and HTF General Closure Plans, which contain the overall plans for removing from service and stabilizing the waste tanks and ancillary structures (LWO–RIP–2009–00009 and SRR–CWDA–2011–00050). A specific Closure Module for each waste tank, ancillary structure, or groupings of waste tanks and ancillary structures will be developed and submitted to the State of South Carolina for approval. Final waste tank stabilization activities shall not proceed until the State of South Carolina grants approval.

Stabilization of individual waste tanks and ancillary structures is anticipated to take place after individual component cleaning is complete.

South Carolina Department of Health and Environmental Control

SCDHEC is the primary regulator of DOE closure activities at SRS. The FTF and HTF waste storage and removal operations are governed by an SCDHEC industrial wastewater construction permit, issued January 25, 1993 (DHEC–01–25–1993). The State issued the permit under the authority of the South Carolina Pollution Control Act (State of South Carolina, 1985, Section 48-1-10) and all applicable regulations implementing the Act. The State of South Carolina has authority for approval of wastewater treatment facility operational closure under Chapter 61, Articles 67 and 82 of the SCDHEC Regulations (SCDHEC R.61-67, SCDHEC R.61-82).

The tank farm General Closure Plan (GCPs) address the State's regulatory authority relevant to removing the SRS waste tanks and ancillary structures from service. The GCP sets forth the general protocol by which DOE intends to remove from service the SRS waste tanks and ancillary structures to protect human health and the environment. The SCDHEC approved the FTF GCP on January 24, 2011, and conditionally[3] approved the HTF GCP on August 2, 2012. Prior to approval by SCDHEC, the GCPs were made available to the public for review and comment (LWO–RIP–2009–00009, SRR–CWDA–2011–00022).

U.S. Environmental Protection Agency

As previously stated, the FFA is an agreement between the EPA, DOE, and the State of South Carolina. EPA is a party to the FFA pursuant to its authority in accordance with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), also known as Superfund, under which EPA is tasked with protecting citizens from the dangers posed by abandoned or uncontrolled hazardous wastes. EPA's involvement with the State is focused on ensuring that proper disposal actions are taken, assisting the state with the design and installation of those actions, and monitoring and evaluating their effectiveness.

Executive Order 12580 delegates the responsibility of implementing the provisions in CERCLA to DOE and the U.S. Department of Defense (DOD). CERCLA also names DOE and DOD as the lead agencies for their respective areas. DOE has several facilities in EPA's Region IV. EPA added SRS to the Superfund National Priorities List in December 1989, which also is the year that SRS was required to have an FFA with the State and EPA.

U.S. Nuclear Regulatory Commission

Section 3116 of the NDAA authorized the Secretary of Energy to manage and dispose of certain waste associated with facility cleanup in Idaho and South Carolina as LLW, in accordance with POs in NRC regulations. Prior to such a determination, DOE is required to consult with NRC regarding its waste determination. Following the Secretary's waste determination, NRC is required to monitor disposal activities in coordination with the covered State.

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[3] SC DHEC reserved the right to amend the General Closure Plan following review of NRC staff's TER for HTF.

NRC's role in monitoring DOE's closure activities derives from Section 3116 of the NDAA. While NRC is not given a formal regulatory role, the NDAA requires that NRC monitor, in coordination with SCDHEC, DOE disposal activities to assess compliance with the POs in 10 CFR Part 61, Subpart C. Thus, DOE complies with a subset of NRC regulations in 10 CFR Part 61, "Licensing Requirements Land Disposal of Radioactive Waste," in carrying out such disposal activities. The regulations in 10 CFR Part 61 establish, for land disposal of radioactive waste, procedures, criteria, and terms and conditions upon which NRC issues licenses for the disposal of radioactive wastes containing byproduct, source, and special nuclear material received from other persons.

NRC recognizes that many of the activities that DOE must carry out prior to tank closure are beyond the scope of NRC monitoring authority. For instance, NRC is concerned with and will monitor aspects of residual waste inventory in each tank because of its direct relationship to compliance with the POs. However, NRC staff will focus only on more risk-significant activities related to the residual waste inventory. For example, while NRC staff will monitor heel removal activities insofar as these activities pertain to as low as is reasonably achievable provisions in 10 CFR 61.41, NRC staff does not plan to monitor more routine inventory-reducing activities, such as bulk waste removal.

This monitoring plan articulates NRC's role to ensure DOE disposal activities associated with residual waste covered by the Secretary of Energy's waste determinations for FTF and HTF are in compliance with the POs of 10 CFR Part 61, Subpart C.

1.4 Coordination with the State of South Carolina

Per Section 3116 of the NDAA, NRC's monitoring role includes coordination with State of South Carolina. During the waste determination reviews, NRC staff began coordinating with SCDHEC by conducting discussions to determine the types of activities that the State monitors under its regulatory authority. These discussions also enabled the State to get a better understanding of NRC's activities. NRC continues to coordinate with the SCDHEC throughout the monitoring process by consulting with SCDHEC in the development of this monitoring plan and reviewing the State's Environmental Surveillance and Oversight Program for use as a source of information to supplement NRC's monitoring plan. SCDHEC uses a holistic monitoring approach with regard to overall performance and safety of SRS. The NRC objective with this NDAA monitoring program is limited to assessment of DOE's compliance with the 10 CFR Part 61 POs. Ultimately, NRC and SCDHEC are concerned with the potential for environmental contamination in ground and surface water, air, milk, and meat. While it is unlikely that any contribution to such contamination from the tank farms could manifest itself offsite in the foreseeable future, review of environmental monitoring data is nonetheless useful to NRC staff in betterer understanding the natural system, as well as providing reassurance that the tank farm facilities are operating as assumed in DOE's models.

During the monitoring phase, NRC activities will be closely coordinated with SCDHEC. To the extent practical, NRC will request SCDHEC's assistance in following up on certain monitoring activities that require a local or onsite presence (e.g., activities related to daily tank grouting activities). SCDHEC also will be invited to contribute to the development of monitoring reports, as well as the overall monitoring plan.

NRC will keep the State abreast of the status of monitoring activities at the site, including any potential findings of noncompliance that require a notification letter as described in Section 1.7 of this Monitoring Plan. At least two business days prior to the release and dissemination of any notification letters, SCDHEC officials will be briefed, in detail, on the reasons for such notification.

1.5 Monitoring Approach

Monitoring is an ongoing process consisting of technical reviews, data reviews, and periodic (i.e., quarterly or less frequently) onsite observation visits of DOE disposal activities related to compliance with the 10 CFR Part 61 POs.

1.5.1 Technical Reviews

Technical reviews by NRC include review and evaluation of analyses conducted by DOE or others related to one or more aspects of site or facility performance. In general, technical reviews are used to evaluate new information that either supports or refutes assumptions made by DOE in the PA that are considered important to DOE disposal action compliance. NRC will document each technical review in a report, which will be publicly available.

1.5.2 Data Reviews

Data reviews focus on real-time monitoring data that may indicate future system performance or a review of records or reports that can be used to directly assess compliance with POs (e.g., review of radiation records). NRC will document each data review, which will be publicly available. Data reviews are a subset of technical reviews and are oftentimes folded into a technical review report. In some cases data may be reviewed during an onsite observation, in which case the data review will be documented in the onsite observation report.

1.5.3 Onsite Observation Visits

As described in NUREG–1854, NRC Staff Guidance for Activities Related to **U.S.** Department of Energy Waste Determinations, Draft Final Report for Interim Use (ML072360184), onsite observation visits are opportunities for NRC to observe and review certain operations as they are being performed, or to discuss results of experiments or technical reviews. Onsite observation visits are performed by NRC staff or its representatives and may include a variety of specific activities that could be used to assess an aspect of current or future site performance. A visit is generally performed to either (i) ensure data collected for a technical review are of sufficient quality or (ii) observe key disposal actions that are important to DOE's compliance demonstration.

Prior to each onsite observation visit, NRC will prepare an Observation Guidance Memorandum that discusses the scope and specific activities that will be monitored during the visit in more detail than is described in this monitoring plan. The activities NRC selects will be based on many aspects, such as completion of DOE technical reports, emergent issues, timely DOE actions related to a Monitoring Factor (MF), availability of staff (i.e., NRC, SCDHEC, DOE), availability of locations at the site, length of time since reviewing an item in an MF, scheduled follow-up actions to previous visits, and available NRC resources. NRC will coordinate with SCDHEC in development of the memorandum to take into account areas that SCDHEC is interested in and availability of SCDHEC experts in those areas of interest. NRC plans to provide the final memorandum to DOE within 30 calendar days prior to the visit. The final memorandum will be publicly available. During a visit, the agenda may change based on what happens during the visit (e.g., new areas of interest are identified) or unforeseen circumstances.

Each visit will be documented in an observation report. The report will include, for the actual areas covered during the visit, specific activities, results of discussions, status of any open issues/follow-up actions, and any NRC conclusions. The areas covered may differ somewhat from the areas of interest identified in the Observation Guidance Memorandum. NRC plans to finalize each report within 60 calendar days after the visit. The final report will be publicly available.

1.5.4 Periodic Data Reports and Closure Documentation

Several DOE documents, including performance assessment documentation, tank closure documents, and environmental monitoring reports, are prepared by DOE to satisfy DOE Orders and regulations or are prepared for DOE's regulators (i.e., DOE, EPA, SCDHEC). NRC staff plan to leverage many of these documents to help fulfill its monitoring responsibilities under the NDAA (i.e., to assess compliance with the POs). In the future, it would be beneficial if DOE could provide to NRC the documents listed in Table 1-1. Some of these reports are issued on a periodic basis, and other documents are triggered by a specific event (e.g., closure of a tank).

1.6 Periodic Compliance Monitoring Report

NRC will publish a Periodic Compliance Monitoring Report [i.e., currently, ML111890412)] to document the major findings associated with the monitoring activities during each calendar year (CY). The report will be for the entire NRC NDAA program for that CY (or CYs) and will be publicly available.

1.7 Notification Letters

In accordance with NRC guidance in NUREG–1854 , there are five types of notification letters. Three of the letters are noncompliance letters (i.e., Types I to III) that NRC developed to implement the authority it has inferred from the statutory language in Section 3116 of the NDAA, and the two other types of letters are for NRC to issue as an interim step when identifying or resolving major issues. NRC may issue a Type IV letter to express a concern and a Type V letter to confirm resolution of a concern. Table 1-2 describes each of the five letters, including NRC's reason for issuing the letter, which NRC staff member signs the letter, and who receives the letter. The information in Table 1-2 is similar to the information in NUREG–1854, Table 10-2, but is supplemented by information that reflects current experiences and lessons learned from previous monitoring activities.

The NRC expects that if it were to issue a Letter of Concern (i.e., Type IV), the timing of this letter would allow DOE sufficient time to respond to NRC concerns prior to issuance of one of the three noncompliant notification letters (i.e., Type I, Type II, Type III). However, that may not be possible or appropriate in all situations. For example, if a worker were to be overexposed in an accident (i.e., received greater than 5 rem exposure) and the NRC was going to issue a Type I Letter of Noncompliance, then the NRC may decide to send that notification letter to Congress, DOE, and the covered State rather than first sending a Type IV Letter of Concern to DOE and the covered State. The NRC would utilize other means of notification (e.g., telephone conference calls or meetings) with both DOE and the covered State before sending the Letter of Noncompliance. Figure 1-1 shows the types of noncompliance with the POs in 10 CFR Part 61, Subpart C, which are based on the collection of indirect and direct evidence.

Table 1-1. Documents Prepared by DOE That Would Be Useful to NRC		
Topical Area	**Document**	**Approximate Availability/Frequency**
Groundwater	Eastern OU Groundwater Monitoring Report	August
	Western OU Groundwater Monitoring Report	August
	FTF Groundwater Monitoring Report	March
	HTF Groundwater Monitoring Report	March
Air Monitoring	SRS Annual Environmental Report	September
Performance Assessment Documentation	SRS Liquid Waste Facilities Performance Assessment Maintenance Annual Implementation Plan	March
	Performance Assessment Revisions	As issued
	Special Analyses	As issued
Tank Operational Reports	Annual Radioactive Waste Tank Inspection Program Report	June
Tank or Tank Farm Closure Documentation	Presentation Requesting Preliminary Approval to Cease Waste Removal and Enter Sampling and Analysis	As issued to support tank closure
	Closure Modules	As issued to support tank closure
	Final Configuration Reports	As issued to support tank closure
DOE = U.S. Department of Energy, NRC = U.S. Nuclear Regulatory Commission, OU = Operable Unit SRS = Savannah River Site, FTF = F-Area Tank Farm, HTF = H-Area Tank Farm		

Table 1-2. Types of Notification Letters

Type	Description/Notification	Signature	Distribution
Non-Compliant Performance Objective Notifications			
I	Evidence Performance Objective Is Not Met NRC staff concludes that direct evidence (e.g., environmental sampling data) exists that indicates DOE disposal actions do not meet one or more POs in 10 CFR Part 61, Subpart C. Notification: NRC will issue a Type I letter of noncompliance if DOE cannot demonstrate that disposal actions currently meet the requirements specified in the POs.	Chairman	DOE, Covered State, and Congress
II	Lack of Compliance Demonstration NRC staff concludes that indirect evidence (e.g., experimental data on a key modeling assumption) exists that indicates DOE disposal actions do not meet one or more of the POs in 10 CFR Part 61, Subpart C. Notification: NRC will issue a Type II letter of noncompliance if DOE cannot adequately address NRC technical concerns.	Chairman	DOE, Covered State, and Congress
III	Insufficient Information NRC staff concludes that insufficient information is available to assess whether DOE disposal actions meet the POs in 10 CFR Part 61, Subpart C. It is not clear to NRC staff that DOE (i) has plans to or (ii) is able to provide the information in a reasonable timeframe to allow NRC staff to assess compliance. Notification: NRC will issue a Type III letter of noncompliance if DOE cannot adequately address NRC technical concerns.	Chairman	DOE, Covered State, and Congress
Other Notification Letters			
IV	Concern NRC staff has concerns that DOE disposal actions do not comply with the POs in 10 CFR Part 61, Subpart C. Notification: NRC will issue a Type IV letter of concern if DOE cannot adequately address the NRC concerns.	NRC Staff Management	DOE and Covered State
V	Resolution NRC staff concludes that DOE has provided sufficient information to resolve the concerns identified in a Type IV letter of concern. Notification: NRC will issue a Type V letter of resolution if DOE adequately addresses the NRC concerns identified in a Type IV letter of concern.	NRC Staff Management	DOE and Covered State

Note: The NRC expects that if it were to issue a Letter of Concern (i.e., Type IV), the timing of this letter would allow DOE sufficient time to respond to NRC staff concerns prior to issuance of one of the three notification letters of noncompliance (i.e., Type I, Type II, or Type III) listed in this table.
NRC = U.S. Nuclear Regulatory Commission, DOE = U.S. Department of Energy, PO = Performance Objective, CFR = Code of Federal Regulations

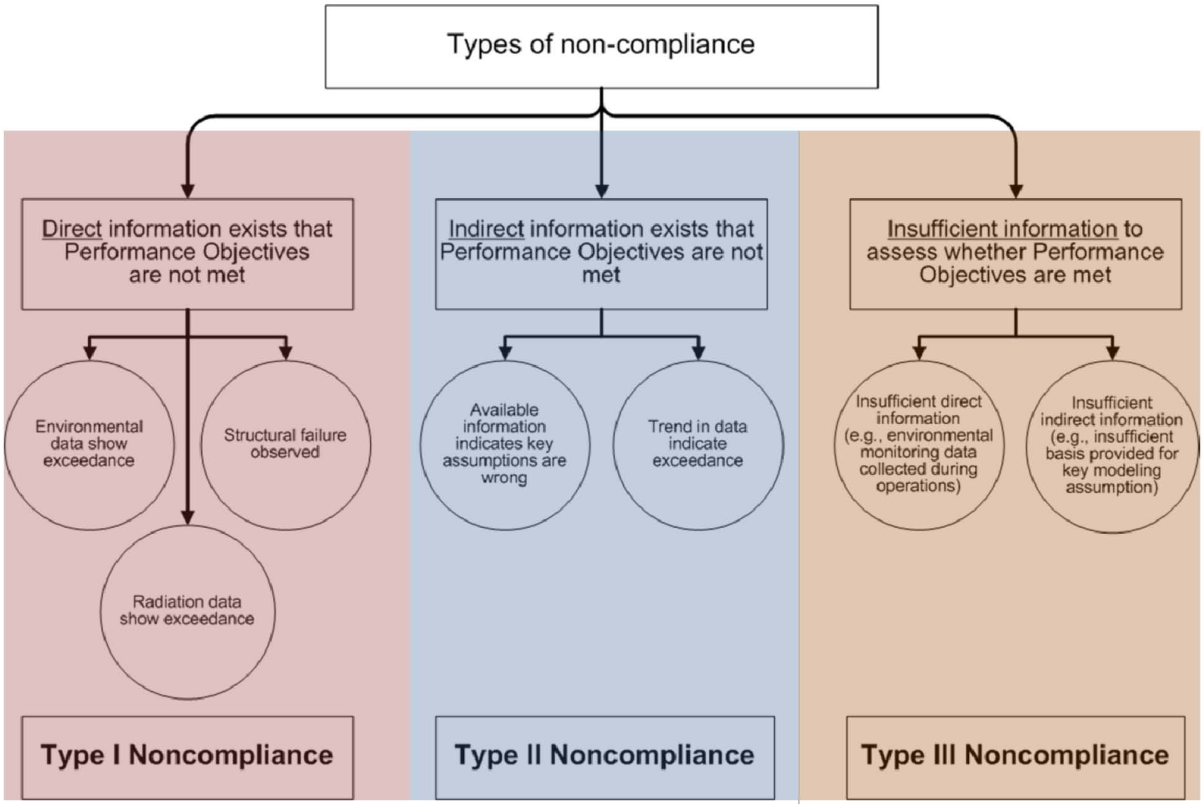

Figure 1-1. Types of Noncompliance With the POs in 10 CFR Part 61, Subpart C

1.8 Monitoring Plan

This monitoring plan presents the basic framework for NRC to perform monitoring activities in accordance with the NDAA for the Tank Farms. The monitoring plan starts with the high level consideration of the four POs. Under each PO, the relevant MAs are identified. Each MA contains a set of MFs important to NRC's assessment of how DOE disposal actions comply with the POs listed in 10 CFR Part 61, Subpart C. New MAs are not expected in the future, but they may be identified and added to the monitoring plan. The MFs were created from the concerns identified in NRC's TERs (ML112371751, ML14094A496). These concerns will now be addressed under the MFs in this monitoring plan. A crosswalk between NRC staff's consultative comments and MFs listed in this monitoring plan is provided in Appendix A.

The identification, description, and status (i.e., open or closed) of each MF will change as monitoring activities continue in the future. New MFs are expected to be added to the monitoring plan in the future as more information is known about the future DOE disposal actions and experiments. Other MFs may be closed in the future as technical issues are resolved or information is provided that decreases the risk significance of the MF(s). NRC expects to revise the monitoring plan in the future to address such items as an updated DOE PA or a new NRC TER.

1.8.1 Linkage Between Recommendations in the Technical Evaluation Report and Monitoring Factors

Appendix A provides a crosswalk between each consultative review comment or recommendation to the MAs and factors developed in this monitoring plan. Appendix A, Table A–2, also provides a crosswalk between DOE's PA Maintenance Plan (SRR–CWDA–2014–00108) and MFs listed in this plan.

1.8.2 Closing Monitoring Factors

NRC will document closure of MFs (e.g., TER, technical review report, or periodic monitoring compliance report). To the extent practical, the information needed by NRC staff to close an MF is provided in Chapters 3 through 6, following each MF identified herein. NRC anticipates that as DOE tank farm closure activities continue, it will identify additional MFs and close others. In general, DOE must provide transparent and technically robust reports, studies, analyses, or experiments that specifically address the technical issues associated with each MF before NRC will close an MF.

2 MONITORING TO ASSESS COMPLIANCE WITH 10 CFR 61.40

Land disposal facilities must be sited, designed, operated, closed, and controlled after closure so that reasonable assurance exists that exposures to humans are within the limits established in the POs in 10 CFR 61.41 through 61.44.

The requirements in 10 CFR Part 40 are general requirements for near-surface disposal of LLW. The DOE disposal actions at the FTF and HTF are unique in that the sites and the waste are pre-existing. Consequently, certain activities specified in the POs are limited in applicability. Siting requirements do not apply, and design is only applicable with respect to the prospective design features of waste disposal, as described in the waste determination. These might include such things as design of the grout mix introduced to the tanks and the site cover. Other activities (i.e., operations, use, closure, and postclosure) are applicable as they relate to disposal of waste covered by the waste determination.

This section requires reasonable assurances that exposures to humans are within the limits established in the other four POs (i.e., 10 CFR 61.41 through 61.44). If DOE provides reasonable assurance that it will meet the other four POs, then DOE will likely have met 10 CFR 61.40. If DOE does not provide reasonable assurance that it will meet the other four POs (i.e., 10 CFR 61.41 through 61.44), then DOE will likely not have met 10 CFR 61.40. Therefore, there are no specific MAs or MFs for 10 CFR 61.40 in this monitoring plan.

With the exception of 10 CFR 61.43, the ability to observe and measure any direct violation of the POs will be very limited in the foreseeable future. The public will have limited and controlled access to environmental media (air or water) that could be contaminated by residual tank farm waste until the federal government cedes the site. Similarly, a receptor who may occupy the site in the future is expected to have low probability of directly intruding upon residual waste. Finally, while current activities could result in long-term stability concerns, major activities that will impact long-term stability (i.e., emplacement of the site cover) will not occur for many years. Therefore, the NRC will rely on indirect indicators, referred to as key MAs, to assess DOE compliance with the POs as it proceeds with closure operations over the next several decades. The key MAs, rationale for their relevance, and specific monitoring activities related to them are summarized herein.

3 MONITORING TO ASSESS COMPLIANCE WITH 10 CFR 61.41

Concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable (ALARA).

Protection of the general population from releases of radioactivity is a dose-based standard that considers potential releases of radioactivity from a LLW disposal facility, such as the tank farm facilities, into the general environment. These releases may cause a receptor to be exposed through direct or indirect contact with various environmental media such as soil, water, air, and plant or animal products (Figure 3-1). Direct pathways include direct radiation exposure or inhalation of buried waste residuals that may migrate to the surface. Indirect (groundwater) pathways include ingestion of crops irrigated with contaminated water, ingestion of animals or animal products exposed to contaminated water and fodder (grown in soil irrigated with contaminated groundwater), ingestion of contaminated groundwater, and incidental ingestion of soil (irrigated with contaminated water). Because tank waste is located several meters below grade underneath closure caps, the primary pathway of exposure of potential receptors to residual waste associated with closed tanks is through leaching of radionuclides into groundwater. Shielding of buried radiation by engineered barriers lowers the potential dose from direct radiation exposure. Transport of buried radioactivity from tank farm components to the surface in the vapor phase also is considered a less risk-significant process. Therefore, direct radiation exposure from buried contamination and releases of radioactivity to air and subsequent transport to the surface are not a focus of the NRC staff's monitoring under 10 CFR 61.41. Review of air monitoring data is, however, an aspect of NRC's evaluation of 10 CFR 61.43 as it pertains to protection of members of the public, particularly during active disposal facility operations such as cleaning, sampling, and grouting of the HLW tanks when the risk of airborne releases is the greatest.

Because the 10 CFR 61.41 evaluations are prospective, a PA analyst must select an evaluation period. However, the time period over which the evaluation should be conducted is not specified in the 10 CFR Part 61 regulation. LLW and waste incidental to reprocessing (WIR) guidance, found in NUREG–1573, A Performance Assessment Methodology for Low-Level Waste Disposal Facilites (ML053250352) and NUREG 1854, suggests that generally a 10,000-year period of performance is sufficient to demonstrate compliance with the PO. However, longer evaluation periods may be necessary to capture the peak dose and provide insights on facility (natural and engineered) performance for certain long-lived wastes. The 10 CFR 61.41 standard also has an ALARA component to ensure that operations and closure are optimized to achieve the lowest overall risk to members of the public, workers, and the environment.

NRC staff evaluates compliance with 10 CFR 61.41 using more recent internal dosimetry methods than available when the 10 CFR Part 61 rule was developed. In lieu of using whole body and individual organ dose limits specified in the 10 CFR Part 61 rule, NRC uses a single dose criterion of 0.25 mSv/yr [25 mrem/yr] total effective dose equivalent to evaluate compliance with 10 CFR 61.41. This departure from the 10 CFR 61.41 rule is explained further in NUREG–1854 (ML072360184) and is consistent with the "Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada" rulemaking (66 FR 55752).

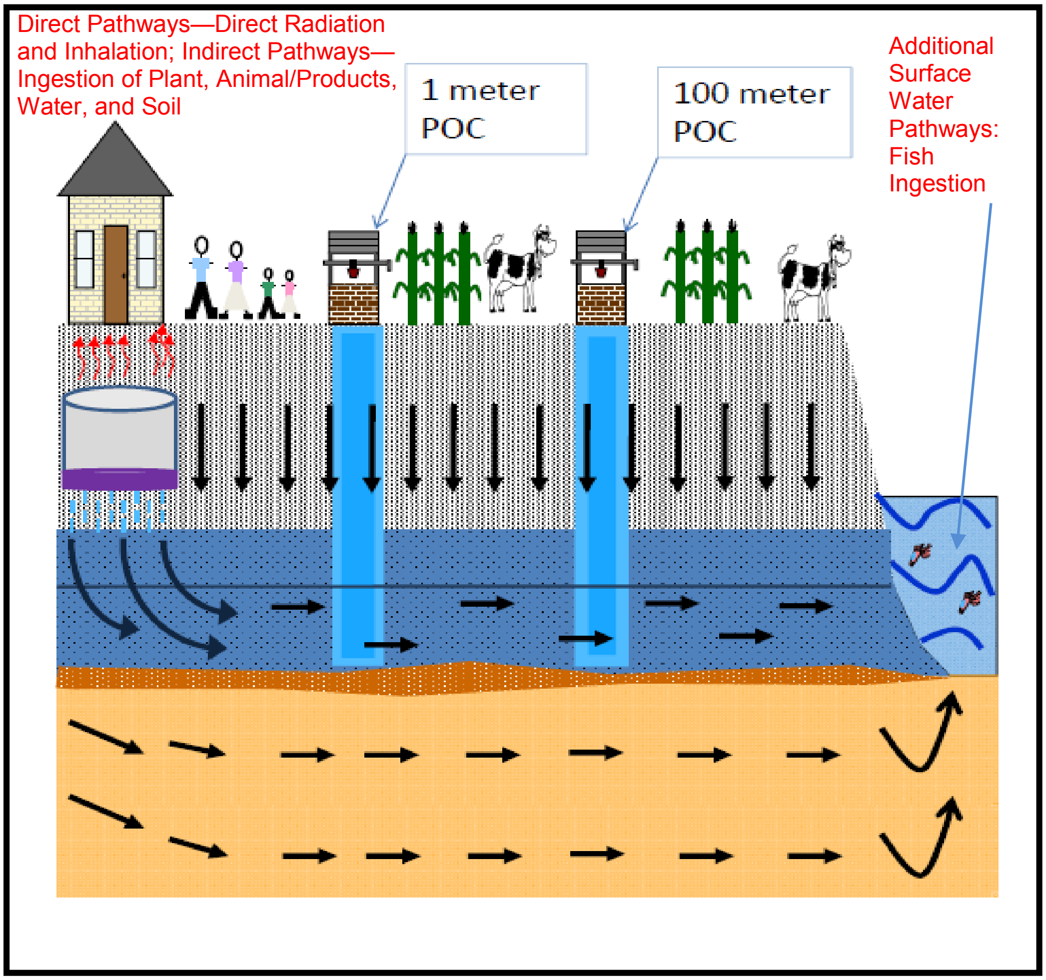

Figure 3-1. Potential Pathways of Exposure to a Member of the Public and Points of Compliance for the 10 CFR 61.41 {100 m [330 ft] and 61.42 1 m [3 ft]} Analyses

To determine the dose to a potential receptor, NRC also must select a point of compliance (POC). NRC guidance in NUREG–1854 (ML072360184) indicates that after the end of the institutional control period,[1] the receptor evaluated to demonstrate compliance with the 10 CFR 61.41 PO is assumed to be located at the point of highest projected dose beyond a 100-m [330 ft] buffer zone surrounding the disposal facility. Figure 3-2 denotes the 100-m [330 ft] and 1-m [3 ft] boundaries, the points at which the dose-based standards in 10 CFR 61.41 and 10 CFR 61.42, respectively, are assessed in the DOE's FTF PA (SRS–REG–2007–00002).[2] Figure 3-3 denotes the 100-m and 1-m boundaries, as well as additional intruder well locations (yellow squares) within the 1-m [3 ft] boundary that were evaluated in DOE's HTF PA (SRR–CWDA–2010–00128).

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[1]Before the end of the institutional control period, the point of compliance is located on the larger site boundary over which DOE maintains access control.
[2]A similar approach is taken for HTF in the HTF PA, although DOE evaluates several points within HTF, in addition to evaluation points along the 1-m boundary outside the footprint of the HTF.

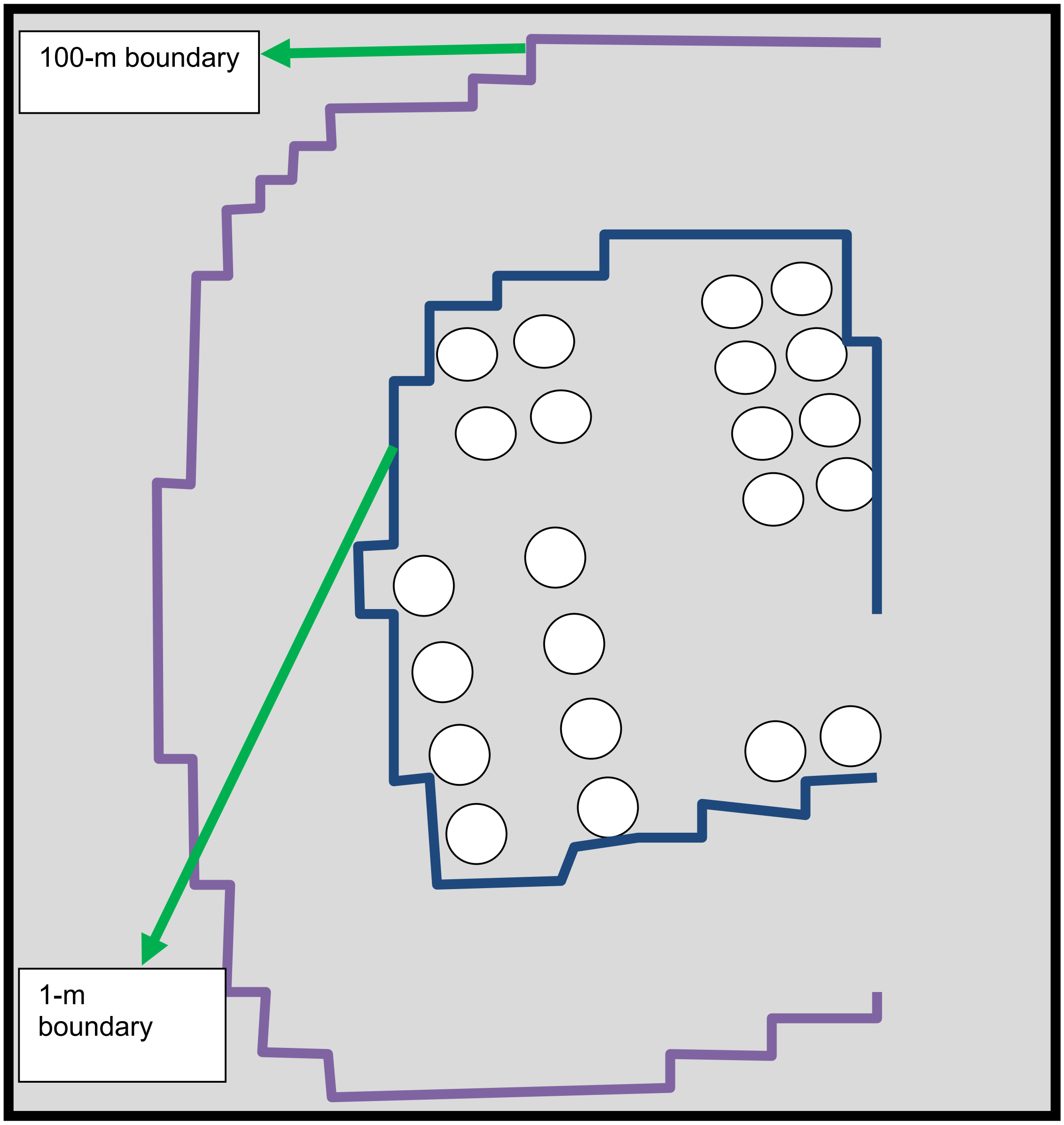

Figure 3-2. Approximate 1-m [3 ft] and 100-m [330 ft] Boundaries Where DOE Evaluates Compliance in Its FTF PORFLOW Model Domain (Adapted from SRS–REG–2007–00002, Figure 5.2-5)

Considering the specific objectives and established paradigms for assessing compliance with 10 CFR 61.41, NRC staff identified key aspects of disposal facility performance that have the largest impact on the 10 CFR 61.41 compliance demonstration based on information provided in DOE's PAs. NRC staff found that several MAs are important to meeting the 10 CFR 61.41 PO. For example, the residual inventory remaining in the cleaned tanks and annuli of certain Type I and II HTF tanks are good indicators of the potential risk associated with each tank (see Section 3.1 on MA 1 "Inventory").

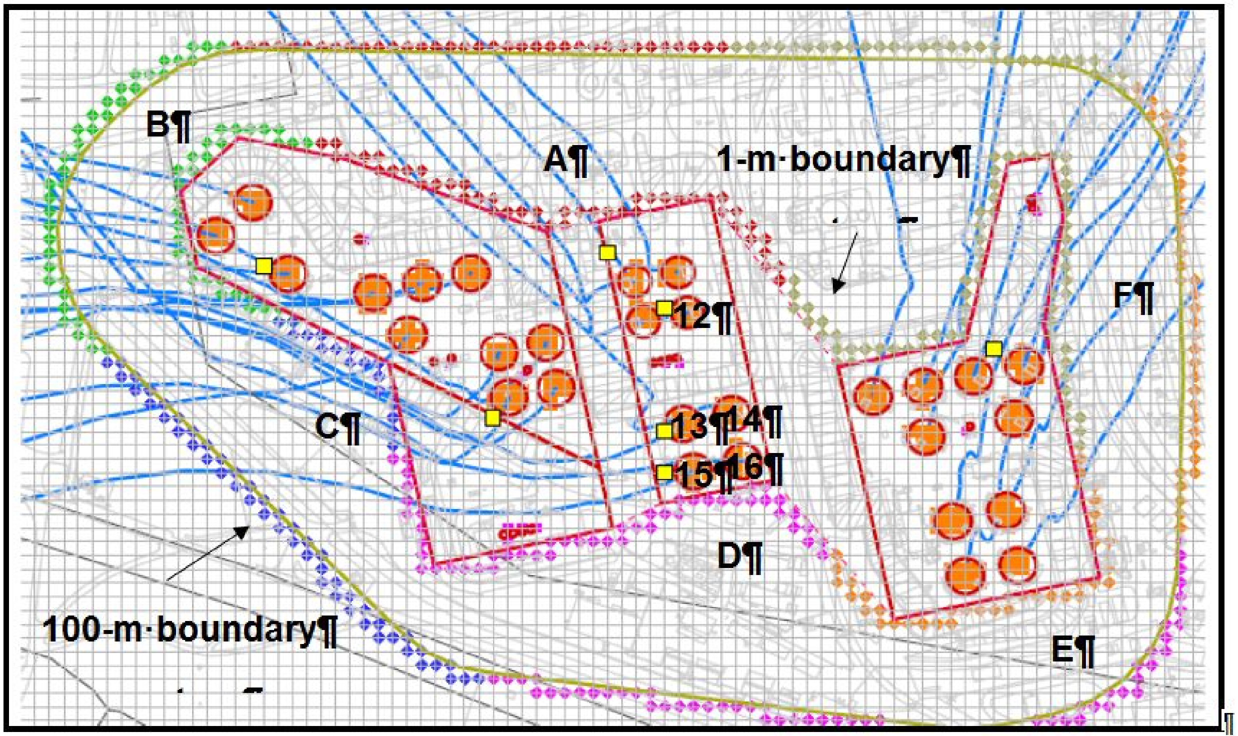

Figure 3-3. Intruder Well Locations at the 1-m [3 ft] Boundary (Inner Boundary Grouped in Sectors A–F) and Within the 1-m [3 ft] Boundary (Yellow Squares) at HTF. Also Illustrated Are Particle Tracks (Blue Lines). (Adapted from Figure 6.5-5 in SRR–CWDA–2010–00128)

However, the extent to which the inventory of key radionuclides affects facility risk also is strongly influenced by the assumed rate of release of the inventory from the tanks. Because the key radionuclides are highly concentrated in a very small volume of waste, solubility limits apply for many key radionuclides. In some cases, solubility control of the radionuclides is the single most important factor controlling release and dose. Therefore, NRC staff established waste release as a key MA (Section 3.2 on MA 2 "Waste Release").

In the case of primary tank and annular inventories, the reducing grout used to fill the tanks and annuli can serve as a significant barrier to waste release. Additionally, for both solubility and nonsolubility controlled radionuclides, releases generally cannot occur from the tanks until the primary and secondary steel liners fail.[3] Furthermore, even after release of radionuclides from the primary tank (and annuli of HTF tanks), key radionuclides must traverse the concrete vault walls surrounding the tanks or concrete basemats underneath the tanks. Thus, because DOE assumes (i) the concrete vaults that house the HLW tanks provide a passive environment that drastically slows corrosion of the tanks, (ii) the reducing grout used to stabilize the inventories in the tanks (and annuli of certain HTF tanks) can be a significant barrier to waste release, and (iii) the walls and floor of the concrete vaults can also substantially attenuate or provide a barrier

[3]This is true with the exception that Type IV tanks do not have a liner top, and annular waste can be released through a path around the secondary liner.

to the release of radionuclides out of the tanks, NRC staff established cementitious material performance as a key MA (Section 3.3 on MA 3 “Cementitious Material Performance”).

Following release from the tanks, the final barrier to waste release is the natural environment surrounding the disposal facility. The natural environment acts as a barrier because it interacts with radioactivity leaving the tanks and causes key radionuclides to move at a slower rate than water and in some cases decreases concentrations in a downgradient well where a potential receptor may be exposed. Dilution of key radionuclides leaching from the tanks into the aquifer below also is an important natural attenuation mechanism that NRC staff will monitor. Therefore, NRC staff created MA 4 “Natural System Performance” as a key MA (Section 3.4). Figure 3-4 provides details regarding the assumed capabilities of each FTF barrier described previously in limiting or mitigating long-term releases from the closed FTF HLW tanks. Similar barriers are relied upon in DOE’s HTF Performance Assessment.

NRC staff also established MAs to address more routine or longer term monitoring activities including the following:

- MA 5, “Closure Cap Performance”
- MA 6, “Performance Assessment Maintenance”

Although NRC staff concluded that the closure cap is oftentimes a redundant barrier[4] in DOE’s PAs, NRC staff nonetheless established MA 5, “Closure Cap Performance,” as an MA because staff concluded that in certain cases, the closure cap could be important to mitigating risk from the disposal facility and in maintaining doses ALARA. Therefore, NRC staff created MA 5 as an MA, given the potential for the closure cap to serve as an important barrier that may help ensure compliance with each of the 10 CFR Part 61, Subpart C, POs. Section 3.5 contains additional details on the MFs related to the closure cap.

NRC staff binned all comments and recommendations from its TERs (ML112371751, ML14094A496) that were of relatively lower risk significance or required long-term action to address in a single category: MA 6, “Performance Assessment Maintenance.” The MA 6 term “Performance Assessment Maintenance” should not be confused with a similar but broader term used by DOE to describe all of the short-term and longer term activities it plans to undertake to maintain its PA, including planned research and tank characterization activities, the results of which may be reflected in future PA revisions. In other words, DOE’s PA maintenance plan encompasses all activities NRC staff might discuss under each key MA, as well as lower priority activities NRC staff discusses under MA 6, “Performance Assessment Maintenance.”

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[4]NRC staff concluded that DOE’s reference or best-estimate PA case shows the closure cap is a redundant hydraulic barrier because other, more robust hydraulic barriers, such as the steel liners and tank grout used to fill the cleaned tanks, are present and expected to outperform the closure cap for longer periods of time under most scenarios, including the reference case used by DOE in its PAs. However, it is important to note that the closure cap is the only barrier assumed to provide long-term, infiltrating-reducing capabilities, albeit at modest levels. Figure 3-4 shows barriers to timing of tank farm releases in DOE’s reference case for FTF. The dark blue barrier represents the closure cap that is assumed in DOE’s PA to be fully or nearly fully effective for less than 1,000 years before its performance drops off rapidly compared to the light blue (tank grout) or green (steel liner) barriers that last in most cases for tens of thousands of years following disposal facility closure. However, it is important to note that after a few thousand years, infiltration through the closure cap is assumed in DOE’s PA to stabilize to a constant rate of approximately 30 cm/yr [12 in/yr] for all time, less than the background infiltration rate of 37 cm/yr [15 in/yr], while no other barrier serves to permanently reduce infiltration.

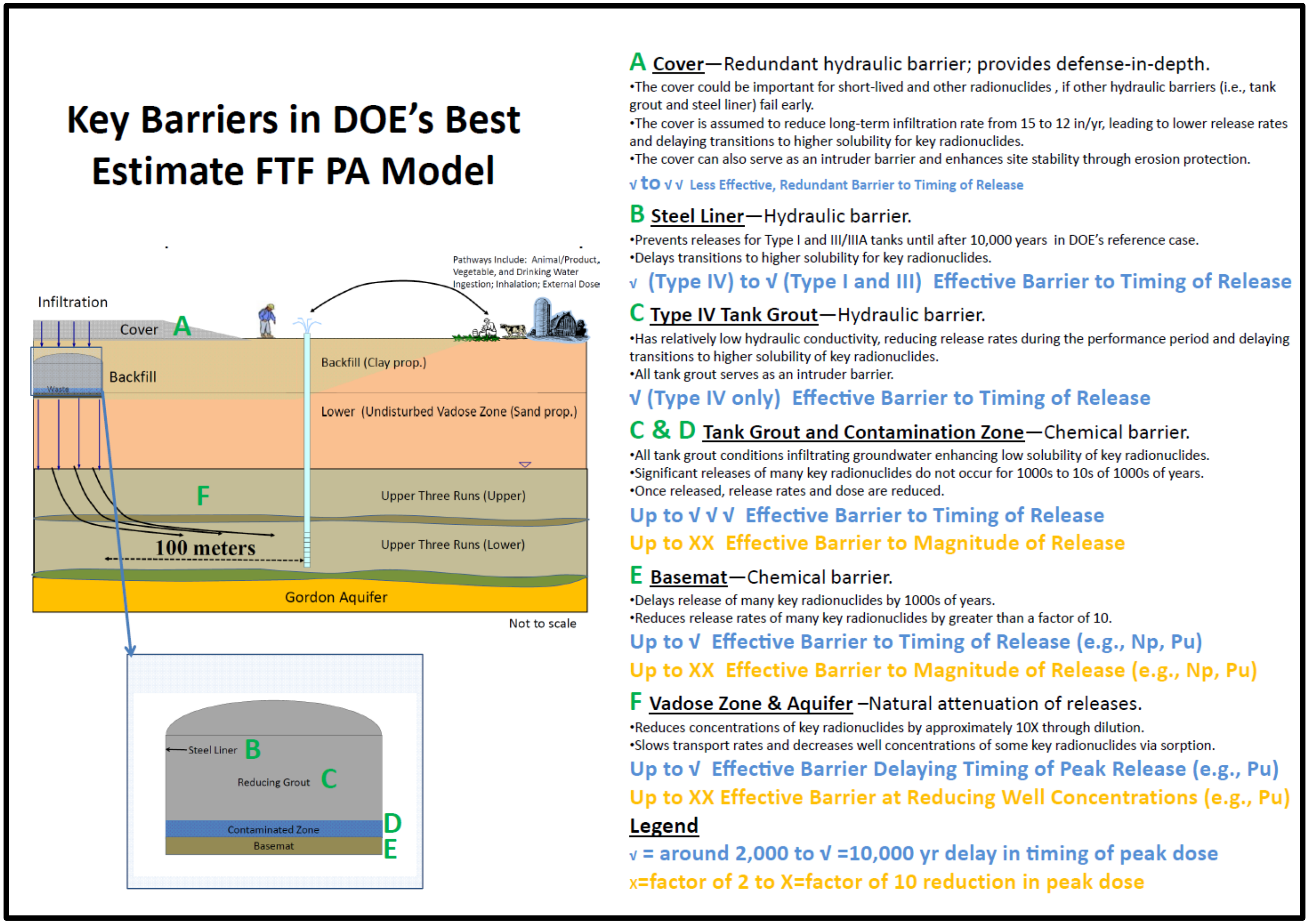

Figure 3-4. Example Barriers in the DOE's FTF Performance Assessment Reference Case. Similar Barriers Are Assumed in DOE's HTF Performance Assessment.

3.1 MA 1 “Inventory”

Inventory for key radionuclides is important to the compliance demonstration because inventory is linearly related to dose for those radionuclides that are not solubility limited. Even for key radionuclides that are solubility controlled, in some cases (e.g., when solubility control is not the primary barrier to release from the engineered disposal system) doses also can be very sensitive to inventory. This is true because with higher inventory more activity can accumulate in a downgradient barrier (e.g., concrete basemats underneath the tanks that may control release for certain key radionuclides). For those radionuclides that are solubility limited, inventory also can be important from a mass depletion perspective. For example, the inventory of a key radionuclide could be released at very low concentrations over a long period of time, such that little to no activity remains when the solubility of the key radionuclide increases to risk-significant values. In these cases, a higher inventory could lead to a significantly higher peak release and dose from the engineered system compared to a lower inventory, because it would take a longer period of time to deplete a radionuclide with a higher residual inventory. Thus, inventory can be very risk significant for both solubility-controlled and non-solubility-controlled constituents and, therefore, is listed as an MA for the Tank Farms.

Because facility risk is sensitive to key radionuclide inventory, in most cases a threshold inventory exists below which a key radionuclide ceases to be important to the compliance demonstration. For some key radionuclides (e.g., relatively long-lived and mobile radionuclides), it may be more cost effective to remove additional activity from the tanks than it would be to provide additional information to support a key modeling assumption relied on for compliance. For example, DOE provided additional information from Tanks 5H and 6H to support a significantly lower inventory estimate for technetium (Tc)-99 in Type I tanks. Until then, Tc-99 had been regarded as the single most risk-significant radionuclide for FTF over longer periods of performance in DOE’s base case analysis, owing to its relatively high mobility in the environment. NRC staff will continue to monitor progress on FTF Type I and other tank closures to ensure the inventory of Tc-99 is reduced to non-risk-significant levels. If Tc-99 inventory cannot be reduced to these non-risk-significant levels, then other barriers to waste release for Tc-99 (such as coprecipitation with iron mineral phases) will become increasingly important. In contrast to assumptions made in the FTF PA, in the HTF PA, DOE assumes that the entire Tc-99 inventory is coprecipitated with iron mineral phases into perpetuity (in the FTF PA Tc-99 was eventually assumed to be released with no solubility control). Because NRC staff does not think that DOE has provided sufficient support to conclude that 100 percent of the Tc-99 inventory remaining in the HTF tanks is coprecipitated with iron and will remain so for all time, additional supporting information will be needed for the longevity and assumed level of solubility control of Tc-99, if the residual inventory of Tc-99 in HTF tanks is found to be risk significant considering no solubility control. If the residual inventory of Tc-99 in HTF tanks is not found to be risk significant, no additional support for the assumed level of solubility control is needed.

Row 1 of Table 3-1 provides information on the relative hazard of three key radionuclides at FTF based heavily on the residual inventory of the radionuclides assumed in the PA (SRS–REG–2007–00002). The relative hazard associated with these radionuclides is expressed in terms of the orders of magnitude reduction needed to reduce the concentrations to a level that would meet the 10 CFR 61.41 PO, if the concentrations were located at the point of compliance (i.e., assuming the entire inventory is placed in the contaminated zone pore water). While assuming the entire waste inventory is in the contaminated zone pore water is unrealistic,

Table 3-1. Relative Risk and Contributions of FTF Barriers to Reducing Risk for Three Key Radionuclides (Tc-99, Pu-239, and Np-237)* in DOE's FTF PA

		Tc	Pu	Np	Notes
1	Total Barrier Performance Needed (Function of Inventory)†	6‡§ (Type I)	9‖ (Type IV, Tank 18F)	6‡ (Type I)	Factor reduction in concentration needed to meet the 10 CFR 61.41 dose standard. The tank/type producing the highest dose for each key radionuclide is provided in parentheses.
	Engineered System				
2a	Solubility Control	0‡	2‡‖	1 to 2‡	Final solubility
2b		(9 to 11)¶	(9 to 11)¶	(5 to 6)	Initial solubility
3	Basemat Attenuation (Sorption)	<1	2¶	2¶	Very important for Pu and Np. Can compensate for solubility.
4	Near-Field Diffusion or Dispersion+	2‖	1¶	1¶	Additional reduction in concentration due to upward diffusion into tank grout, large cell size, or dispersion.
	Natural System				
5	Aquifer Dilution	1	1	1	Based on simple aquifer mixing model; comparison of concentrations between vadose zone and saturated zones; and between source and POC. Pu sorption can compensate for other barrier underperformance.
6	Sorption	<<1	1‡	<<1	
7	Additional Dispersion+ to POC	1–2¶	1¶	1¶	
8	Total Barrier Performance	5	8	6 to 7	Sum of rows 2a, 3-7.
9	Calculated Safety Margin	−1§	−1‖	0 to 1	Difference between Row 8 and Row 1.

*All values in the table are approximate (order of magnitude). Values only are intended to provide relative information on the contributions of various barriers in DOE's FTF PA and are not expected to be exact. Many of the values for the various barriers were estimated based on tracking the concentrations of the three key radionuclides from the contaminated zone to the point of compliance in DOE's PORFLOW models for the tank/type listed in Row 1.

†The "total barrier performance needed" is calculated by assuming the single tank inventory assumed in the FTF PA is located in the pore water of the contaminated zone. While virtually impossible, assuming the total inventory is available to a potential receptor is necessary to provide a starting point from which to evaluate the contributions of various barriers to reducing risk and to provide a measure of the relative hazard associated with each key radionuclide listed based on inventory and groundwater pathway dose conversion factor of each radionuclide. The contaminated zone is assumed to be 1 in thick with a porosity of 0.27. For example, a value of "6" for Tc-99 in the first row corresponds to a factor of 10^6, or 1,000,000, the factor by which the concentration in the waste zone needs to be reduced to produce a groundwater concentration at the point of compliance equivalent to 0.25 mSv/yr [0.25 mSv/yr] total effective dose equivalent based on DOE biosphere modeling in the FTF PA.

‡Most tractable

§In the Tanks 5F and 6F Special Analysis SRR–CWDA–2012–00106, DOE showed that the Tc-99 inventory was overestimated by one to two orders of magnitude (i.e., Row 1 could be as low as four orders of magnitude and Row 9 could be one order of magnitude safety margin).

‖In the Tanks 18F and 19F Special Analysis SRR–CWDA–2010–00124, DOE's updated best estimate final solubility (Row 2) was significantly higher than that assumed in the FTF PA, leading to a peak dose from Pu-239 less than the 10 CFR 61.41 PO (i.e., positive safety margin in Row 9). Using what was described as a more conservative Pu solubility, the results could also be similar to those reported in the FTF PA and this table.

¶Potentially optimistic

+Dispersion is used in a broad sense to describe diffusion, numerical, and physical dispersion in DOE's PA models. Because Tc is ultimately assumed to be highly soluble and mobile in DOE's PA model, almost all the attenuation of Tc-99 is due to dilution and dispersion. No solubility control is assumed for Tc upon transition to the final chemical state.

FTF = F-Area Tank Farm, Tc = technetium, Pu = Plutonium, Np = Neptunium, U.S. Department of Energy, PA = Performance Assessment, POC = Point of Compliance the calculation was performed to indicate the relative hazard of these three key radionuclides based primarily on inventory and groundwater pathway dose conversion factors alone. The calculation was also performed to illustrate how DOE assumes each of the barriers acts to reduce the risk associated with release of the radionuclides into the accessible environment. In subsequent sections of this plan, NRC staff will describe in more detail which barriers are important to DOE's compliance demonstration and which barriers require additional support.

Table 3-1 is introduced in this section, because it provides information on NRC staff's current thinking that inventory reduction may be one of the most effective means of demonstrating that the 10 CFR 61.41 PO can be met for Tc-99 and Neptunium (Np)-237. NRC staff thinks that additional support for the assumed level of performance of natural or engineered barriers for these two radionuclides is needed, but supporting information may be difficult to obtain. It is important to note that the inventory of Americium (Am)-241, parent to Np-237, should also be considered in assessing the residual risk associated with Np-237 in the tank farms. While Table 3-1 presents information for FTF based on the original FTF PA, parallels can be drawn to HTF. A notable exception is that while Radium (Ra)-226 was identified as an important radionuclide contributing to dose in the FTF PA, the long-term risk associated with Ra-226 due to in-growth from its parents (i.e., Plutonium (Pu)-238, Uranium (U)-234, Thorium (Th)-230) is expected to be relatively greater for HTF compared to FTF due to the relatively high inventory of Pu-238 expected to remain in HTF tanks compared to FTF tanks (e.g., factor of 20 times higher Pu-238 inventory expected in HTF).
Additionally, DOE included Ra-228 and Th-232 in the list of 54 radionuclides for consideration in the assessment of compliance with the POs in DOE's HTF PA because thorium fuel was exclusively processed at the H-Canyon. Because the two tank farms were fed from different processing facilities, differences between the FTF and HTF inventories are expected (SRNL–STI–2012–00479).

NRC Monitoring Under MA 1 "Inventory"

As listed in Appendix A and documented in more detail in NRC's TERs (ML112371751, ML14094A496), NRC staff will consider the following MFs related to inventory that are considered important to meeting the 10 CFR 61.41 PO: MF 1.1 "Final Inventory and Risk Estimates."

The following factors support development of the final inventory (e.g., sampling and volume data are used to estimate a final inventory) and also are listed as MFs under MA 1, "Inventory."

- MF 1.2 "Residual waste sampling"
- MF 1.3 "Residual waste volume"
- MF 1.4 "Ancillary equipment inventory"

The following factor, related to the final tank inventory, is important to meeting ALARA criteria in 10 CFR 61.41 and will therefore be listed as an MF under MA 1, "Inventory": MF 1.5 "Waste Removal As It Pertains to ALARA."

3.1.1 Monitoring Factor 1.1: Final Inventory and Risk Estimates

DOE has committed to sample each tank following waste retrieval activities. During the monitoring period, NRC staff will review special analyses typically performed at the time of closure of each tank that provide updated inventories and risk estimates for the entire tank farm that is the subject of the special analysis.[8] NRC staff will assess the degree to which DOE demonstrates that the tank farm meets the POs with the new projected radionuclide inventories and will assess other PA updates. As part of the evaluation, NRC staff will assess the degree to which DOE's special analyses evaluate uncertainty in the revised inventory. NRC staff should independently verify whether the change in inventory, or changes to other modeling parameters, are expected to lead to an exceedance of the dose-based POs (i.e., a 0.25 mSv/yr [25 mrem/yr] limit to a member of the public under 10 CFR 61.41 or an applied 5 mSv/yr [500 mrem/yr] limit to an intruder under 10 CFR 61.42). This factor can be closed following NRC review of the last tank or equipment-specific special analysis prepared by DOE for FTF and HTF.

Several FTF and HTF tanks have known leak sites. The waste tank annulus provides a collection point for any potential leakage from the primary tank. Type I Tanks 9H and 10H and Type II Tanks 14H and 16H in HTF are known to have leak sites that led to a potentially risk-significant inventory in their annuli as noted in the final waste determination for HTF (DOE/SRS–WD–2014–001). Following issuance of the final waste determination for HTF, DOE developed a special analysis for Tank 16H (SRR–CWDA–2014–00106). NRC staff is in the process of evaluating updated risk estimates for Tank 16H to assess the risk of the final residual waste inventory estimated to remain in the Tank 16H annulus at the time of closure. The results of NRC staff's evaluation of the Tank 16H Special Analysis may influence conclusions regarding the acceptability of annulus waste inventories with regard to their ability to meet the 10 CFR Part 61, Subpart C, POs.

3.1.2 Monitoring Factor 1.2: Residual Waste Sampling

To accurately estimate the postcleaning inventory that will be stabilized in FTF and HTF tanks, DOE must sample and analyze the residual waste concentration in each tank after it is cleaned, as well as characterize the solids density and estimate residual waste volumes. NRC staff will review sampling and analysis plans developed for each tank.

NRC's technical review of sampling and analysis plans should include, but may not be limited to, the following considerations:

- Consideration of intratank waste variability that is important to the sampling design, including the basis for assumptions regarding homogeneity and the number of samples to be collected

- Use of floor concentration samples for assigning residual waste inventory for tank walls

[8] It is important to note that DOE must demonstrate compliance with an entire tank farm; therefore, a single tank can put DOE out of compliance with the POs. Additionally, the distribution of residual waste may also be important to the compliance demonstration (e.g., waste located in tanks located nearer the 100-m [330 ft] boundary may pose a greater risk than tanks located further upgradient of the boundary due to greater modeled natural attenuation). Additionally, following closure of each tank, DOE prepares a special analysis that evaluates the impact of updates to the inventory and other modeling changes to the results of the performance assessment considering not only the single tank, but all of the tanks in the tank farm. Therefore, it is important for NRC to review each special analysis that is completed following closure of each tank or groups of tanks addressed in the special analysis.

- DOE’s support for assumptions regarding normality of radionuclide concentration when developing deterministic and probabilistic inventory parameters

- Sampling of HRRs or basis for removal of HRRs from the list of radionuclides to be sampled

As documented in NRC’s review of Tanks 5F and 6F Final Inventories (ML13085A291), the NRC expects DOE to address the following technical concerns in future tank sampling efforts:

- DOE should consider, in its tank sampling design, historical information on tank waste receipts, and information related to the alteration and redistribution of waste due to cleaning operations that may impact horizontal and vertical waste heterogeneity.

- DOE should evaluate the option to composite samples within segments (or strata) to preserve information about segment (or strata) variance.

- DOE should evaluate and present information on the relative contributions of various forms of uncertainty in its estimation of mean tank concentrations.

- DOE should clarify the statistical approach used to estimate the 95th percent upper confidence level (UCL95) (e.g., treatment of all nine measurements as independent when computing the UCL95).

- DOE should also consider how it can better assure sample representativeness by improving tank sampling designs, collection tools, and instructions.

The technical issues documented in the Tanks 5F and 6F technical review report (ML13085A291) with respect to residual waste sampling were repeated in the HTF TER (ML14094A496). In addition to review of sampling and analysis plans, NRC staff also will conduct its own independent assessment to verify the list of HRRs in DOE’s assessment is complete. If additional HRRs are identified, NRC staff will meet with DOE to resolve the discrepancies in the list and suggest actions, as appropriate, that DOE could take to ensure that risks are appropriately assessed and managed. The NRC staff recommends that DOE continue to evaluate its HRR list and provide sufficient justification for any changes as additional information becomes available. The HRR list should be evaluated especially where it is used to inform decisions, such as the selection of radionuclides characterized in residual waste and the screening of radionuclides for the purpose of detailed PA calculations. Technical review efforts under this MA should be coordinated with onsite observations of waste sampling to evaluate whether samples are being collected in accordance with sampling analysis plans and the quality of data is sufficient to meet data quality objectives.

This MF can be closed following review of the last sampling and analysis plan for a tank and following the last planned onsite observation of sampling of a tank (may occur prior to the last tank or ancillary equipment being sampled). NRC will use a graded approach in reviewing sampling and analysis plans. After technical issues are resolved, NRC staff’s reviews will be focused on changes to the programmatic approach and/or a cursory review to make sure DOE is implementing the plan as documented.

3.1.3 Monitoring Factor 1.3: Residual Waste Volume

Residual waste volume is multiplied by density and radionuclide concentrations to estimate the residual inventory and is, therefore, important to development of the final inventory. As documented in its FTF TER (ML112371751), NRC staff noted there is significant uncertainty in DOE's current material mapping approach used for volume estimation. NRC staff recommended DOE explore methods to improve the process by which it estimates residual waste volumes and associated uncertainty, including evaluation of the costs and benefits of alternative technologies available for mapping.

As documented in NRC's more recent review of Tanks 5F and 6F Final Inventories (ML13085A291), NRC expects DOE to address the following technical concerns when estimating residual tank waste volumes in the future:

- DOE should better understand the accuracy of mapping team height estimates through additional field validation activities for a range of solid material heights.

- DOE should clearly communicate how it determines the size of areas to be mapped and how it manages uncertainty related to height estimates for discretized areas in its deterministic analysis. Likewise, DOE should clarify how it represents uncertainty in the assignment of high and low end heights to these areas (e.g., whether it uses a height that is clearly below/above the nonuniform surface of the delineated areas).

- DOE should consider uncertainty in the volume estimates resulting from the transfer of data from photographic and video evidence to hand-contoured maps (and then to Excel® spreadsheets with a finer discretization).

- DOE should be more transparent with respect to its approach to (i) mapping annular volumes, including use of a crawler to inspect internal surfaces, and (ii) estimating residual waste volumes in ventilation ducts. DOE should consider uncertainty in annulus volume estimates.

In lieu of improving the method by which DOE estimates residual waste volume, DOE could manage inventory uncertainty with conservative estimates (i.e., volume estimates that clearly err on the side of higher values). The technical issues documented in the Tanks 5F and 6F technical review report (ML13085A291) with respect to development of final volume estimates were repeated in the HTF TER (ML14094A496).

DOE indicates its intent to improve the method of estimating residual volumes in its PA Maintenance Programs (e.g., SRR–CWDA–2012–00022 and SRR–CWDA–2014–00108). NRC staff will monitor DOE's progress in this area. NRC staff also will attempt to observe DOE's use of video and photographic records to develop residual waste volumes during an onsite observation. This factor will be closed once NRC staff concludes DOE has taken steps to improve the process by which it estimates residual volumes or shows that DOE has appropriately managed volume uncertainty. This factor may be reopened if NRC staff identifies issues with DOE's approach to developing or considering uncertainty in volumes estimates.

3.1.4 Monitoring Factor 1.4: Ancillary Equipment Inventory

The low risk significance of ancillary equipment to meeting the 10 CFR 61.41 PO is predicated on the assumed inventory for key radionuclides in DOE's PAs. Therefore, the inventory for ancillary equipment should be confirmed to support NRC staff's understanding of the low risk significance of these tank components. DOE indicated, in response to NRC comment (SRR–CWDA–2009–00054), its intent to verify PA assumptions regarding transfer line inventories consistent with Section 8.2, "Further Work," in DOE's PA (SRS–REG–2007–00002). NRC staff will meet with DOE to discuss DOE's schedule for characterization of transfer lines to ensure conclusions regarding the relatively low risk estimates for transfer lines are confirmed. Additionally, transfer line inventories are important for the intruder analysis because DOE assumes an intruder can more easily access the residual inventory in a transfer line than in a tank. Transfer line inventories are discussed in more detail in Chapter 4, which includes information on MFs related to assessing compliance with the 10 CFR 61.42 PO.

This MF can be closed once NRC staff concludes that DOE characterization has confirmed the low risk of ancillary components.

3.1.5 Monitoring Factor 1.5: Waste Removal (As It Pertains to ALARA)

In the final FTF and HTF waste determinations, DOE cites its ability to meet the NDAA criteria "removal of HRRs to the maximum extent practical" (MEP demonstration) as the primary means by which it meets the ALARA criteria in 10 CFR 61.41. NRC will evaluate removal to the maximum extent practical for each cleaned tank to ensure DOE disposal actions are consistent with ALARA criteria. Because none of the HTF tanks had undergone an MEP demonstration at the time of issuance of the final waste determination, the NRC evaluated the process for MEP demonstration as opposed to reaching a conclusion for any of the HTF tanks. NRC staff will assess DOE compliance with ALARA objectives through review of DOE documentation completed in conjunction with the federal facility agreement closure process. As provided in NRC guidance in NUREG–1854 (ML072360184), NRC staff also should pay special attention to the distribution of residual inventory in the cleaned tanks to ensure compliance with ALARA (e.g., removal of waste from areas susceptible to preferential pathways, such as tank walls).

This MF can be closed once all the tanks are cleaned and NRC staff has reviewed DOE documentation of removal to the maximum extent practical.

Closure of Monitoring Factors Related to MA 1, "Inventory"

NRC staff expects that MFs related to inventory will be closed after tank cleaning activities and subsequent postcleaning sampling activities are completed for the tank farms.

3.2 MA 2, "Waste Release"

Importance of MA 2, "Waste Release"

In the FTF and HTF PA reference (or best estimate) cases, DOE assumes for many key radionuclides that concentrations released from the primary liners of the tanks are limited to low values for long periods of time.[9] Key radionuclide concentrations in the aqueous phase of the waste zone are controlled by solubility (or concentration) limits. If waste zone aqueous-phase concentrations are limited to low values, then exposure to a member of the public that may result from use of contaminated groundwater at the points of compliance (maximum concentrations on the 1- or 100-m boundaries) will also be limited. Solubility (or waste release) assumptions are, therefore, important to DOE's demonstration of compliance with the 10 CFR 61.41 PO, as well as the 10 CFR 61.42 PO discussed in Section 4, and are therefore a focus of NRC staff's monitoring of the SRS tank farms.

The solid phases that are assumed to be present in the waste (or contaminated) zone within the primary liner dictate the solubility (or aqueous-phase concentration) limits of key radionuclides. The key radionuclides that are (i) important to dose and (ii) sensitive to solubility limits are Tc, Np, and Pu. Solubility limits for these elements are modeled, in DOE's PAs, for (i) pure phases consisting only of the key radionuclide itself as a precipitated solid and (ii) as coprecipitated[10] with iron-bearing mineral solids in the waste residue. NRC staff will, therefore, focus on these three elements, their assumed solubility-limiting phases, and associated solubility limits during tank farm monitoring as part of this MA, under MF 2.1.

In addition to the solubility-limiting phases and associated solubility limits for key radionuclides, assumptions regarding the length of time that key radionuclides remain in a low solubility phase may also be important to the compliance demonstration from a timing perspective (e.g., if the higher solubilities lead to peak doses above the PO but following the period of compliance). DOE assumes groundwater vertically infiltrating the tank system will typically be conditioned by the tank grout[11] through which it must first flow to get to the contaminated zone located in the primary liner. Conditioning of the groundwater through its interaction with the tank grout is assumed to occur for thousands to tens of thousands of years (e.g., see purple barriers in Figure 3-5 for FTF tanks and times listed in Table 3-2 for FTF and HTF tanks that signal the assumed transitions of key radionuclides to higher solubility).[12] Conditioning of the groundwater

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[9]MA 2 focuses on waste located in the primary liner. DOE also considers a waste inventory in the annuli of Types I and II tanks in the HTF PA; however, the waste in the annuli of these tanks is not assumed to be solubility controlled and is not considered under MA 2. MF 3.5, "Vault and Annulus Sorption," under MA 3, "Cementitious Material Performance," discusses monitoring of waste release assumptions for the annuli of these HTF tanks.

[10]DOE uses the term "coprecipitated" in a broad sense to refer to the incorporation of key radionuclides into a solid iron mineral (rather than being a pure solid composed of just that key radionuclide). The solubility of the key radionuclide is assumed to be controlled by the solubility of the iron mineral.

[11]Grout is added to the tank and annulus to stabilize the waste residuals and to provide stability to the engineered system at the time of closure. Reductants are added to the grout to help retain certain key radionuclides in a low solubility form.

[12]The primary difference between chemical transition times for FTF and HTF tanks are related to the timing of steel liner failure. For example, certain Type I and II tanks in HTF are assumed to have initially failed liners, and therefore, water is able to begin infiltrating the tank and depleting the tank grout of reducing and buffering components earlier in time leading to more rapid chemical transitions. Additionally, four Type I tanks at HTF are fully submerged in the water table aquifer and are treated differently than other tanks at HTF or FTF. To determine the chemistry of the water in contact with the contaminated zone in the primary liner for Type I tanks at HTF, DOE considers various

through its interactions with tank grout is important because in most cases DOE assumes the chemical properties of the conditioned groundwater helps to maintain the low solubility of key radionuclides in the contaminated zone. In some cases, aging of the grout through its interactions with infiltrating groundwater can lead to chemical transitions to relatively high Eh[13] (or what is referred to as “oxidized” conditions) or relatively low pH[14] (or what is referred to as “Region III” conditions) and associated higher solubility releases of key radionuclides. In these cases, the timing of the risk-significant release may be important to the compliance demonstration if the releases result in peak doses above the compliance limits. The longevity of the chemical conditioning of infiltrating groundwater via the tank grout that maintains key radionuclides in a low solubility form is primarily a function of (i) the flow path of water movement through the grout mass (i.e., bypass flow through preferential pathways leading to minimal contact of water with grout or matrix flow through the grout monolith with maximum contact of water with the grout) and (ii) the geochemical interactions between the water and the contacted grout mass. The assumptions regarding the movement of infiltrating water through the grout mass are discussed further in MA 3, “Cementitious Material Performance,” Section 3.2. Assumptions regarding the longevity of reducing conditions and high pH that are based on DOE’s geochemical modeling (and associated assumptions regarding the tank grout components that provide reductive and buffering capacity and their ability to interact with infiltrating groundwater) are the subject of this MA and are discussed in more detail under MF 2.2.

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cases where unconditioned saturated groundwater flowing primarily horizontally through the engineered system mixes with a smaller quantity of conditioned groundwater that is assumed to flow vertically through the tank grout into the contaminated zone to determine the chemistry of the water in contact with the contaminated zone in the primary liner. However, after considering the combined effect of assumptions regarding the chemistry of the saturated groundwater (low dissolved oxygen that tends to prolong chemical transition times) and additional horizontal flow through the tank grout (that tends to shorten chemical transition times), the chemical transition times for Type I tanks are generally faster than other comparable tanks (see, for example, Table 3-2 Type I tanks versus Type II tank transition times). Additional discussion regarding DOE assumptions with respect to the chemistry of the saturated groundwater at HTF and the cross-flow factors used by DOE at HTF are provided in Appendix C.

[13]Eh is a measure of oxidation-reduction potential or electron activity (or concentration). Eh is measured in millivolts and varies from approximately −500 to +800 in natural environments. Many key radionuclides are less mobile or less soluble at lower values of Eh or what is referred to as “reducing conditions.” Solubility of many key radionuclides increases when Eh value rises (e.g., Pu solubility increases significantly when Eh rises above a value of around +0.5 volts in DOE’s solubility modeling (SRNL–STI–2012–00087 and SRNL–STI–2012–00404) or when the system becomes “oxidized”). Oxidation signals the transition from a chemical state that DOE refers to as Reduced Region II to a chemical state referred to as Oxidized Region II. For example, the transition from reduced to oxidized conditions is marked in Figure 3-5 by the vertically oriented, green dashed line.

[14]Measure of hydrogen ion activity (or concentration) or measure of acidity. The pH is a unitless number calculated as the negative of the log of the hydrogen ion concentration that is measured in mol/L. The pH of the Upper Three Runs aquifer at SRS ranges from 5.2 to 7.7 (ML073510127). Undegraded cementitious materials tend to increase pH to values as high as 12.5. In DOE’s reference (or best estimate) case, a decrease in pH to approximately nine generally leads to a chemical transition from what DOE refers to as Oxidized Region II to Oxidized Region III. The effect of this pH transition on radionuclide solubility limits (i.e., increasing versus decreasing solubility limits) depends on the radionuclide. The Eh-based chemical transition discussed in the preceding footnote occurs prior to the pH-based chemical transition, with the two transitions delineating the three chemical states and a solubility specified for each key radionuclide and chemical state, which DOE assumes in its PAs.

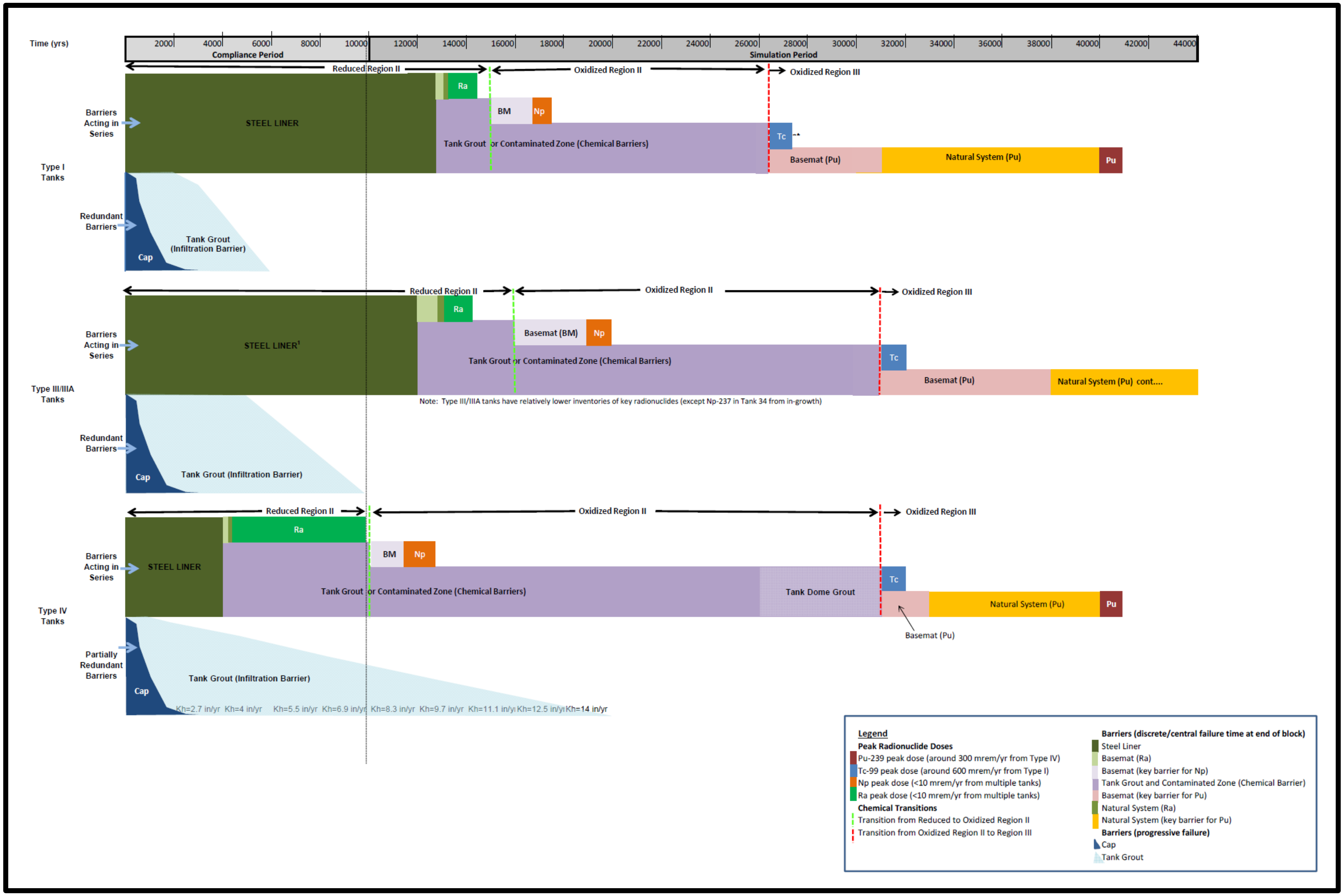

Figure 3-5. Barriers to Timing in the DOE's FTF Reference (or Best Estimate) Performance Assessment Case[15]

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[15]This figure is consistent with the results of the FTF PA (SRR–CWDA–2010–00128). DOE provided updated PA results in its special analyses for Tanks 18F and 19F (SRR–CWDA–2010–00124) and Tanks 5F and 6F (SRR–CWDA–2012-00106), which this figure may not reflect (e.g., updated geochemical modeling result which show that Pu could be released at high solubility significantly earlier in time upon transition to Oxidized Region II (see green vertical dashed lines), or it could remain in a relatively low solubility state into perpetuity, dependent on the assumed Eh in the contaminated zone; chemical transition times were also updated in the Tanks 18F and 19F Special Analysis and are estimated by DOE to be slightly prolonged (see Table 3-2)).

Table 3-2. Summary of Chemical Transition Times in the HTF and FTF PAs

Submergence of Tank	Transition	Number of Pore Volumes Required [CZ Transition Time (Year)]	
		HTF PA	**FTF PA**
Partially and Nonsubmerged	Reduced Region II to Oxidized Region II	523 (7,900 Type IV; 9,200 Type II NL; 15,000 Type II; 16,000 Type III)	371[†] (10,500 Type IV; 15,500 Type I; 15,500 Type III/IIIA)
	Oxidized Region II to Oxidized Region III	2,119 (19,000 Type II NL; 22,000 Type IV; 25,000 Type II; 28,000 Type III)	2,063[‡] (20,000 Type IV; 20,000 Type I; 20,000 Type III/IIIA)[§]
Submerged	Reduced Region II to Oxidized Region II (Condition C to D)	1,787 (7,700 Type I NL; 12,000 Type I)	NA
	Oxidized Region II to Oxidized Region III (Condition D to Oxidized Region III)	2,442 (8,100 Type I NL; 12,000 Type I)	NA

Notes:

[†]Transition to Oxidized Region II occurs at 371 DPV in original FTF PA (SRR–CWDA–2010–00128) but changed to 523 DPV in the Tanks 18 and 19 Special Analysis (SRR–CWDA–2010–00124), consistent with what was later used in the HTF PA.

[‡]Transition to Oxidized Region III occurs at 2,063 DPV in original FTF PA (SRR–CWDA–2010–00128) but changed to 2,119 DPV in Tanks 18 and 19 Special Analysis (SRR–CWDA–2010–00124), consistent with what was later used in the HTF PA.

[§]Although the calculated chemical transition time based on the displaced pore volume count would occur after 20,000 years, the final chemical transition was assumed to occur at 20,000 years, because most of the simulations ended prior to the transition from Oxidized Region II to Oxidized Region III. DOE did provide results to 100,000 years in one simulation.

NL=no liner, HTF = H-Area Tank Farm, FTF = F-Area Tank Farm, CZ = Contaminated Zone, PA = Performance Assessment

NRC Monitoring Under MA 2, "Waste Release"

As listed in Appendix A and documented in more detail in NRC's TERs (ML112371751, ML14094A496), NRC will consider the following MF related to waste release that is considered important to meeting the 10 CFR 61.41 PO:

MF 2.1 "Solubility-Limiting Phases/Limits and Validation"

Due to DOE's reliance on timing of peak dose to demonstrate compliance, NRC staff also will monitor the following factor, which may be important to DOE's demonstration of compliance with the 10 CFR 61.41 PO:

MF 2.2 "Chemical Transition Times"

Additional discussion regarding NRC's MFs related to waste release is available in Appendix C.

3.2.1 Monitoring Factor 2.1: Solubility-Limiting Phases/Limits and Validation

Given its importance to the timing and magnitude of peak dose, in its TERs, NRC staff recommended DOE conduct waste release experiments to increase support for key modeling assumptions related to (i) chemical forms of key radionuclides in residual wastes and (ii) expected solubility of key radionuclides under a range of environmental or service conditions that the contaminated zone is expected to be exposed to over time. DOE has provided additional support for several waste release assumptions because the NRC staff first recommended a need for increased support for key modeling assumptions. This included (i) convening a Pu solubility peer review that provided expert technical advice related to residual Pu in Tank 18F (LA–UR–12–00079), (ii) conducting spectroscopic analyses of residual waste samples from Tank 18F (SRNL–L3100–2012–00017), (iii) conducting updated geochemical modeling of Pu in Tank 18F using the Nuclear Energy Agency thermodynamic database (SRNL–STI–2012–00087), and (iv) expanding the updated geochemical modeling to include additional radionuclides and effects of oxalic acid in the HTF PA (SRR–CWDA–2010–00128). However the additional model support has not obviated the need for experimental support for modeled waste release.

NRC continues to recommend that DOE design and perform waste release experiments using actual tank residual samples as soon as practical. DOE staff should continue to discuss its plans with NRC to ensure experiments are designed to optimize their potential usefulness in supporting the 10 CFR 61.41 compliance demonstrations. This monitoring activity is considered to be the highest priority by NRC staff at this time from both a timing and importance perspective. Furthermore, as indicated in Table 3-1, NRC staff thinks that in addition to being one of the most important barriers in the PAs, determining the solubility of Tc, Pu, Np, and other key radionuclides is expected to be one of the more tractable key technical issues.[16]

To address NRC staff's MF related to the need for waste release experiments, DOE developed

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[16]Following issuance of NRC staff's FTF TER, DOE convened a Pu peer review group to evaluate the need for solubility experiments. LA–UR–2012–00079 concurred with NRC staff's recommendations in this area and concluded the following: "To provide a stronger scientific foundation to justify the use of geochemical modeling in the tank closure performance assessment, validation and verification of the model and assumptions is required. This involves both solid phase characterization of the residual wastes (as described previously) and leachability testing."

a technical task and quality assurance plan to perform waste release experiments using Tank 18F residuals (SRNL–RP–2013–00203). Preliminary testing results were presented at the March 2014 onsite observation (ML14106A573). NRC staff encourages DOE to continue the work that was initiated in FY2014 with respect to obtaining support for the assumed solubility limits of key radionuclides in tank farm waste. Pending results of the waste release experiments, NRC will evaluate the need for additional experiments for other tank waste.

Given its importance to risk and overall tank closure, NRC supports DOE's efforts to obtain support for the assumed Np-237 solubility (SRNL–RP–2013–00203). Although NRC staff generally found DOE's assumed Np-237 solubilities reasonable in the FTF PA, updated geochemical modeling performed to support the HTF PA indicates that Np solubility is fairly uncertain as it appears to be very sensitive to Eh over a range of Eh that may be encountered in the field.[17] Further, DOE has not provided sufficient support for the assumed level of performance of the basemats in its PAs. Experimental support for the assumed solubility limits could alleviate the burden of providing additional support for other Np-237 barriers, such as the vault basemats. Table 3-1 shows the importance of the basemat in meeting the 10 CFR 61.41 PO for FTF.[18] If the basemat does not perform as well as assumed in DOE's reference of "best estimate" case, data on solubility control may assist in demonstrating that POs can be met.

For tanks that have not been cleaned, DOE should consider the effects of reagents (e.g., oxalic acid) used to remove radionuclides from the tank residue, including formation of new compounds that may alter leachability of key radionuclides. Execution of this monitoring activity may be contingent on results of other analyses. For example, final estimated Tc-99 inventories in Type I tanks, as described in Section 3.1, may determine the need for Tc-99 waste release experiments. Final Tc-99 inventories estimated for Tanks 5F and 6F were significantly lower than assumed in the FTF PA, alleviating the need for waste release experiments to support the assumed low solubility of Tc-99 for those tanks.

This MF can be closed once DOE provides experimental support for the assumed solubilities of key radionuclides relied on for performance. The results of near-term waste release experiments may inform the extent to which additional recommendations made in NRC's TERs (ML112371751, ML14094A496) would need to be implemented by DOE. Should the results of the experiments indicate less than favorable performance, NRC staff expects DOE to assess the impact of the results on the PAs. NRC staff also will assess the need for additional experiments, data collection, and modeling to provide support for key barriers in DOE's PAs that might serve to mitigate underperformance of chemical barriers. If the results of the experiments show that key radionuclides are strongly retained in the residual waste, NRC staff expects that in addition to this MF, other MAs or MA components will become less important and can be closed.

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[17]In the HTF TER (ML14094A496), NRC staff note that the solubility limit for Np is sensitive to Eh in Oxidized Region III; however, the Eh transition occurs from Reduced Region II to Oxidized Region II and is assumed to remain stable from Oxidized Region II to Oxidized Region III. Figure 24 in SRNL–STI–2012–00404 shows Np solubility is highly sensitive to Eh over a relevant range of Eh/pH that may be encountered in the field, which includes both Oxidized Region II and Oxidized Region III conditions calculated and for which solubility limits are derived in the PA modeling.

[18]In the FTF PA, the basemats were shown to be an important barrier in attenuating the releases of key radionuclides (e.g., Pu, Np). Although solubility control may be more important for Pu and Np in the HTF PA compared to the FTF PA, the NRC staff also expects the basemats to be important in the HTF PA.

3.2.2 Monitoring Factor 2.2: Chemical Transition Times

In some cases, DOE relies on barriers that delay the timing of peak dose to demonstrate compliance with the POs in 10 CFR 61.41; therefore, PA assumptions regarding the timing of transition of key radionuclides to higher solubility phases can be important to the compliance demonstrations. DOE relies on geochemical modeling to estimate the time at which two key chemical transitions take place: (i) the transition from reduced to oxidized conditions reflected in an increase in Eh (e.g., see bright green, vertically oriented dashed lines in Figure 3-5 and time of transition from Reduced Region II to Oxidized Region II in Table 3-2) and (ii) the transition from a relatively high to a relatively low pH (see red, vertically oriented dashed lines in Figure 3-5 and time of transition from Oxidized Region II to Oxidized Region III in Table 3-2) as the cementitious materials continue to degrade over time. In its TERs (ML112371751, ML14094A496), NRC staff discussed concerns with the geochemical modeling results, which may be attributable to assumptions such as (i) the characteristics of the infiltrating groundwater, including the chemistry of the saturated groundwater assumed to impact the chemistry in the contaminated zone for submerged, Type I tanks at HTF; (ii) the solid phases that comprise the tank grout; (iii) uncertainties in the thermodynamic data used in the modeling; or (iv) assumptions regarding the ability of grout components to react with and condition infiltrating groundwater and the residual waste.

As part of this MF, NRC staff also will evaluate the efficacy of DOE's use of two chemical transitions, three chemical states, and no more than three solubilities for each key radionuclide with solubility changes assumed in DOE's PAs to occur at the same time for each key radionuclide for a given tank type. It may be more reasonable to assume that solubility of each key radionuclide has a unique sensitivity to Eh and pH, making it difficult to make generalizations about the manner in which solubility changes over time. This assumption is important because the timing of transition to higher solubility and releases, if they occur, may be critical to DOE's compliance demonstration, as indicated previously. The adequacy of DOE's approach to modeling solubility changes will be evaluated through NRC review of the literature, DOE-generated geochemical modeling, or independent geochemical modeling.

NRC staff also may observe DOE experiments related to this MF in conjunction with an onsite observation at the FTF or HTF. This MF can be closed when (i) DOE shows that chemical transition times are no longer important to its compliance demonstration (i.e., predicted dose is less than the dose standards for all time) or (ii) DOE provides adequate experimental support for its assumptions regarding chemical transition times.

Closure of the Group of Monitoring Factors Related to MA 2, "Waste Release"

The MF regarding chemical transition times can be closed when DOE completes experiments to study the evolution of pH and Eh in the tank grout over time to provide additional support for its estimates of chemical transition times to higher solubility chemical conditions. Alternatively, this MF can be closed if DOE can provide (i) support that the highest solubility for each key radionuclide developed under MF 2.1, under any relevant geochemical condition, will not lead to an exceedance of the 10 CFR 61.41 and 10 CFR 61.42 PO (i.e., DOE does not rely on timing of the peak dose to demonstrate compliance) or (ii) adequate support for other barriers relied on to delay the timing or reduce the magnitude of peak dose for key radionuclides is generated to demonstrate compliance.

Depending on the results of initial waste release experiments and other factors (e.g., continued confirmation of the relatively low risk significance of final estimated inventories for Tc-99), the factors in this MA can be closed in the short term following waste release experiments. Likewise, if closed, NRC could reopen the MFs in this MA as additional information is obtained on expected final tank inventories or the performance of other important barriers.

3.3 MA 3, "Cementitious Material Performance"

Importance of MA 3, "Cementitious Material Performance"

As illustrated in Figure 3-5 (see dark green barrier) and steel liner failure times listed in Table 3-3 for FTF and HTF tanks, the steel liners (or tanks) often serve as an important barrier significantly delaying the timing of releases from tank farm tanks for thousands to tens of thousands of years. In the case of Types I, II and III/IIIA tanks with initially intact liners,[19] DOE assumes the tanks do not fail until after the 10,000-year compliance period in the reference case. The longevity of the steel liners is directly related to PA assumptions regarding the capability of the concrete vaults, which house the steel liners, to provide an effective barrier to fluid flow, thereby minimizing the transport of corrosive agents such as chloride, oxygen, and carbon dioxide through the concrete or to the surface of the steel liners. Additionally, NRC staff considers assumptions regarding the hydraulic performance of the concrete vaults with respect to their ability to mitigate groundwater inleakage an important component of DOE's compliance demonstration. Type IV tanks at FTF are particularly susceptible to early corrosion due to the fact that the tanks (i) have a thin layer of concrete applied using a technique known as Shotcrete, (ii) do not have an annulus between the Shotcrete and liner, (iii) do not have a tank top, (iv) have bottoms located in close proximity to the water table, (v) have experienced groundwater in-leakage in the past, and (vi) have the thinnest steel liners. Although Type IV tanks at HTF are not located in the zone of water table fluctuation, these tanks are also expected to be susceptible to corrosion for the reasons stated previously.

Table 3-3. Summary of Steel Liner Failure Times in the HTF and FTF PAs

	HTF (Years)	FTF (Years)
Type I	11,397*	12,747
Type II	12,687†	N/A
Type III/IIIA	12,751	12,751
Type IV	3,638	3,638

*Tank 12H is initially failed in HTF PA
†Tanks 14H, 15H, and 16H are initially failed in HTF PA

HTF = H-Area Tank Farm, FTF = F-Area Tank Farm, PAs = Performance Assessments

While all Types I and II tanks at HTF are assumed to contain an inventory in the annulus of the tank vaults due to leakage from the primary liner, Tanks 9H, 10H, 14H, and 16H are assumed to have a more risk-significant inventory in the annulus (12.5 m^3 of residual waste compared to 0.4 m^3 of waste in other Types I and II tanks). The waste in Type I and II tanks at HTF is assumed to be located in the annulus grout in Type I tanks that do not have sand pads, and in

[19] DOE assumes Type I Tank 12H and Type II Tanks 14H, 15H, and 16H are initially failed at HTF.

the sand pads of Type II tanks. As discussed in the HTF TER, DOE may not have adequately assessed the risk of release of the annular inventory in Types I and II tanks at HTF through preferential pathways. DOE attempted to address NRC staff's HTF TER comments related to annular waste release in the Tank 16H Special Analysis. NRC staff will evaluate DOE's efforts to consider the risk of annular waste releases, including the presence of preferential pathways through the tank vaults, annulus, and sand pads.

As discussed in MA 2, "Waste Release," in some cases, DOE relies on the timing of peak dose occurring after the 10,000-year compliance period to meet the 10 CFR 61.41 PO.[20] Therefore, barriers that delay the timing of peak dose may be important to DOE's compliance demonstration for the FTF. In the HTF PA, DOE assumes Tc and Pu are never released at risk-significant solubilities in their reference case. However, in alternative cases, risk-significant releases of Tc and Pu at higher assumed solubilities have been shown to lead to exceedances of the POs. The reducing tank grout and contaminated zone chemical barriers (represented by a single purple barrier in Figure 3-5 and the transition time listed in Table 3-2) are two of the most effective barriers in DOE's FTF PA in delaying the timing of the peak dose. Chemical transition times are directly dependent on the nature of water flow through the grouted tanks and on the likelihood and frequency of tank flooding due to water table rise. For example, NRC staff has technical concerns related to the potential for (i) groundwater to bypass or have minimal contact with the reducing tank grout as a result of flow via preferential pathways such as cracks or shrinkage gaps and (ii) water table rise above the tank bottoms.[21] NRC staff is concerned because these scenarios could lead to a situation where relatively oxidized and acidic groundwater has minimal contact with the tank grout that DOE's PA assumes will condition the groundwater to higher pH and lower Eh, thereby maintaining the low solubility of key radionuclides in the contaminated zone. If the infiltrating groundwater is not well conditioned, key radionuclides may have higher solubility and be released at significantly higher concentrations much earlier in time. In fact, the peer review group tasked by DOE to review DOE's Pu solubility modeling indicated that flow through cracks in the grout should be expected (LA–UR–2012–00079). Therefore, NRC staff will monitor DOE's PA assumptions related to the nature of water flow into the contaminated zone, including assumptions regarding the extent to which in-tank water is conditioned by the tank grout, the timing of chemical transitions, and the magnitude of key radionuclide releases and dose.

Additionally, because preferential flow through the tank grout is a strong function of the extent to which tank grout shrinks and cracks, NRC staff also will monitor DOE's PA assumptions regarding shrinkage and cracking. Specifically, NRC staff will monitor DOE's efforts to minimize tank grout shrinkage through additional shrinkage compensating admixtures. Shrinkage of grout away from tank walls and intratank components may lead to formation of preferential flow pathways. The Center for Nuclear Waste Regulatory Analyses (CNWRA®) staff, who have developed and tested physical analog models of NDAA-type grout monoliths, have observed

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[20]Type I tanks and Tank 18F are the sources of exceedance of the 10 CFR 61.41 standard in DOE's FTF PA over longer periods of compliance (beyond 10,000 years). DOE thinks the Type I tank inventories of Tc-99 that led to the exceedance were overestimated in the FTF PA; based on the final inventories developed for Tanks 5F and 6F, this appears to be supported. Updated special analyses show the peak dose from Tank 18F may be above or below the 0.25 mSv/yr [25 mrem/yr] dose standard, depending most significantly on assumed solubility of Pu-239. Additional information is needed to support the updated best-estimate solubility listed in DOE's Tank 18F and 19F Special Analysis, as indicated in NRC staff's waste release technical review report (ML12272A082).
[21]Water table rise is especially important for Type IV FTF tanks, which have bottoms located at or near the water table, and for FTF Type I tanks (SRNL–STI–2012–00079). At HTF, Type II tanks are partially submerged in the saturated zone and tank waste can be in the zone of water table fluctuation.

shrinkage between grout lifts and flow lobes[22] with both horizontally and vertically oriented, imperfectly bonded seams that form at their interfaces when placing relatively viscous formulations that tend to form lobes (Figure 3-6), enhancing preferential flow through the grout monolith. Although the CNWRA experiments may not be completely analogous to SRS tank conditions[23] (e.g., differences in final formulations and difficulty in exactly replicating curing conditions), significant effort was made to mimic actual conditions. Important insights can be gained from these experiments that may be applicable to NDAA tank closure.

Because temperature rise and gradients that form due to grout curing can lead to thermal cracking, NRC staff will monitor DOE's assessment and, as applicable, plans to reduce the potential for thermal cracking. NRC staff will also monitor other tank farm design features to minimize adverse conditions, such as Alkali-Silica Reaction (ASR) that results in dissolution of silica phases and cracking due to alkali-silicate gel formation and expansion. The risk of ASR-based dissolution and cracking increases in the presence of cement or externally introduced alkalis, amorphous silica phases of certain concrete aggregates, and moisture. Although the final formulation has a relatively low cement content compared to other concretes used in construction applications, DOE's final formulation uses an aggregate potentially susceptible to ASR. Current standards calling for short-term testing (16 day tests) may not be sufficiently robust to evaluate the potential for long-term degradation associated with ASR. Finally, NRC staff will monitor tank farm design features to minimize cracking of the tank grout due to differential settlement. Differential settlement may occur due to loading stresses imposed by the weight of the closure cap and may be enhanced by dissolution of calcareous zone materials at depth and subsequent collapse of overlying materials (see Chapter 6).

Because the DOE PAs made a number of assumptions regarding the chemical and hydraulic properties of the as-emplaced grout used to fill the tanks and vault annuli, NRC will monitor DOE's efforts to develop and test grout formulations that will meet PA requirements. Additionally, NRC staff will monitor DOE's efforts to deliver a high-quality grout from design to placement in the field that performs as well as DOE assumed in its PAs.

After releases occur through the steel liners, the tank basemats are estimated by DOE's PAs to serve as an important barrier for many key radionuclides. In fact, in some cases, the tank basemats can work alone to mitigate releases and compensate for other failures such as solubility control (i.e., barriers can act in isolation to mitigate releases from the tanks when all other engineered barriers have failed). For instance, the basemats may serve as the most effective barrier in the FTF PA after long periods of time when the closure cap, steel liner, and tank grout have all failed as hydraulic barriers and key radionuclide solubility limits are at their highest levels (Oxidized Region III). Likewise, HTF PA sensitivity cases suggest that the basemats provide significant retention of key radionuclides (e.g., Np) in cases with higher solubilities than assumed in the base case. However, anecdotal and other evidence discussed

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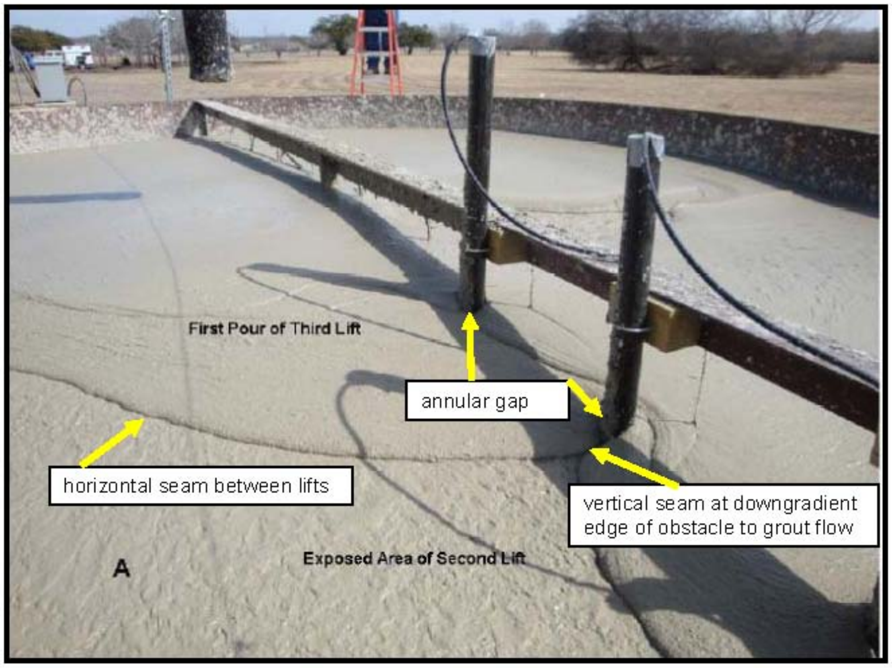
[22]A grout flow lobe is a fan-shaped mass of grout that forms on a slope by the changing direction of flow.
[23]DOE has raised concerns with differences in climate between San Antonio, Texas, and SRS. It is important to note that Dinwiddie, et al. (2012b) concluded that "the climate of San Antonio, Texas, is similar to that of the SRS, South Carolina, in terms of temperature and humidity, but has lower mean annual precipitation. Like the SRS, San Antonio is subject to extreme precipitation events associated with tropical storms and the remnants of hurricanes." Dinwiddie, et al. (2012b) concluded that San Antonio, Texas, would serve as a good analog to SRS for engineered cover testing with respect to average climate conditions.



Panel A

Panel B

Figure 3-6. Tank Grout Features Important to Performance: Panel A Is a Close-In View of Grout Seams and Gaps (Dinwiddie, et. al., 2012a, Figure 3-8) and Panel B Is an Example of Grout Lobes From FTF Tank 18F Grouting (Photo Taken During June 12, 2012, Onsite Observation)

previously suggests that preferential flow pathways may be present in the tank vaults and that these pathways may have a significant impact on contaminant flow and transport.

For example, in 1960, waste that leaked from HTF Tank 16H is thought to have breached the concrete vault and entered the surrounding soil (DPSPU–77–11–17). Tank documentation suggests that groundwater has historically intruded into tank vaults (DPSPU–82–10–11, SRR–ESH–2013–00078). Therefore, NRC staff is concerned that assumptions regarding the ability of the concrete vaults to reduce radionuclide releases from the tanks are overly optimistic. For these reasons, NRC staff will monitor assumed basemat performance for key radionuclides such as Pu and Np.

Finally, the vault, sand pads, and annular grout can be a significant barrier to waste release in tanks with waste located outside of primary containment. Although release of waste from the annuli of these tanks is not assumed to be solubility controlled, NRC staff noted potential issues with the modeling treatment of the waste located in the annulus of Types I and II tanks. NRC staff will monitor cementitious material sorption to verify that the assumed level of performance in the PAs will be achieved in the field following closure.

NRC Monitoring Under MA 3, "Cementitious Material Performance"

As listed in Appendix A and documented in more detail in NRC's TERs (ML112371751, ML14094A496),[24] NRC staff will consider the following MFs related to cementitious material performance that are considered important to meeting the 10 CFR 61.41 PO:

- MF 3.1 "Hydraulic Performance of Concrete Vault and Annulus (As It Relates to Steel Liner Corrosion and Waste Release)"
- MF 3.2 "Groundwater Conditioning via Reducing Grout"
- MF 3.3 "Shrinkage and Cracking of Reducing Grout"
- MF 3.4 "Grout Performance"
- MF 3.5 "Vault and Annulus Sorption"
- MF 3.6 "Waste Stabilization (As It Impacts ALARA)"

More detailed discussion regarding NRC's concerns related to some of the aforementioned MFs is available in Appendix D.

3.3.1 Monitoring Factor 3.1: Hydraulic Performance of Concrete Vault and Annulus (As It Relates to Steel Liner Corrosion and Waste Release)

DOE assumes the grouted[25] concrete vaults that house the HLW tanks act as hydraulic barriers to fluid flow and provide a relatively passive environment for the steel liners or tanks, significantly limiting tank corrosion following closure. In some cases (for some Types I and II and for all Type III tanks[26]), DOE assumes steel liners are a barrier to fluid flow and prevent significant releases from the tanks for over 10,000 years. DOE also assumes the concrete

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[24]Monitoring factors related to cementitious material performance are described in NRC staff's TERs (ML112371751, ML14094A496) except for MF 3.3 related to tank grout design measures to minimize shrinkage and cracking. Mitigation of cracking is important to minimizing the occurrence of preferential flow pathways through the tank system, which is discussed in detail in NRC staff's TERs.
[25]Type IV tanks have no annulus and, therefore, do not require grout outside of the primary liner.
[26]DOE assumes Type I Tank 12H, and Type II Tanks 14H, 15H, and 16H, are initially failed at HTF.

vaults will limit releases of radioactivity from the annuli of Types I and II HTF tanks with annular contamination. However, observations of cracking and groundwater in-leakage and previous release from Tank 16H[27] into the environment suggest a limited ability of the vault concrete to either act as a fully effective and uniform barrier to the transport of species controlling steel corrosion over the vault's lifetime or to mitigate the releases of radioactivity from the annulus.

In its HTF TER (ML14094A496), NRC staff also questioned DOE's assumption of low corrosion rates because the oxidation and reduction reactions that control corrosion could be macroscopically separated. Metal locations where oxygen reduction occurs can be physically separated from locations where iron is oxidized and dissolved if the two locations are electrically connected. In other words, limited supply and transport of oxygen to the liner surface may not necessarily limit corrosion rates.

Therefore, NRC staff will review reports, analog studies, and other information used to support DOE's assumption regarding initial conditions and performance of the concrete vaults to protect the steel liner and limit releases of radioactivity from the annulus. For example, NRC staff will review annual tank inspection reports that provide information regarding trenching, scarifying, and cracking of the concrete vaults, as well as information about groundwater intrusion into the tank vaults. NRC staff will review reports related to previous events that led to potential releases or groundwater in-leakage through joints or cracks in the concrete vaults. Analog studies could include review and evaluation of information obtained from West Valley or other analog sites to better understand the potential for and rates of corrosion of HLW tanks/components, as well as mitigative design measures. As part of this MF, NRC staff also will consider the potential for earlier steel liner failure than assumed in DOE's PA due to corrosion of steel components (e.g., rebar) in the concrete vaults that are close to the vault surface or that may be physically separated but electrically connected.

If DOE performs additional modeling or experiments to study the potential for transport of deleterious species into the tank vaults or the separation of iron dissolution and oxygen reduction and subsequent corrosion of steel liners or tanks, NRC staff will review the documentation or provide input on the design and results of the experiments. Experiments to study steel liner corrosion are expected to be relatively difficult to implement with unknown benefit compared to other experimental investigations recommended in NRC's TERs and discussed in this monitoring plan. Therefore, NRC staff does not consider these experiments to be a high priority at this time. Until such time that DOE provides additional support for the estimated lifetimes of the steel liners, NRC staff (i) will assume steel liners will not be effective at mitigating releases for the long time periods DOE relies on the steel liners for performance in the tank farm PAs and (ii) will investigate the support for the performance of other barriers to ensure POs can be met until such support for steel liner performance is provided. Should results of other investigations indicate other barriers that DOE relies on in its reference (or best estimate) PA cases are not expected to perform as well as assumed, additional thought can be given to methods that may be used to provide additional support for steel liner performance assumptions.

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[27]See WSRC–TR–93–761, WSRC–STI–2009–00352, SRR–STI–2010–00283, DOE/SRS–WD–2013–001, SRNS–STI–2008–00096, and SRR–CWDA–2010–00128 for groundwater in-leakage observations. See DP-1358 for waste release from Tank 16H annulus into the environment.

3.3.2 Monitoring Factor 3.2: Groundwater Conditioning via Reducing Grout

As stated previously, DOE assumes that groundwater infiltrating from above is able to flow through every pore space of the grout monolith, rather than coming into contact with a relatively small volume of potentially armored[28] tank grout along crack or fracture faces. Reactions between the infiltrating groundwater and tank grout cause the pH to increase from approximately 5 to 12 and the Eh to decrease from as high as +500 mV to as low as −600 mV. Conditioning the groundwater contacting the waste to high pH and low Eh is important to maintaining low solubility, concentrations, and dose, because the chemistry of the groundwater dictates the solubility limits assigned to key radionuclides in the contaminated zone in DOE's reference PA cases. If the infiltrating groundwater that has a drastically different chemistry than DOE assumed in the PAs is able to contact the radioactivity in the contaminated zone, then concentrations leached from the tanks could be significantly higher than predicted much earlier in time.

For Type I tanks at HTF, which are fully submerged, DOE assumes that a fraction of the groundwater contacting the waste will be conditioned by the reducing grout, which can still provide a significant chemical barrier to release. Some FTF and HTF tank bottoms[29] are located in the zone of water table fluctuation, and water table rise could result in unconditioned groundwater contacting the waste zone at the bottom of the tanks. The potential for groundwater to contact the residual waste in these tanks without contacting reducing grout calls into question whether groundwater contacting the waste will be conditioned by the reducing grout to a significant degree.

Because groundwater table rise and preferential flow through the tank grout may lead to higher solubilities and releases from the tanks, NRC staff will monitor DOE experiments to study the potential for groundwater flow through cracks that may form in the tank grout (the potential for cracking is addressed in MF 3.3). If DOE cannot rule out bypass flow through the tank grout under MF 3.3 or water table rise above the bottom of FTF tanks under this MF, then it will be important for DOE to demonstrate the extent to which groundwater is conditioned when flow is primarily through preferential pathways through the tank grout. Although DOE assumes little to no conditioning in Configuration[30] G, a tank grout bypass scenario evaluated for the FTF in response to NRC RAIs,[31] the dose prediction in Configuration G exceeded the 10 CFR 61.41 PO within the 10,000-year compliance period. Although DOE assumes the likelihood of Configuration G is low, NRC staff thinks the likelihood of this scenario may be underestimated. Likewise, DOE's sensitivity analyses of the impact of varying the grout transition time and the number of pore volumes required for chemical transition indicate that the PO could be exceeded within 10,000 years if the water contacting the waste is not conditioned by the overlying grout

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[28]Armoring may occur through precipitation of calcium carbonate on fracture and crack faces through a concrete degradation process referred to as carbonation. Armoring may preclude interaction of infiltrating groundwater with tank grout components interior to fracture faces that serve to condition the groundwater and maintain low solubilities or concentrations of key radionuclides.
[29]Water table rise is especially important for Type IV FTF tanks, which have bottoms located at or near the water table and for FTF Type I tanks (SRNL–STI–2012–00079). Type II tank bottoms at HTF are also located within the zone of water table fluctuation (SRNL-STI-2010-00148).
[30]The term "configuration" is used in DOE's PA to describe various scenarios that are generally run to evaluate differences in waste release model and parameter assumptions.
[31]Configuration G is evaluated in DOE RAI responses (SRR–CWDA–2009–00054) and discussed in more detail in NRC staff's FTF TER (ML112371751).

(as in Case E of the HTF PA). Therefore, more credit for groundwater conditioning may be needed in alternative flow scenarios to demonstrate compliance with the PO.

NRC staff will monitor DOE experiments or perform its own independent experiments to better understand the nature of flow through the tank grout as it impacts the extent to which infiltrating groundwater interacts with and is conditioned by the tank grout (this factor is closely related to MF 2.2).[32] If NRC staff concludes that bypass flow through preferential pathways in the tank grout is significant, DOE should implement an alternative conceptual model consistent with preferential flow through the tank grout to compute chemical transition times.

NRC staff also will review information regarding water table rise to evaluate the likelihood of this alternative conceptual model for waste release. Based on the results of the water table rise investigation, an alternative conceptual model may be proposed for a subset of tanks to assess the impact on the compliance demonstration. Specifically, NRC staff will review historical water table elevation data for wells to assess the likelihood of water table rise above the bottom of the tanks. NRC staff also will review design and construction of any DOE mitigation measures used to ensure that the water table remains below the bottom of the tanks. The water table is most likely to rise above FTF Type IV tank bottoms, followed by FTF Type I tank bottoms because of the lower elevations at which these tanks were constructed (SRNL–STI–2012–00079). Type II tank bottoms at HTF are also located within the zone of water table fluctuation (SRNL-STI-2010-00148).

In the case where flow is primarily through preferential pathways, such as shrinkage gaps and cracks, DOE should design experiments to provide information on the expected level of groundwater conditioning for this type of flow. DOE has designed and constructed a lysimeter field experiment at the SRS to study the mobility of various radionuclides in a saltstone waste form. This experiment could be leveraged to study the potential for groundwater conditioning for what is expected to be a relatively impermeable cementitious waste form. If infiltrating groundwater is not conditioned, DOE could design and construct column experiments with cracked tank grout to study the extent to which groundwater may be conditioned by the tank grout under what is currently considered a more realistic scenario by NRC staff.
Under contract with the NRC, CNWRA is conducting experiments to study the extent of groundwater conditioning when flow is primarily through preferential pathways or through a cracked grout specimen. The objectives of these experiments are to understand the extent to which infiltrating water chemistry (primarily pH and Eh) is modified by contact with the tank grout and how the tank grout buffering capacities for pH and Eh may change with contact to infiltrating water. Documentation of results of these experiments are expected in CY2015.

NRC will also review documentation provided by DOE to support assumptions regarding the extent of groundwater conditioning for as-emplaced tank grout. NRC staff may conduct the technical review activities in conjunction with an onsite observation to observe any laboratory or field experiments in this area. If results of waste release experiments conducted under MF 2.1 show key radionuclides in waste residuals have sufficiently low solubility when in contact with unconditioned SRS groundwaters, MF 3.2 related to the extent of conditioning (and 2.2 related

[32]The difference between MF 2.2 and MF 3.2 is that MF 2.2 focuses on the actual geochemical reactions that are occurring between groundwater and tank grout components that determine how the chemistry of the groundwater changes over time, whereas MF 3.2 assesses the nature of flow through the tank grout. In other words, MF 2.2 is focused on the chemical aspects of how groundwater and tank grout components interact, while MF 3.2 is focused on the extent to which groundwater physically interacts with (i.e., flows through) the tank grout.

to the longevity of conditioning) will no longer be needed by DOE to support the compliance demonstration and can be closed. If MF 2.1 results indicate unconditioned flow may lead to unacceptably high doses, then this MF will need to be evaluated by NRC and can be closed after DOE (i) shows matrix flow through the grout will dominate waste release or (ii) provides information to support assumptions regarding the level of groundwater conditioning for degraded (cracked) grout.

3.3.3 Monitoring Factor 3.3: Shrinkage and Cracking of Reducing Grout

As discussed, there are many mechanisms that could lead to cracking or creation of void space in the tank and vault grout, which increases the likelihood of early, risk-significant releases and doses from the tanks or annuli,[33] including the following:

- Steel component corrosion
- Shrinkage gap development and poor grout-bond quality
- Thermal cracking
- ASR
- Differential settlement and related cracking

DOE should consider design measures to minimize the occurrence of negative features, events, or processes that may promote shrinkage or cracking. For example, DOE should consider removal of in-tank equipment that could lead to development of shrinkage-induced annuli around equipment or corrosion of steel components and associated cracking due to corrosion product expansion. DOE also should promote the ability of the grout to fill all void spaces (e.g., grout should be self-leveling) to minimize imperfectly bonded grout seams and voids that may form in between grout pours. DOE should research and evaluate shrinkage compensating agents for use in its grout formulations to minimize shrinkage, shrinkage gap formation, and creation of annuli and void space within the grout. DOE should ensure temperature gradients are sufficiently low to prevent excessive thermal cracking. Calculations could be conducted to evaluate potential thermal gradients and/or instrumentation could be used to evaluate as-emplaced thermal evolution of the grout. Finally, DOE should ensure the grout is designed to consider the potential for cracking due to differential settlement (see Chapter 6 on site stability for more detailed discussion). It may also be useful for DOE to research and deploy methods of detecting early crack development in reducing grout used to fill tanks and vaults (e.g., through use of devices such as acoustic sensors). For instance, under contract with the NRC, CNWRA is conducting an acoustic emission feasibility study on small scale tank grout samples to develop an approach to passively monitor larger scale monoliths for cracking events during the curing process. The primary objective of this study is to develop an acoustic emissions monitoring technique to locate and timestamp cracking events within a curing grout monolith using commercially available acoustic emissions equipment. Results of this feasibility study are expected to be documented in CY2015.

NRC staff will review grout formulations, calculations, research, test methods, and results to ensure the disposal facility is designed to minimize fast flow path development. NRC staff may conduct technical reviews in conjunction with onsite observations that could include such

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[33]Types I and II tanks at HTF contain residual waste in the annulus between the primary and secondary tank liners.

activities as video inspections of grout pours, observations of grout tests, and inspection of test specimens.

It is important to note the intended low matrix hydraulic conductivity of the grout monolith may accentuate fast crack or bypass flow through the system because the grout matrix is expected to be quite impermeable to water flow,[34] particularly for Type IV tanks that do not have cooling coils and are assumed, therefore, to degrade more slowly than grout in tanks containing internal fixtures. If it becomes clear that (i) it will be difficult to prevent preferential pathways from forming in the system, (ii) these preferential pathways may conduct a significant amount of unconditioned water; and (iii) unconditioned releases may exceed the dose standard, then it might be useful for DOE to explore methods under MF 3.2 to enhance contact of infiltrating water with the tank grout if such contact is shown to condition infiltrating groundwater and limit releases from the tanks and vaults to non-risk-significant levels.

MF 3.3 can be closed when DOE demonstrates (i) preferential fast flow into the waste zone of the tanks or through the waste in the annuli for Types I and II tanks at HTF will not occur or (ii) preferential fast flow into the waste zone of the tanks or through the annuli for Types I and II tanks at HTF will not adversely impact performance (e.g., the PO can be met under all chemical conditions as discussed in more detail under MA 2, “Waste Release”).

3.3.4 Monitoring Factor 3.4: Grout Performance

NRC will perform technical review activities related to DOE’s testing and development of grout formulations to meet design specifications. Additionally, NRC will monitor DOE’s efforts to deliver a grout mix of sufficient quality to meet performance assumptions in DOE’s PAs from design to as-emplaced conditions in the field. NRC staff will review relevant procedures and documentation related to such items as grout material procurement, production, testing, acceptance, and placement in tank farm components. NRC staff will perform technical review activities in conjunction with onsite observations. Onsite observations will include such activities as observations of grout material storage, tests, and acceptance of grout materials; live video streams of grouting operations; review of archived video footage; review of batch tickets for accepted and rejected loads; tour of the command center; and observation of mock-up tests or visual examination of test specimens. NRC staff can close this MF after it completes (i) review of DOE-generated grouting documentation and (ii) monitoring of grouting operations. If NRC identifies any issues, DOE must also adequately address the issues or provide plans to address the issues under another MF.

3.3.5 Monitoring Factor 3.5: Vault and Annulus Sorption

The concrete vaults and annulus grout are the last engineered defense against releases from SRS tanks and the annuli of tanks with a significant annular inventory (e.g., Types I and II tanks at HTF). In particular, the concrete basemats can be the most effective barrier, limiting peak releases and doses in DOE’s reference PA cases for some key radionuclides such as Np and Pu. Attenuation in the vault and annular grout may also be significant for some short-lived radionuclides such as Strontium (Sr) and Cesium (Cs) that are present in risk-significant

[34]The lower the hydraulic conductivity of the matrix, the more likely water will flow through cracks. A low permeability matrix may not be sufficiently conductive to transmit all of the incoming moisture. If the matrix cannot accommodate all of the moisture, then locally saturated conditions will exist and fracture flow is more likely to occur.

quantities in the annuli of the Types I and II tanks at HTF. Because the basemats are, in most cases, more than 50 years old and have supported the weight of the waste-filled HLW tanks for many years, the basemats may be chemically degraded and cracked. Additionally, tank vaults may contain features conducive to bypass flow (e.g., leak detection channels or construction joints). Because attenuation of Np and Pu in the basemat can be very important to the compliance demonstration and may be less than assumed in DOE's PAs in the case of flow through cracks or other preferential pathways or if sorption potential for these two constituents is overestimated, NRC staff will monitor DOE efforts to study basemat sorption for these two constituents. DOE should evaluate whether experiments used to develop basemat distribution coefficients (K_ds) for Pu and Np represented solubility rather than sorption and otherwise provide defensible basemat K_ds for key radionuclides that rely heavily on basemat sorption performance. DOE should also address the potential for degradation of the attenuating properties of the basemats over time (i.e., old, cracked concrete materials may be less sorptive than newer, uncracked concrete materials). NRC staff will review documentation and any analog studies that may provide additional information regarding the ability of the concrete basemats to attenuate release from the tanks or annuli of Types I and II tanks at HTF, including information regarding groundwater in-leakage and release from construction joints or other discrete features such as those implicated in the release from HTF Tank 16H.

This MF can be closed when (i) sufficient information is available to support assumptions regarding attenuation of key radionuclides (e.g., Pu, Np, Cs, Sr) in the basemats, vaults, or annular grout or (ii) DOE provides sufficient information to show that doses from key radionuclides will be below the dose limits prescribed in the POs with little to no performance from the concrete basemats and vaults and annular grout (e.g., solubility limits for unconditioned groundwater are sufficiently low or natural attenuation of key radionuclides is sufficiently high to compensate for underperformance of the concrete basemat and vaults and annular grout).

3.3.6 Monitoring Factor 3.6: Waste Stabilization (As It Impacts ALARA)

DOE considers tank and vault grouting consistent with ALARA criteria. In its final Waste Determinations (WD) (DOE/SRS–WD–2012–001 and DOE/SRS–WD–2014–001), DOE explains that residual material remaining in the waste tanks after key radionuclides have been removed to the maximum extent practical will be stabilized with reducing grout, a chemically reducing environment known to minimize the mobility of the contaminants after closure. DOE indicates that waste tank grout fill is designed to have a low matrix permeability to enhance its ability to limit the migration of contaminants after closure. DOE also indicates that waste tank concrete vaults serve to significantly retard water flow through the waste tanks. In addition, DOE will fill the waste tank liners and annular space between liner and vault, if applicable, with cementitious material to further limit the amount of water infiltration into the waste tanks.

Consistent with WIR guidance in NUREG–1854 (ML072360184), NRC staff will review use of stabilizing materials to determine whether DOE has made a reasonable effort to optimize mixing or encapsulating the waste with the stabilizing material. DOE should evaluate options to move or stabilize the waste present along the edge of the tanks that may present a relatively higher risk, including options to minimize shrinkage along the tank wall, if deemed ALARA. NRC staff will evaluate DOE's use of stabilizing materials to grout features of the tank and vault system that might otherwise lead to preferential flow through the engineered system and into the environment (e.g., grouting of leak detection channels and sumps contained within the concrete basemats).

NRC staff will conduct technical reviews and onsite observations under MFs 3.1 to 3.5, bearing in mind the additional function of the stabilizing grout to maintain doses ALARA. NRC staff can close MF 3.6 when MFs 3.1 through 3.5 are closed, and if NRC staff finds DOE's use of stabilizing cementitious materials consistent with ALARA criteria.

Closure of the Group of Monitoring Factors Related to MA 3, "Cementitious Material Performance"

MF 3.1 is contingent on the results of other studies. MFs 3.2 and 3.3 can be closed after DOE demonstrates that preferential pathways will not occur or will not significantly alter the compliance demonstration. MF 3.4 can be closed following grouting of the tanks. MF 3.5 can be closed when DOE demonstrates that vault materials can effectively immobilize key radionuclides such as Np and Pu that are released from the tanks or annuli, that solubility control is effective at reducing key radionuclide releases to non-risk-significant levels, or that natural system attenuation is sufficient to compensate for underperformance of the vault materials. MF 3.6 will be closed when MFs 3.1 through 3.5 are closed, if NRC staff finds stabilization operations consistent with ALARA criteria.

3.4 MA 4, "Natural System Performance"

Importance of MA 4, "Natural System Performance"

The hydrogeological system at the tank farms performs as a significant natural barrier, helping to attenuate key radionuclide releases from tanks to groundwater through such processes as dilution, dispersion, sorption,[35] and decay.[36] Natural attenuation can serve to (i) delay the timing of the peak dose and (ii) reduce concentrations and dose at the POC. Therefore, NRC staff will monitor natural system performance to assess compliance with the 10 CFR 61.41 PO.

NRC staff made two primary recommendations related to natural system performance in its FTF TER (ML112371751): (i) DOE should obtain support for averaging K_ds of multiple oxidation states to simulate the transport of Pu in the natural environment and (ii) DOE should provide additional data from tracer tests and calcareous zone outcrop locations to allow NRC and DOE to evaluate the significance of calcareous zone dissolution on flow and transport from the FTF. As shown in Figures 3-4 and 3-5 and Table 3-1, DOE assumes a significant amount of performance is achieved for sorption of Pu in the natural system: (i) an approximately 10,000-year delay in the timing of the peak dose due to travel times in the vadose and saturated zones (Figure 3-5) and (ii) a reduction in the peak dose from Pu due to sorption in the natural system by approximately a factor of 10 (Table 3-1). The risk significance of the Pu K_ds is evident. Regarding characterization of the calcareous "soft zones" that are located in the lower portion of the Upper Three Runs Aquifer (UTRA), NRC staff is concerned these zones could act as conduits for fast groundwater flow, decreasing travel times and potentially minimizing dilution and natural attenuation in the aquifer. Site-specific sorption coefficients for the calcareous zones have not been developed, and it is not clear the extent to which key radionuclide mobility will be affected by the presence of these zones. Faster travel times could lead to less decay,

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[35]Sorption is used in a broad sense to describe the association of a groundwater contaminant with subsurface materials that can lead to (i) longer travel times or (ii) decreased concentration at the point of compliance.
[36]Decay can be significant when travel times to a well are expected to be similar to the half-life of key radionuclides [e.g., for key radionuclides such as Pu-239, Sr-90, and Cs-137 in DOE's reference (or best estimate) PA case].

higher concentrations, and earlier peak doses; less dilution and natural attenuation also could lead to higher predicted concentrations and doses at the POC.

In the HTF TER (ML14094A496), NRC staff continued to express the same concerns expressed in the FTF TER with respect to the Pu K_d averaging approach as well as concerns with assumptions regarding the impact of calcareous zones on flow and transport from HTF tanks. NRC staff also listed several concerns with calibration of DOE's HTF local groundwater model in the HTF TER. However, the technical issues associated with DOE's far-field model calibration are not expected to be addressed in the near-term but will be monitored by NRC staff under longer term performance assessment maintenance activities (MA 6, "Performance Assessment Maintenance").

During its review of the Tanks 5F and 6F Special Analysis (SRR–CWDA–2012–00106), NRC staff noted that additional information related to the Niobium (Nb) distribution coefficient, or K_d, is needed to have reasonable assurance that DOE disposal actions at the FTF will meet the POs in 10 CFR Part 61, Subpart C. Therefore, MF 4.1 is being broadened to address key radionuclide natural attenuation (only Pu natural attenuation is addressed in the FTF Monitoring Plan).

NRC Monitoring Under MA 4, "Natural System Performance"

As listed in Appendix A and documented in more detail in its TERs (ML112371751, ML14094A496),[37] NRC staff will consider the following MFs related to natural system performance that it considers important to meeting the 10 CFR 61.41 PO:

- MF 4.1 "Natural Attenuation of Key Radionuclides"
- MF 4.2 "Characterization of Calcareous Zones"
- MF 4.3 "Environmental Monitoring"

3.4.1 Monitoring Factor 4.1: Natural Attenuation of Key Radionuclides

This monitoring factor is focused on the models and parameters used to simulate natural attenuation in the subsurface. In the FTF Rev. 0 Monitoring Plan (ML12212A192), this monitoring factor was titled, "Natural Attenuation of Plutonium." The monitoring factor was originally focused on the K_d averaging approach employed by DOE to simulate Pu transport in the subsurface given the risk significance of Pu-239 in Tank 18F at the time of preparation of the monitoring plan. The K_d averaging approach used by DOE in the FTF Performance Assessment (SRS–REG–2007–00002) was retained in the HTF performance assessment (SRR–CWDA–2010–00128) and is still a technical issue; however, Monitoring Factor 4.1 is broadened to include other model and parameter issues related to natural attenuation of key radionuclides at the tank farms.

Depending on the K_d of Pu assumed in the natural environment, travel times from Tank 18F to the 1-m or 100-m points of compliance used in the intruder and member of the public dose assessments, respectively, could range from hundreds to tens of thousands of years. This issue is also a concern for other tanks with a significant inventory of Pu. NRC staff concludes

[37]MF 4.3 related to environmental monitoring is not discussed in NRC staff's TERs. Nonetheless, NRC staff will review environmental monitoring data to ensure the disposal facility is performing as assumed in DOE's PAs.

that DOE has not addressed issues associated with its K_d averaging approach.[38] Site-specific studies indicate a range of K_d anywhere from a few (three) L/kg to thousands (1,000s) L/kg for different oxidation states of Pu, with higher oxidation states of Pu tending to be more mobile. If arguments based on travel times are relied on to demonstrate compliance with the POs, then DOE should demonstrate that more mobile forms of Pu that can be transported to the 1- or 100-m [3-ft or 330-ft]-points of compliance in hundreds of years cannot exist in risk-significant quantities in the subsurface at SRS. If arguments based on magnitude of peak dose are relied on to demonstrate compliance with the POs, then DOE should show that consideration of a combination of barriers leads to a dose below the POs and that adequate support exists for the assumed level of barrier performance.

Appendix E discusses technical issues with DOE's assumed plutonium K_d for sandy sediment. The sandy sediment K_d for plutonium of 650 mL/g is derived from SRNL–STI–2011–00672. This study bases the recommended value on (i) information from a modeling analysis (Demirkanli, et al., 2007) of long-term lysimeter studies (Kaplan, et al., 2006) indicating that the K_d should be 1,800 mL/g and (ii) the site-wide statistical analysis showing that the 290 mL/g value used for the FTF PA is in the lower quantiles. The sediment in the lysimeter appears to have had more clay in it than typically found at the FTF location; therefore, the 1,800 mL/g value was lowered to 650 mL/g. The NRC staff does not find the argument for the 650 mL/g to be well supported. Furthermore, as expressed in the HTF TER (ML14094A496), NRC staff has technical issues associated with the cement leachate factors applied in the HTF PA (SRR–CWDA–2010–00128, Table 4.2-25) based on information provided in SRNL–STI–2009–00473. NRC will monitor DOE's efforts to develop site-specific sorption coefficients that consider the impact of cement-impacted leachate released from the tanks.

In a technical review report related to FTF monitoring (ML13273A299), NRC staff included a follow-up action for DOE to provide additional support for the revised Nb distribution coefficient it selected in the Tanks 5F and 6F special analysis. A low value distribution coefficient of 0 L/kg was selected in the FTF Rev. 1 PA (SRS–REG–2007–00002) because no additional credit was needed for Nb sorption at the time. However, after DOE updated its inventories and risk projections in the Tanks 5F and 6F Special Analysis (SRR–CWDA–2012–00106), DOE revised the distribution coefficient (K_d) for Niobium (Nb) from 0 L/kg to 160 L/kg. This adjustment was needed because the final Zirconium (Zr)-93 inventory estimated from characterization and sampling of Tanks 5F and 6F at the time of closure was a factor of 10,000 times higher than estimated in the FTF Rev. 1 Performance Assessment, increasing the risk significance of Zr-93's daughter product, Nb-93m. NRC staff will review any DOE-generated reports or other documentation that provides additional information related to site-specific Nb distribution coefficient values.

Technical review activities may be conducted in conjunction with onsite observations of any experiments developed to study the attenuation of Pu, Nb, and other key radionuclides in SRS soils. This MF can be closed when DOE provides support for its treatment of Pu, Nb, and other key radionuclide sorption in the subsurface at FTF or DOE shows that Pu, Nb, and other key radionuclide sorption in the subsurface is not needed to support its compliance demonstration

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[38]In lieu of modeling different oxidation states of Pu that may be present in the natural system, DOE averages the K_ds of multiple oxidation states together in assigning a K_d for Pu.

(e.g., solubility control effectively limits Pu releases into the natural environment to non-risk-significant levels).

3.4.2 Monitoring Factor 4.2: Calcareous Zone Characterization

Another source of uncertainty in DOE's far-field model is the treatment of the calcareous "soft zones," located in the lower portion of the UTRA. Calcareous zone studies have focused on facility or site stability. NRC staff observed that DOE studies appear to give less attention to the hydrogeologic properties of these zones that may impact contaminant flow and transport from the tank farms. DOE argues that monitoring data have not revealed any noticeable impacts on hydraulic heads or contaminant transport to date, but no tracer testing has been performed to improve understanding of transport within the pseudo-karst-like soft zones, nor has downhole imaging of water velocities been performed at known soft zone locations. Additional information was provided in the HTF PA regarding the occurrence and impact of soft zones on site stability and contaminant flow and transport (SRR–CWDA–2010–00128), including a new reference: "A Review of Subsurface Soft Zones at Savannah River Site with Emphasis on H Area Tank Farm (U)" (SRNL–TR–2012–00160). NRC staff reviewed the new reference but still concludes that additional information is needed to assess the impact of calcareous zones on contaminant fate and transport.

DOE could monitor flow velocities at screen levels both consistent and inconsistent with known existing soft zones to assess local fast flow path gradients of soft zones to provide additional confidence that current PA groundwater modeling treatment is acceptable. To date, mapping of surface water seeps from the UTRA-Lower Zone rocks along Upper Three Runs Creek and Four Mile Branch has not focused on surface seeps or other features associated with these zones, but DOE has suggested it is willing to perform both tracer testing and outcrop mapping of seeps.

NRC staff should observe field tests and review and evaluate results of tracer tests and field mapping DOE may conduct to ascertain the significance of existing calcareous soft zones on flow and transport from the tank farms. NRC staff will review relevant geotechnical logs acquired in the vicinity of tank farms to stay informed of the potential for and characteristics of soft zones that may be identified in the future. Finally, if DOE opts to employ downhole visualization or other methods to monitor local groundwater velocities associated with soft zones, NRC staff will review and evaluate DOE's analysis of these data. NRC may conduct technical review activities in conjunction with onsite observations of field activities, such as calcareous zone outcrop mapping on Upper Three Runs Creek. This MF can be closed when DOE has provided NRC sufficient information to show its treatment of calcareous zones in the tank farm PAs is reasonable or adequate to assess risk. If NRC concludes that DOE's treatment of calcareous zones in the tank farm PAs is not reasonable or appropriate, DOE should evaluate the risk significance of a more adequate representation.

3.4.3 Monitoring Factor 4.3: Environmental Monitoring

NRC staff will review any data collected by DOE for the tank farms for the purpose of evaluating disposal facility performance. While early releases from the disposal facility are not expected, groundwater monitoring can serve as a valuable tool for early detection of potential issues with the disposal facility design to allow sufficient time to institute mitigative measures. Additionally, groundwater monitoring data can provide useful validation data from which to assess the adequacy of DOE PA models in evaluating risk from the tank farm disposal facilities. For these reasons, NRC staff will review and evaluate groundwater monitoring data as a technical review activity under this MF.

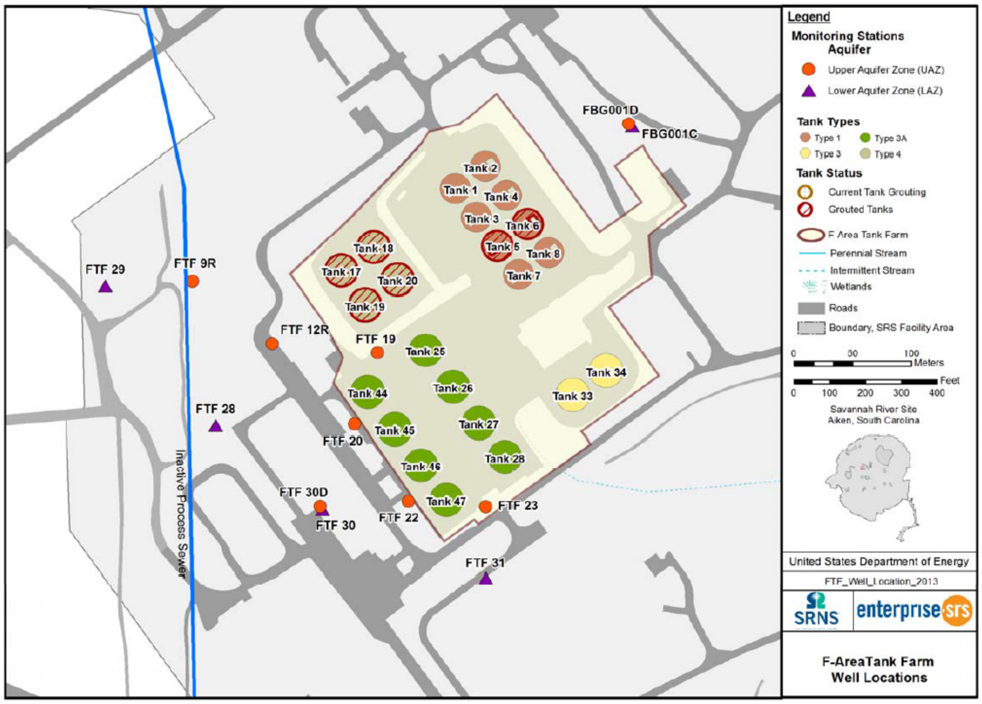
The FTF Farm Groundwater Sampling and Analysis Plan (SRNS–RP–2012–00287) and the HTF Groundwater Monitoring Plan and Sampling and Analysis Plan (SRNS–RP–2012–00146) provide specific details of the groundwater monitoring programs. Monitoring well locations are provided in Figure 3-7(a) for FTF and Figure 3-7(b) for HTF. The groundwater monitoring plan for the FTF includes sampling twice per year at a network of 13 monitoring wells consisting of 6 existing wells and 7 newer wells installed in 2012. The well network is located around the downgradient perimeter of the tank farm and includes wells screened in the Upper Aquifer Zone or UAZ) (7) and Lower Aquifer zone or LAZ (4) and two background wells (UAZ and LAZ). As required by the FTF Sampling Analysis Plan, FTF samples were analyzed for gross alpha, nonvolatile beta, tritium, nitrate-nitrite, cadmium, chromium, manganese, and sodium. In addition, Tc-99 was analyzed to provide information on existing Tc-99 activities. As provided in the FTF Sampling Analysis Plan, SRS will perform contingent analyses for specific radionuclides if screening results for gross alpha and nonvolatile beta exceed trigger levels of 15 pCi/L and 50 pCi/L, respectively.

The groundwater monitoring plan for the HTF indicates that sampling will be conducted twice per year at a network of 46 monitoring wells consisting of 36 existing wells and 10 newer wells (HAA 17 through HAA 21) installed in 2012. The well network is located around the downgradient perimeter of the tank farm facility and consists of wells screened in the UAZ (17), LAZ (28), and Gordon Aquifer or GA (1), including three background wells. The wells are set in three aquifer zones. The “A” wells are set in the GA. The “B” and “C” wells are set in the LAZ, and the “D” wells are in the UAZ of the UTRA. The same constituents are analyzed at HTF as are analyzed at FTF, as well as tritium and Tc-99.

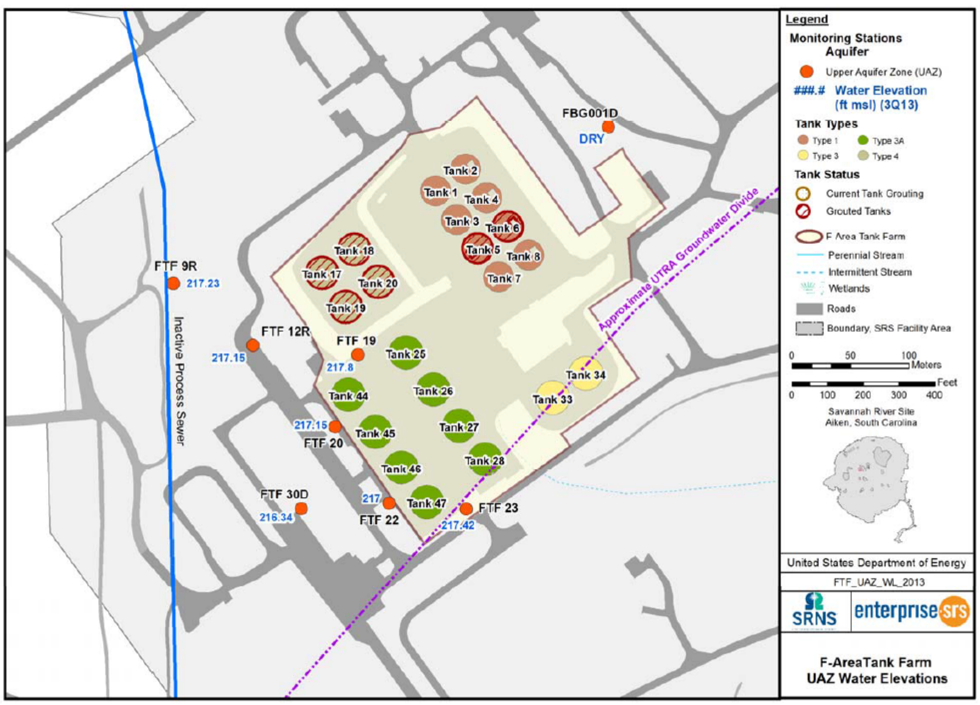
NRC staff reviewed DOE’s F-Tank Farm monitoring well network as part of a technical review activity (ML12272A124). In the technical review report, NRC staff indicated that it will continue to review the adequacy of the tank farm monitoring well network with respect to its ability to detect releases from the tank farms (see Appendices B and E for additional details).

Closure of the Group of Monitoring Factors Under MA 4, “Natural System Performance”

NRC may conduct technical review activities for this monitoring activity in conjunction with onsite observations related to groundwater sampling, well construction, and other field activities. SCDHEC oversight may be leveraged in this area to ensure the quality of data collected. MA 4 will be renamed “Environmental Monitoring” once MF 4.1 and 4.2 have been closed. MA 4 will remain open indefinitely.



(a)



(b)

Figure 3-7. Proposed FTF and HTF Groundwater Monitoring Locations (SRNS–RP–2014–00226)

3.5 MA 5, “Closure Cap Performance”

Importance of MA 5, “Closure Cap Performance”

Although DOE’s sensitivity and uncertainty analyses indicate the closure cap has minimal impact on peak dose and in most cases serves as a redundant barrier,[39] NRC staff concluded that in certain cases, the closure cap could be important to mitigating risk from the disposal facility and in maintaining doses ALARA. In fact, DOE’s barrier analysis shows that if other barriers do not perform as well as expected, the closure cap could become a more important barrier limiting release from the disposal facility. Over long periods of time, DOE also assumes that the closure cap limits infiltration rates to 30.5 cm/yr [12 in/yr], below the background infiltration rate of 38 cm/yr [15 in/yr]. Longer term lowering of the infiltration rate helps to (i) decrease releases of key radionuclides from the disposal facility and (ii) prolong transition times to higher solubility of many key radionuclides. Based on the potential importance of the closure cap in meeting the POs in 10 CFR Part 61 and the fact that DOE is in the early stages of closure cap design, NRC staff will monitor progress on the design and construction of the closure cap, as well as development of support for the assumed level of performance of this engineered barrier.

NRC Monitoring Under MA 5, “Closure Cap Performance”

As listed in Appendix A and documented in more detail in its TERs (ML112371751, ML14094A496), NRC staff will consider the following MFs related to the closure cap that are considered important to meeting the 10 CFR 61.41 PO:

- MF 5.1 “Long-Term Hydraulic Performance of the Closure Cap”
- MF 5.2 “Long-Term Erosion Protection Design”
- MF 5.3 “Closure Cap Functions as They Pertain to ALARA”

3.5.1 Monitoring Factor 5.1: Long-Term Hydraulic Performance of the Closure Cap

In its TERs (ML112371751, ML14094A496), NRC staff discussed (i) the uncertainty in the processes being modeled for the closure caps and (ii) the limited support for several of the closure cap assumptions. DOE should provide additional support for the long-term hydraulic conductivity of the foundation layer, which acts to reduce the long-term infiltration to the disposal facilities. DOE assumed the foundation layer would limit the infiltration rate to 30.5 cm/yr, slightly less than the estimated background infiltration rate of 38 cm/yr. NRC will monitor additional information to support the assumed long-term hydraulic conductivity of the foundation layer.

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[39]NRC staff concluded that DOE’s reference (or best estimate) PA case shows the closure cap is a redundant hydraulic barrier because other, more robust hydraulic barriers, such as the steel liners and tank grout used to fill the cleaned tanks, are present and expected to outperform the closure cap for longer periods of time under most scenarios, including the reference case DOE used in its Tank Farm PAs. However, several points are important to Note: (i) several of the steel liners at the HTF are assumed to be initially failed, (ii) several of the tanks have contamination outside of the primary steel liners, and (iii) the closure cap is the only barrier assumed to provide long-term, infiltration-reducing capabilities, albeit at modest levels. Figure 3-5 shows barriers to timing of FTF releases in DOE’s reference case.

In addition, NRC staff will monitor construction quality and settlement at the Tank Farms to help ensure assumed performance of the High Density Polyethylene/Geosynthetic Clay Liner (HDPE/GCL) composite layer is not adversely impacted. Although the HDPE/GCL composite layer does not significantly contribute to the long-term hydraulic performance of the closure cap, DOE assumes it is a significant barrier to infiltration for several hundred years after site closure. Because the performance of the HDPE/GCL layer is sensitive to construction quality and differential settlement, NRC will monitor the quality assurance/quality control for closure cap construction and settlement data collected during Tank Farm operations as well as at nearby facilities. NRC also will review relevant studies and tests related to HDPE/GCL performance. This MF can be closed after DOE's construction of the closure caps and demonstration of its hydraulic performance.

3.5.2 Monitoring Factor 5.2: Long-Term Erosion Protection Design

As documented in its TERs (ML6112371751, ML14094A496), NRC staff recommended that DOE provide additional support for the long-term erosion of the topsoil layer and conduct a preliminary evaluation of erosion protection designs. Long-term maintenance of the topsoil and vegetative closure cap is important to closure cap performance because evapotranspiration dominates the modeled water balance distribution for SRS precipitation. DOE should evaluate potential loss of soil and development of gullies due to cumulative effects of soil loss from frequent rainfall events. Effects of high frequency and low intensity events can dominate long-term erosion processes. In addition, DOE did not evaluate the resistance of a degraded vegetation cover to gully erosion. A Bahia grass, bamboo, or pine forest vegetative cover could be degraded by fire or extended drought, thereby affecting the capability of the engineered cover to resist erosion. NRC staff will review and evaluate information pertaining to erosion processes of the vegetative and topsoil layers, including cover maintenance activities.

DOE should conduct a preliminary evaluation of erosion protection designs (e.g., evaluation of an acceptable rock source, the ability of an integrated drainage system to accommodate design features) to verify assumptions related to closure cap performance can be met. The design of perimeter drainage structures that convey runoff and infiltration from the cover and divert runoff from surrounding areas will affect resistance of these structures to erosion that could also affect the stability of the cover side slopes and the cover itself. If the vertical hydraulic conductivity of the native soil, on which the perimeter drainage channel is constructed, is not sufficiently high to allow ponded water to infiltrate vertically, it could flow toward the tanks. The final design for the cover and associated drainage structures should consider their performance and degradation during the long, post-institutional control period. If DOE performs simulations of the influence of clogging and ponding in the perimeter drainage structures on flow in the vadose zone, NRC will review results of these simulations to evaluate risk significance of the uncertainties in the long-term performance of the perimeter drainage structure. This MF can be closed after DOE's construction of the closure cap and demonstration of its physical stability.

3.5.3 Monitoring Factor 5.3: Closure Cap Functions That Maintain Doses ALARA

DOE lists the infiltration-reducing function of the closure cap as part of its ALARA demonstration under 10 CFR 61.41. In addition to reducing short-term, as well as long-term, infiltration rates, the closure cap serves many functions that are not specifically discussed in DOE's Tank Farm PAs. For example, the closure cap provides defense in depth to ensure relatively high specific activity radionuclides present in significant quantities, such as Sr-90 and Cs-137, are not released from FTF tanks and ancillary equipment before they decay to negligible levels. During the period of a few hundred years after closure, the closure caps may reasonably be assumed to be effective in minimizing infiltration through the disposal facilities.

Although not specifically discussed in DOE's PA, another important function of the closure cap is that it may limit infiltration and transport of deleterious species, such as carbon dioxide, oxygen, chloride, sulfate, and slightly acidic groundwater, into the engineered disposal system that could accelerate material degradation of cement vaults, as well as corrosion of the HLW tanks. Therefore, construction of a well-designed closure cap also may benefit the longevity of other engineered barriers at the Tank Farms.

Finally, the closure caps may have a minor but detectable impact on water table elevations local to Tank Farms. Barriers constructed to reduce the likelihood of periodic water table rise above the bottom of the tanks may be needed to support the compliance demonstration and may be considered ALARA. The alternative waste release configuration where the water table rises and falls above and below the tank bottoms is especially important for Type IV tanks at FTF and Type II tanks at HTF that are located at or in close proximity to the water table, based on historical water table data because the configuration could lead to accelerated corrosion and higher release rates of key radionuclides to the UTRA.

For these reasons and other closure cap functions listed in Chapter 4, related to the 10 CFR 61.42 PO, NRC staff will monitor DOE's disposal actions as they pertain to Tank Farm closure cap design, construction, and maintenance consistent with ALARA criteria.

Closure of the Group of Monitoring Factors Under MA 5, "Closure Cap Performance"

This MA will remain open throughout DOE's development, construction, and completion of final closure caps, unless final design information indicates the MFs are not risk significant. When DOE develops final closure cap designs, NRC will revise the monitoring plan, as appropriate, to describe the monitoring activities relevant to the final designs. NRC staff will monitor DOE's development of specific designs for the closure caps and determine whether these designs are likely to significantly alter DOE and NRC conclusions regarding the conceptual design analyzed in the PA. Prior to any construction activities, NRC staff will review specifications for closure cap construction materials and quality assurance/quality control procedures for assuring these materials meet specifications. During construction, NRC staff should observe the placement of these materials and the quality control testing to assure the as-built closure cap will meet design specifications. NRC staff also will evaluate available data from similar covers built on the larger SRS site and other humid sites.

3.6 MA 6, "Performance Assessment Maintenance"

Importance of MA 6, "Performance Assessment Maintenance"

DOE Manual 435.1-1, Change 1, requires DOE PAs to be maintained to evaluate changes that could affect the performance, design, and operation bases for the facility. DOE Manual 435.11-1 requires the maintenance to include research, field studies, and monitoring necessary to address uncertainties or gaps in existing data. DOE prepares an annual PA maintenance program implementation plan that summarizes activities related to the following areas for the tank farms: (i) annual maintenance program activities, (ii) PA development or revisions, and (iii) research and testing activities. The implementation plan for fiscal year 2015 is documented in SRR–CWDA–2014–00108.

NRC used risk insights to prioritize the recommendations identified in its TERs (ML112371751, ML14094A496) and anticipates that DOE, as part of its PA maintenance program, might use a graded approach to focus on development of support for key modeling assumptions, such as those identified under other MAs (e.g., MA 2) to enhance confidence in the PAs. NRC will monitor DOE's PA maintenance activities related to key modeling assumptions under other MAs identified in this monitoring plan. The insights generated from focusing on key modeling assumptions would then inform the need for further data collection, experimental studies, and modeling to address MFs identified under this MA.

NRC Monitoring Under MA 6, "Performance Assessment Maintenance"

Under this MA, NRC will monitor DOE activities associated with the PA maintenance program that are related to NRC recommendations to improve model support and parameter justification, including representation of uncertainty in models and parameters. Appendix A provides a crosswalk of specific NRC recommendations identified in its TERs (ML112371751, ML14094A496) that fall under this MA. Specifically, NRC will consider the following MFs related to DOE's PA maintenance activities for recommendations that NRC, based on the current understanding, identified as being of lower significance to demonstrating compliance with the POs or may require a longer time horizon to complete based on current information:

- MF 6.1 "Scenario Analysis"
- MF 6.2 "Model and Parameter Support"
- MF 6.3 "Tank Farm PA Revisions"

3.6.1 Monitoring Factor 6.1: Scenario Analysis

During the monitoring period, NRC staff will review PA revisions to evaluate adequacy of scenarios considered. Specifically, NRC staff will review the DOE methodology for identification, screening, and dispositioning of features, events, and processes (FEPs) and the formation of scenarios considered in the PAs. NRC staff should verify FEPs identified by DOE, including all FEPs having a potential to influence compliance with POs. NRC staff should examine the technical basis for screening FEPs from further consideration in the PA. NRC staff also should examine DOE bases for the formation of scenarios considered in the PAs to determine whether they include all FEPs that have not been screened from further consideration.

Since NRC issued its FTF TER (ML112371751), DOE documented an evaluation of FEPs for the SRS and crosswalked the FEPs to the FTF PA. NRC staff reviewed the FEPs analysis (SRR–CWDA–2012–00011) and documented the results of its review in a technical review report (ML13277A063). The NRC staff's review of DOE's identification of FEPs found that DOE's identification is adequate. The NRC staff's review of the DOE screening methodology finds that DOE properly focused on likelihood and impact as criteria for screening, but identifies several concerns with DOE's screening of FEPs, including the membership of the FEPs screening team and the documentation of each subject matter expert's basis for judgment. Finally, the NRC staff indicated that is it not confident that all relevant FEPs were adequately considered in the FTF PA due to lack of transparency and traceability in documentation, which crosswalks FEPs with the FTF PA (SRR–CWDA–2012–00022). NRC indicated that the questions and issues raised in the technical review report could be addressed as part of DOE's PA maintenance program or as part of special analyses for specific tank closures. In the HTF TER (ML14094A496), similar to the findings in the technical review report for FTF, NRC staff recommended that DOE include subject matter experts on the screening team in the specific engineering and scientific disciplines that are pertinent to the professional judgments being made. NRC staff also recommended that DOE improve the transparency and traceability of its implementation of FEPs (SRR–CWDA–2012–00044) to ensure comprehensive, accurate, and traceable links to clear descriptions of how included FEPs are actually implemented in the HTF PA. NRC will close this MF when DOE demonstrates that all risk-significant FEPs have been (or will be under another MF) adequately evaluated in PA documentation.

3.6.2 Monitoring Factor 6.2: Model and Parameter Support

As documented in NRC's TERs (ML112371751, ML14094A496), NRC staff provided a number of recommendations regarding the technical bases for model selection and justification of parameter ranges and distributions. NRC staff will review DOE's PA revisions to evaluate the selection of models and justification of parameters. Specifically, NRC staff will examine information DOE generates, including experimental and site characterization data and information from literature, to support model selection and justify parameters. NRC staff also will review DOE methods to characterize data and model uncertainty and propagate the uncertainty through the PAs. NRC staff will use a graded approach to focus on aspects of most importance to demonstrating compliance with the POs. This MF can be closed when DOE provides sufficient information to support risk-significant models and/or model parameters listed in Appendix A related to MF 6.2.

3.6.3 Monitoring Factor 6.3: Tank Farm PA Revisions

It is anticipated that DOE will update its current Tank Farm PAs (SRS–REG–2007–00002, SRR–CWDA–2010–00128) in the future, to incorporate new and significant information collected since preparation of the PAs. NRC staff will review the revised PAs and issue a TER documenting the results of its review. NRC anticipates results of the review, as documented in NRC's TER, will be used by NRC to update this monitoring plan in the future. NRC staff will pay special attention to supporting documentation generated since the last PA revision, including results of experiments, analog studies, models, and peer reviews conducted to support the key MAs listed in this monitoring plan, as well as lower priority items listed under MA 6, "PA Maintenance." Evaluation of revisions to the Tank Farm PAs is considered critical to NRC staff's execution of its monitoring responsibilities to assess compliance of DOE disposal actions with the POs in 10 CFR Part 61, Subpart C. The Tank Farm PAs and special analyses provide the technical support for DOE's demonstration of compliance with the POs in 10 CFR Part 61, Subpart C.

Closure of the Group of Monitoring Factors Under MA 6-PA Maintenance

NRC staff expects the PA Maintenance MA will remain active until all technical issues have been resolved (or are deemed unnecessary to the compliance demonstration) and possibly for the entire duration over which DOE performs maintenance activities related to the Tank Farm PAs. Alternatively, NRC staff could close this group of MFs if it determines DOE's PA maintenance program is sufficient to evaluate new and significant information related to tank farm compliance with 10 CFR 61.41 in the future.

4 MONITORING TO ASSESS COMPLIANCE WITH 10 CFR 61.42

Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed.

Protection of individuals from inadvertent intrusion considers the potential risks to individuals who are unknowingly exposed to radiation from disposed waste while engaging in normal activities while occupying the site. Generally, compliance with the waste classification system at 10 CFR 61.55 ensures protection of inadvertent intruders. However, for waste streams that were not considered in the development of 10 CFR Part 61 in NUREG–0945 (ML052590184), such as the residual waste projected to remain in the tank farms, it would be prudent to assess the performance of the disposal facility to limit radiological exposures to inadvertent intruders to demonstrate compliance with the PO.

Exposures to radiation can be through direct contact with the waste or indirect exposure to the radiation from buried waste while onsite. Direct contact could occur as a result of an activity that disturbs the waste zone directly. Examples of activities that could lead to direct contact of radioactivity by an inadvertent intruder include excavation during dwelling construction and well drilling. DOE rules out excavation for dwelling construction in its PA because DOE assumes a minimum of 3-m [10-ft] clean cover is present and most residential dwellings disturb less than 3 m [10 ft] of soil. Although well drilling was considered a potential direct intrusion event in DOE's PA, well drilling into an HLW tank was considered unlikely in DOE's PA, given the presence of multiple redundant barriers, such as the closure cap, tank grout, and steel liner, that would make drilling more difficult and, based on regional experience, would likely alert a driller accustomed to drilling into softer materials to the potential hazards of the disposal facility. Instead, DOE considered intrusion into transfer lines more likely. Nonetheless, because tank farm waste is located several meters below grade underneath a closure cap, DOE also considers exposures resulting from indirect contact with contaminated onsite groundwater as a more likely exposure scenario for an inadvertent intruder. The basis for the 10 CFR 61.42 compliance demonstrations is therefore calculations of potential dose to a well driller who intrudes into the tank farm transfer lines and the potential dose to a groundwater receptor.

Because 10 CFR Part 61 relies on the waste classification system to ensure protection of inadvertent intruders, the regulation does not specify a time period for an assessment. LLW and WIR guidance found in NUREG–1573 and NUREG–1854 suggest a 10,000-year period of performance is generally sufficient for demonstration of compliance with 10 CFR 61.41. Likewise, the NRC staff considers this time period appropriate for assessment of compliance with 10 CFR 61.42. However, longer evaluation periods may be necessary to capture the peak dose and provide insights on facility (natural and engineered) performance for certain long-lived wastes.

To determine the dose to a potential receptor, DOE also must select a POC. NRC assumes in the development of 10 CFR Part 61 in NUREG–0945, Final Environmental Impact Statement on 10 CFR Part 61, Licensing Requirements for Land Disposal of Radioactive Waste, Volume 1, Summary and Main Report (ML052590184) the intruder excavated into a disposal cell or extracted water from a well located at the boundary of the disposal area after the end of the institutional control period. DOE assumes the inadvertent intruder installs a well located 1 m from the boundary of the disposal facility (see Figures 3-2 and Figure 3-3). In the HTF PA (SRR–CWDA–2010–00128), DOE also evaluates several additional compliance points next to tank sources within the tank farm boundary (see Figure 3-3).

Because the groundwater pathway is evaluated for both the 10 CFR 61.41 and 61.42 POs, with the only difference being the POC (100 m [330 ft] versus 1 m [3.28 ft], respectively) and the allowable dose (0.25 mSv/yr [25 mrem/yr] versus 5.0 mSv/yr [500 mrem/yr]), each MA that is important for demonstrating compliance with 10 CFR 61.41 also is important for demonstrating compliance with 10 CFR 61.42. In general, NRC staff expects that compliance with the 10 CFR 61.41 PO will be bounding for the 10 CFR 61.42 evaluations. This is true for long-lived radionuclides because the factor difference between the dose standards (20 times higher for the 10 CFR 61.42 evaluations) is greater than the difference in concentrations between the 1-m [3.28 ft] and 100-m [328 ft] POCs for most key radionuclides. This generalization would not be true for relatively short-lived radionuclides such as Cs-137 and Sr-90 whose concentrations drop off substantially with distance from the source to the 100-m [328 ft] POC. Additionally, because in some cases DOE relies on timing of the peak dose to demonstrate compliance with the POs, the 10 CFR 61.42 compliance demonstration could be bounding for those radionuclides whose travel times are assumed to be prolonged between the 1 m [3.28 ft] and 100-m [328 ft] POCs (e.g., Pu-239). Finally, because 10 CFR 61.41 does not consider a direct intrusion case (e.g., intrusion into the transfer lines), constituents important to the 10 CFR 61.42 evaluations may not be important for the 10 CFR 61.41 evaluations and will be highlighted in MA 1, "Residual Inventory."[1] In general, NRC staff considers MA and MA factors discussed in Chapter 3 with respect to 10 CFR 61.41 applicable to 10 CFR 61.42 discussed in Chapter 4 and will not be repeated. However, special considerations are discussed below for each MA.

4.1 MA 1, "Inventory"

Monitoring Factor 1.1: Final Inventory and Risk Estimates (Additional Considerations)

In the FTF PA (SRS–REG–2007–00002), DOE evaluates a well driller scenario in which a worker is acutely exposed to radioactivity during construction of a well that intersects a 8 cm [3-in] transfer line and a resident is chronically exposed to contaminated drill cuttings brought to the surface following well construction. The FTF PA indicates that primary radionuclides contributing to dose in the acute intruder exposure scenario are Cs-137/Ba-137m. DOE also reports a peak 10,000-year dose for the chronic intruder of 0.73 mSv/yr [73 mrem/yr] with the most important pathway being ingestion of vegetables contaminated with drill cuttings at the time of intrusion at 100 years. The primary radionuclides contributing to dose within 10,000 years are Sr-90/Y-90 and Cs-137/Ba-137m. The peak 20,000-year dose for the chronic intruder is slightly higher at 0.75 mSv/yr [75 mrem/yr] due to groundwater-dependent pathways; the majority of the dose is from vegetable and water ingestion from Np-237. Results of the probabilistic analysis show the potential for doses in excess of the 5 mSv/yr [500 mrem/yr] applied dose standard for 10 CFR 61.42. Sensitivity analysis indicated the potential for other radionuclides in addition to Np-237 to dominate the groundwater-dependent pathway dose.[2] Other potentially important radionuclides from the groundwater pathway include Th-229 and U-233, although DOE indicated its plans to eliminate these two radionuclides from the list of highly radioactive radionuclides (HRRs) that is used to identify constituents in the waste residue

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[1] In general, groundwater-dependent scenarios dominate the intruder dose; however, groundwater-independent scenario doses and key radionuclides are listed for completeness.

[2] The peak of the mean dose in the probabilistic analysis is 6.4 mSv/yr [640 mrem/yr]. DOE performed a sensitivity analysis and identified Pu inventory, Pu and Tc solubility limits, Pu sand K_d, steel liner failure times, and aquifer thickness as important to peak intruder dose from groundwater-dependent pathways.

to be sampled by DOE, following cleaning, based on low inventories of these two radionuclides in cleaned Tanks 18F and 19F.

In the HTF PA (SRR–CWDA–2010–00128), DOE also evaluates the same well driller scenario evaluated in the FTF PA. Most of the dose to the acute well driller is from key radionuclide Cs-137, with Sr-90, Pu-238, and Am-241 also contributing less significantly to peak dose. With respect to groundwater-dependent pathway peak dose (0.51 mSv/yr or [51 mrem/yr]) within 10,000 years,[3] primary radionuclides include Ra-226, U-234, and U-233. At the end of the institutional control period (at 100 years), the dose (0.4 mSv/yr or [40 mrem/yr]) is dominated by water-independent pathways or dose attributable to direct exposure from the drill cuttings. The primary radionuclides contributing to peak dose at 100 years are Sr-90/Y-90.

NRC staff noted in the HTF TER (ML14094A514) that differences in the timing of the peak dose between the deterministic and probabilistic analysis[4] may be important to the compliance demonstration (i.e., doses may be above the PO within the compliance period considering uncertainty in the timing of the peak dose). Additionally, based on DOE's response to a request for additional information, the intruder dose could be above the 10 CFR 61.42 PO for alternative cases(i.e., Case E results indicate a peak chronic intruder dose of 10 mSv/yr [1,000 mrem/yr] at around 2,000 years). The peak Case E dose is attributed to Np-237. Because Np-237 has a relatively high solubility under oxidizing conditions and high mobility in the natural environment, only the tank basemats provide a significant barrier to Np-237 release when the system becomes oxidized. Therefore, when the attenuating properties of the basemat are degraded in Case E, the Np-237 dose is significantly greater than in the compliance case, Case A.

Also, for HTF, the NRC staff believes the potential dose contributions of short-lived radionuclides in the annuli of the tanks, such as Cs-137 and Sr-90, may not have been fully evaluated by DOE in alternative cases. Of particular concern to the NRC staff is the risk-significant inventory of Sr-90 located in HTF tank annuli, such as Tanks 9H, 10H, 14H, and 16H. Evidence of the potential risk significance of Sr-90 in primary tank waste is found in alternative case results performed for the 10 CFR 61.41 evaluation. In its HTF TER (ML14094A496), NRC staff also expressed concern with the selection of the 1-m compliance boundary in the HTF PA. Because DOE evaluated compliance points next to tank sources, NRC staff was able to evaluate the potential impact of selection of the compliance boundary on intruder dose results [e.g., the highest intruder dose associated with an evaluation point next to Tank 12H was a factor of five times higher than the highest intruder dose reported for any location along the 1-m [3.28 ft] boundary].

NRC staff will review special analyses prepared for each cleaned tank to ensure intruder risks reported in the tank farm PAs are appropriately assessed and evaluated under MF 1.1, paying special attention to the key radionuclides and technical issues discussed in this section. This MF can be closed after NRC staff reviews each special analysis developed by DOE for the tank farms and concludes that DOE has adequately evaluated risk to the inadvertent intruder.

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[3]The dose is significantly higher in the 20,000-year time period; however, no information was provided on key radionuclides during this time period.
[4]Probabilistic analysis results presented in the HTF PA indicate a peak of the mean dose of 7.6 mSv/yr [760 mrem/yr]. Sensitivity analysis results show (1) the importance of the aquifer in which the well is completed and (2)Tc related parameters important to dose.

Monitoring Factor 1.2: Residual Waste Sampling (Additional Considerations)

DOE's conclusion that inventories of Th-229 and U-233, which may be important to the 10 CFR 61.42 analysis, were overestimated in the FTF PA, is based on analyses of these radionuclides in cleaned Tanks 18F and 19F. However, NRC indicated in the technical evaluation report for FTF (ML112371751) that unless DOE can show that final inventories in other tanks are similar to final inventories in Tanks 18F and 19F, DOE should continue to characterize samples for these radionuclides. With respect to HTF, U-233 is considered to be a key radionuclide because H-Canyon processing of Th-232 targets irradiated for the production of U-233 led to a significantly greater expected inventory of U-233 in HTF compared to FTF (factor of 10^8 times higher inventory of U-233 is expected in HTF compared to FTF according to SRNL–STI–2012–00479). Based on process knowledge and sampling, DOE could provide additional information to eliminate U-233 from consideration as a key radionuclide at FTF.

NRC staff will review sampling and analysis plans to ensure all HRRs are sampled or a basis for exclusion of an HRR is provided. This MF can be closed when NRC concludes that DOE has provided sufficient information to support its list of HRRs and has addressed the other technical issues identified in Section 3.1.2.

Monitoring Factor 1.3: Residual Waste Volume

There are no special considerations under MF 1.3 for the 10 CFR 61.42 analyses.

Monitoring Factor 1.4: Ancillary Equipment Inventory

Short-lived radionuclides Sr-90/Y-90 and Cs-137/Ba-137 that may not be considered important by DOE to the 10 CFR 61.41 evaluation could be more important for the 10 CFR 61.42 analysis, because the 10 CFR 61.42 analysis considers direct intrusion into the tank farm transfer lines at 100 years, when these radionuclides may still be present in risk-significant quantities.[5] In fact, the dose at 100 years for the chronic intruder scenario is 0.73 mSv/yr [73 mrem/yr] at FTF and 0.40 mSv/yr [40 mrem/yr] at HTF due primarily to relatively short-lived radionuclides Sr-90/Y-90 and Cs-137/Ba-137m. However, because the estimated does is significantly below the 5-mSv/yr [500-mrem/yr] applied dose standard, inventory of these radionuclides could potentially be higher, while still maintaining compliance with the dose standard. NRC staff should ensure risks associated with these relatively short-lived radionuclides are bounded by the PAs or a special analysis is performed to assess the increased risk associated with a higher than assumed inventory, once final estimates of transfer line inventories are assessed through additional characterization. DOE indicated in response to an NRC comment (SRR–CWDA–2009–00054) its intent to verify PA assumptions regarding transfer line inventories and listed this activity under Section 8.2, "Further Work," in its FTF and HTF PAs (SRS–REG–2007–00002, and SRR–CWDA–2010–00128). NRC staff will monitor DOE's efforts in this area to ensure the assumed transfer line inventories are sufficiently bounding or that increased risk is

[5]The 10 CFR 61.41 analyses are dominated by groundwater-dependent pathways and in most cases risk-significant releases from tank farm components are not assumed to occur for hundreds to thousands of years, allowing sufficient time for decay of relatively short-lived radionuclides, such as Cs-137 and Sr-90. In HTF, NRC staff is concerned that risk-significant releases of short-lived radionuclides could occur in tanks with liners that are assumed to be initially failed and that have a significant inventory in the annulus.

assessed. This MF can be closed when NRC staff concludes that DOE has adequately assessed the risk associated with transfer lines.

Monitoring Factor 1.5: Waste Removal (As It Impacts ALARA)

MF 1.5 related to ALARA does not apply to the 10 CFR 61.42 evaluations.

4.2 MA 2, "Waste Release"

Monitoring Factor 2.1: Solubility-Limiting Phases/Limits and Validation

There are no special considerations under MF 2.1 for the 10 CFR 61.42 analyses.

Monitoring Factor 2.2: Chemical Transition Times

There are no special considerations under MF 2.2 for the 10 CFR 61.42 analyses.

4.3 MA 3, "Cementitious Material Performance"

Monitoring Factor 3.1: Hydraulic Performance of Concrete Vault and Annulus (As it Relates to Steel Liner Corrosion and Waste Release) (Additional Considerations)

Because DOE relies on grouted tanks and vaults in the tank farm PAs to deter inadvertent intrusion into the HLW tanks,[6] NRC staff will perform routine monitoring of DOE's reliance on cementitious materials to ensure tank farm PA assumptions regarding the ability of the tank vaults to serve as a recognizable and durable barrier to intrusion are valid. This MF will be reviewed in conjunction with MF 3.4 and can be closed following closure of tanks at FTF and HTF.

Monitoring Factor 3.2: Groundwater Conditioning via Reducing Grout

There are no special considerations under MF 3.2 for the 10 CFR 61.42 analyses.

Monitoring Factor 3.3: Shrinkage and Cracking of Reducing Grout

There are no special considerations under MF 3.3 for the 10 CFR 61.42 analyses.

Monitoring Factors 3.4: Grout Performance (Additional Considerations)

Because DOE relies on the grouted tanks and vaults in the tank farm PAs to deter inadvertent intrusion into the HLW tanks,[7] grouting activities under MA 3, "Cementitious Materials Performance," will also be monitored under 10 CFR 61.42. NRC will perform routine monitoring of DOE's use of grout materials to stabilize HLW tanks to ensure tank farm PA assumptions

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[6]DOE only considers intrusion into the HLW tanks in sensitivity analyses due to assumed robustness of the grouted tank and vault system.
[7]DOE only considers intrusion into the HLW tanks in sensitivity analyses due to assumed robustness of the grouted tank and vault system.

regarding the ability of the grouted tank and vaults to serve as a recognizable and durable barrier to intrusion remain valid. This MF will be reviewed in conjunction with MF 3.1 and can be closed following closure of tanks at FTF and HTF.

Monitoring Factor 3.5: Vault and Annulus Sorption

There are no special considerations under MF 3.5 for the 10 CFR 61.42 analyses.

Monitoring Factor 3.6: Waste Stabilization (As it Impacts ALARA)

MF 3.6 related to ALARA does not apply to the 10 CFR 61.42 evaluations (there are no ALARA provisions in 10 CFR 61.42).

4.4 MA 4, "Natural System Performance"

Monitoring Factor 4.1: Natural Attenuation of Key Radionuclides (Additional Considerations)

Due to potential reliance on travel time of Pu to the 100-m [328 ft] POC for the 10 CFR 61.41 analyses, NRC will specifically consider whether the shorter distance and travel time to the 1-m [3.28 ft] POC for the 10 CFR 61.42 analyses make compliance with the latter PO bounding. As discussed in Section 3.4.1, NRC staff has concerns with the K_d averaging approach used by DOE that tends to delay travel times to the 10 CFR 61.41 and 61.42 POCs. NRC staff will review information generated by DOE and perform independent modeling to assess whether more mobile forms of Pu, if evaluated explicitly in DOE's PA modeling, could reach the inadvertent intruder POC within 10,000 years. This MF can be closed when NRC staff concludes that DOE has adequately assessed the timing and magnitude of Pu-239 release and transport to the 1-m [3.28 ft] POC.

Monitoring Factor 4.2: Calcareous Zone Characterization

There are no special considerations under MF 4.2 for the 10 CFR 61.42 analyses.

Monitoring Factor 4.3: Environmental Monitoring

There are no special considerations under MF 4.3 for the 10 CFR 61.42 analyses.

4.5 MA 5, "Closure Cap Performance"

Monitoring Factor 5.1: Long-Term Hydraulic Performance

There are no special considerations under MF 5.1 for the 10 CFR 61.42 analyses.

Monitoring Factor 5.2: Long-Term Erosion Protection Design (Additional Considerations)

DOE relies on the erosion barrier to maintain a minimum 3-m [10-ft] clean cover to prevent intrusion into Tank Farm waste (DOE/SRS–WD–2012–001 and DOE/SRS–WD–2014–001), thereby eliminating certain shallow intrusion scenarios from analysis in DOE's PAs (SRS–REG–2007–00002 and SRR–CWDA–2010–00128). DOE also considers the erosion barrier part of a system of durable engineered barriers that would cause a regional driller not accustomed to encountering hard materials to change location. For these reasons, NRC will specifically monitor use of the engineered closure cap as a barrier to intrusion. This MF can be closed after construction of the closure cap.

Monitoring Factor 5.3: Closure Cap Functions that Maintain Doses ALARA

MF 5.3 related to ALARA does not apply to the 10 CFR 61.42 evaluations.

4.6 MA 6, "Performance Assessment Maintenance"

Monitoring Factor 6.1: Scenario Analysis (Additional Considerations)

NRC will pay particular attention to DOE's consideration of various scenarios related to inadvertent intrusion in its tank farm PAs. NRC will also evaluate DOE's consideration of FEPs related to inadvertent intrusion. In a technical review report (ML13277A063), NRC evaluated DOE's FEPs analysis (SRR–CWDA–2012–00011) and crosswalk of the FEPs analysis to the FTF PA (SRR–CWDA–2012–00022). In the HTF TER (ML14094A496), NRC also evaluated SRR–CWDA–2012–00044, which crosswalks the FEPs described in SRR–CWDA–2012–00011, to the HTF PA. NRC staff can close this MF when it concludes that DOE has adequately addressed exposure scenarios and FEPs related to inadvertent intrusion in its PA documentation.

Monitoring Factor 6.2: Model and Parameter Support

There are no special considerations under MF 6.2 for the 10 CFR 61.42 analyses.

Monitoring Factor 6.3: Tank Farm PA Revisions (Additional Considerations)

NRC will evaluate any revisions to the tank farm PAs to ensure inadvertent intrusion into tank farm components were properly evaluated in the 10 CFR 61.42 analyses. Evaluation of revisions to the tank farm PAs is considered critical to NRC staff's execution of its monitoring responsibilities to assess compliance of DOE disposal actions with the POs in 10 CFR Part 61, Subpart C. The tank farm PAs and special analyses provide the technical support for DOE's demonstrations of compliance with the POs in 10 CFR Part 61, Subpart C. This MF can be closed when NRC staff concludes that DOE has adequately evaluated FEPs and scenarios related to inadvertent intrusion in its PA documentation and that its PA maintenance program is sufficient to evaluate new and significant information related to inadvertent intrusion in the future.

5 MONITORING TO ASSESS COMPLIANCE WITH 10 CFR 61.43

Operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in Part 20 of this chapter, except for releases of radioactivity in effluents from the land disposal facility, which shall be governed by 10 CFR 61.41 of this part. Every reasonable effort shall be made to maintain radiation exposures as low as is reasonably achievable.

The NRC interprets the term “operations” as those DOE activities related to waste retrieval (i.e., heel removal), grouting, stabilization, observation, maintenance, or other similar activities. NRC intends to evaluate this PO from the time that DOE issues its final waste determination until the end of the institutional control period. For workers performing activities (e.g., construction and maintenance of closure caps) at the tank farms on the larger DOE-controlled site and under DOE’s radiation protection program, the 50-mSv/yr [5-rem/yr] radiation worker dose limit applies. For members of the public who may visit the site prior to the end of the institutional control period,[1] including workers performing limited activities not covered under a DOE radiation protection program, the 1-mSv/yr [100-mrem/yr] dose limit for members of the public applies from sources other than effluents.[2] 10 CFR 20.1101(d) further specifies that the maximum annual dose that a member of the public can receive from airborne emissions is 0.10 mSv [10 mrem/yr]. DOE also must demonstrate that dose in any one hour in an unrestricted areas is less than 0.02 mSv [2 mrem].

DOE has a radiation protection program to ensure protection of individuals during operations. In DOE’s 2010 FTF waste determination and 2014 HTF waste determination (DOE/SRS–WD–2012–001 and DOE/SRS–WD–2014–001), DOE provided a crosswalk of the relevant DOE regulation or limit consistent with that provided in 10 CFR 20 to demonstrate that the DOE regulation provides an equivalent level of protection.

During operations associated with tank farm disposal at the SRS, the primary pathway of concern will be through the air. No significant releases to the subsurface or surface water from the waste in the tank farm tanks are expected during the time of operations. Additionally, the release of radionuclides from the tank farms to the subsurface is being monitored in assessments of compliance with 10 CFR 61.41 (Chapter 3) and 10 CFR 61.42 (Chapter 4). Any leaching of contaminants from the vaults observed while the tank farms are still in operation may indicate the ability of the waste form to retain the radionuclides is less than expected and that 10 CFR 61.41 and 10 CFR 61.42 may not be met.

Importance of MA 7, “Protection of Individuals During Operations”

The NDAA requires NRC, in coordination with the State of South Carolina, to monitor DOE disposal actions to assess compliance with the POs in 10 CFR Part 61, Subpart C. 10 CFR 61.43 is related to protection of individuals during operations, including workers and members of the public. NRC expects the following DOE activities to incur the largest risks to workers and members of the public during tank farm closure operations: (i) tank cleaning, (ii) waste

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[1]The 10 CFR 61.42 performance objective, related to protection of individuals from inadvertent intrusion, provides standards to protect individuals who may occupy the site following the institutional control period.
[2]The public dose limit is 1 mSv/yr [100 mrem/yr]. However, 10 CFR 61.43 indicates that effluents will be addressed under 10 CFR 61.41. The 10 CFR 61.41 dose based standard is 0.25 mSv/yr [25 mrem/yr]. The point of compliance during active disposal facility operations under 10 CFR 61.41 is the larger SRS site boundary.

sampling, (iii) waste stabilization, and (iv) other maintenance activities. Tank cleaning activities could include use of high pressure water that has the potential to lead to releases or radioactivity into secondary containment and the environment. Waste sampling may lead to significant exposures to workers collecting and processing samples. Radioactivity also may be released to the tank vapor space during tank grouting activities. Modification and maintenance of tank equipment and ventilation systems during tank cleaning, sampling, grouting, and other tank farm activities are expected to incur worker dose. Therefore, NRC may observe installation and removal of equipment from HLW tanks during an onsite observation, as practical.

NRC Monitoring Under MA7, "Protection of Individuals During Operations"

NRC staff has developed the following MFs related to protection of individuals during operations:

- MF 7.1 "Protection of Workers During Operations"
- MF 7.2 "Air Monitoring"
- MF 7.3 "ALARA"

5.1 Monitoring Factor 7.1: Protection of Workers During Operations

Compliance with the dose requirements for protection of individuals during operations is expected to be assessed by NRC through the use of dosimetry and the monitoring of radiation data and radiation records. NRC staff should review, on at least an annual basis, DOE reports and records that are related to dose during waste disposal operations to assess whether doses are within the limits found in 10 CFR Part 20 and are ALARA.

NRC staff should periodically confirm programs and policies presented in the waste determination (DOE/SRS–WD–2012–001) continue to be in effect during the operational period. In particular, NRC staff should verify personnel involved in waste disposal operations are provided dosimetry and are familiar with requirements of the radiation protection program. NRC will leverage staff in its Region I office with experience in radiation protection inspections to support onsite observations in this area. Any NRC staff participating in an onsite observation should abide by DOE's onsite radiation protection program requirements, as well as obtain dosimetry from NRC's Office of Administration, if not already assigned, prior to the onsite observation.

This factor will be closed at the end of the assumed 100-year institutional control period or after operational doses are expected to be reduced to non-risk-significant levels following tank closure activities.

5.2 Monitoring Factor 7.2: Air Monitoring

DOE monitors air quality at SRS using air sampling stations located at the site boundary as well as in other locations throughout the site. NRC staff should review air monitoring data to determine whether activity released in the air, as a result of tank farm disposal facility activities, could cause a member of the public located at the SRS site boundary to receive an annual dose of greater than 0.10 mSv/yr [10 mrem/yr] through the air pathway.

NRC staff should periodically confirm the air monitoring program continues to adequately assess the risk of tank farm operations. As part of this review, NRC staff should evaluate whether sampling locations and sampling methodologies are adequate to assess airborne emissions from the tank farms or rely on independent verification from the SCDHEC. NRC staff expects the dose from airborne emissions to be small. If the airborne emissions dose becomes more risk significant, then NRC staff will need to evaluate the air monitoring program in greater detail.

This factor will be closed at the end of the assumed 100-year institutional control period or when operational doses are expected to be reduced to non-risk-significant levels following tank closure activities.

5.3 Monitoring Factor 7.3: As Low As Is Reasonably Achievable

The NRC regulation at 10 CFR 20.1003 defines ALARA in relevant part:

ALARA … means making every reasonable effort to maintain exposures to radiation as far below the dose limits … as is practical consistent with the purpose for which the … activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

10 CFR 835 and relevant DOE Orders, which establish DOE regulatory and contractual requirements for DOE facilities and activities, establish a definition of ALARA that is similar to the definition at 10 CFR 20.1003. DOE regulation at 10 CFR 835.2 defines ALARA as "… the approach to radiation protection to manage and control exposures (both individual and collective) to the work force and to the general public to as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations."

Furthermore, the DOE regulation at 10 CFR 835.101(c) requires the contents of each radiation protection program (RPP) to include formal plans and measures for applying the ALARA process to occupational exposure. As such, NRC staff's monitoring of ALARA under 10 CFR 61.43 will be carried out through monitoring of the Radiation Protection Program and related activities.

NRC staff should periodically (or at the appropriate time relevant to each measure) review documents associated with the following measures for ensuring ALARA: (i) a documented RPP; (ii) a Documented Safety Analysis; (iii) radiological design for protection of occupational workers and the public; (iv) regulatory and contractual enforcement mechanisms; (v) access controls, training, and dosimetry; and (vi) occupational radiation exposure history. These measures are described in the waste determination or basis documents (DOE/SRS–WD–2012–001 and DOE/SRS–WD–2014–001).

This factor will be closed at the end of an assumed 100-year institutional control period or when operational doses are expected to be reduced to non-risk-significant levels following tank closure activities.

6 MONITORING TO ASSESS COMPLIANCE WITH 10 CFR 61.44

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.

These requirements relate to both stability of the disposal site and control of releases within acceptable limits. Ensuring site stability helps to minimize the access of water to the residual waste by helping to maintain the performance of the closure cap. In addition, site stability is important in protecting against inadvertent intrusion.

The MA for site stability includes FEPs that are external to the individual disposal facility components (e.g., settlement of the subsurface) that may impact individual barrier performance. FEPs that are internal to the individual components (e.g., grout shrinkage, erosion of the topsoil layer) are discussed under the relevant POs and MAs.

Importance of MA 8, "Site Stability"

Site stability is an integral aspect to limiting the infiltration through the disposal site and in maintaining an adequate barrier to intrusion. The key attributes responsible for providing stability of the tank farms are the grouting of the HLW tanks and annular spaces and the erosion protection designs associated with the closure cap. The DOE assumes that tank grout used to fill the tanks will create a solid monolith with little void space and eliminate differential settlement due to structural collapse of the tanks.

Site stability could be affected by settlement. Settlement could lead to cracking of the vault concrete and tank grout. Cracking is not expected to result in significant structural tank collapse; however, the integrity of the vault concrete and tank grout is important to steel liner performance and waste release, as discussed under MF 3.1. Settlement may impact the hydraulic performance of the closure cap due to (i) modifications of the closure cap slope and surface drainage patterns and (ii) disruption to closure cap components (e.g., HDPE/GCL composite layer, foundation layer, lateral drainage layer). The erosion protection design is important in maintaining a minimum of 3 m [10 ft] of clean material above the tanks and significant ancillary equipment, which is discussed in Chapter 4.

NRC Monitoring Under MA 8, "Site Stability"

Because other MFs related to site stability are discussed in the preceding chapters, monitoring activities to assess compliance with 10 CFR 61.44 will focus on settlement.

6.1 Monitoring Factor 8.1: Settlement

Settlement could result from (i) increase in overburden from the tank grout and closure cap and (ii) the ongoing dissolution of calcareous sediment in the lower portion of the UTRA (i.e., the Santee Formation). Increased loading resulting from the increase in overburden may lead to compression of subsurface layers and consequently, differential settlement. Differential settlement has the potential to disrupt the HDPE/GCL composite layer, which acts as a significant barrier to infiltration in the early part of the performance period. Hydraulic isolation of the residual waste during this period is important in the retention of short-lived radionuclides before significant decay. Differential settlement may also affect the continuity and therefore performance of the foundation layer and lateral drainage layer, both of which act as long-term barriers to infiltration. DOE should account for the potential effects of the additional overburden of the engineered barriers on site stability. Technical reviews and onsite observations of settlement will be conducted by the NRC staff to assess compliance with 10 CFR 61.44. Reviews will focus on (i) settlement data collected during closure operations of the tank farms, (ii) settlement data collected from analogous sites, and (iii) updated settlement modeling investigations.

In addition to settlement from loading, settlement may result from the dissolution of calcareous sediment. Elevated bicarbonate ion concentrations and relatively high pH groundwater in and near the Santee Formation suggests ongoing dissolution of the calcareous zones within the lower zone of the UTRA (U.S. Army Corps of Engineers, 1952). Although dissolution of calcareous sediment may be a very slow process, DOE has not demonstrated that dissolution will be insignificant to site stability throughout the performance period. Such dissolution previously has created a soil structure that is characterized by arching, underconsolidation, and historic, periodic collapses. The U.S. Army Corps of Engineers (1952) identified seven surface depressions (i.e., Carolina Bays) thought to be sinks within F-Area, including one sink located within the 100-m [330-ft] compliance boundary. In H-Area, several depressions are outlined as potential sinks. However, the authors noted that the amount of drilling in H-Area was insufficient to interpret the geology in detail. DOE's calculations do not account for the stability of calcareous soft zones in the Santee Formation, given the additional overburden that is to be contributed by waste-stabilizing grout and the engineered closure cap, or for additional subsidence that could occur as a result of future dissolution of subsurface material during the performance period. DOE should account for the potential effects of future dissolution of calcareous zones on ground subsidence over the long-term period of performance or demonstrate that future dissolution of calcareous sediment will be insignificant to site performance. Technical reviews related to the risk significance of calcareous zones will be conducted to assess compliance with 10 CFR 61.44. Reviews will focus on (i) processes that have resulted in the formation of sinks at the SRS and specifically at the tank farms at the General Separations Area, (ii) the potential for these processes to affect site stability throughout the performance period, and (iii) the potential dose consequences from subsidence related to dissolution of calcareous sediment. DOE stated that it will consider static-loading-induced settlement, seismically induced liquefaction and subsequent settlement, and seismically induced slope instability in the final design of the closure cap. NRC staff will review DOE's consideration of these processes as information is made available.

Compliance or noncompliance with the PO for 10 CFR 61.44 is associated with the status of the aforementioned monitoring activities. If surveillance, monitoring, and custodial care are carried out after closure, NRC staff expects DOE to inform it of changes to features in the immediate area that might affect site stability. These changes may include (i) vegetation denudation at the surface due to fires or storms; (ii) erosion features caused by extreme precipitation events or long-term processes; or (iii) visible surface changes due to significant biotic intrusion, earthquakes, or other geological processes.

6.2 Closure of MA, 8 "Site Stability"

To assess compliance with 10 CFR 61.44, NRC staff will visually observe the facility for obvious signs of degeneration of the facility. For example, evidence of ponded water on the cap surface may be a sign of differential settlement. Surface fractures may be evidence of underlying displacement. NRC staff also may plan site visits to observe the facility after severe weather events (e.g., storms, tornados) to ascertain how well the facility can withstand these events.

DOE is expected to carry out an active maintenance program for the facility through the end of the institutional control period; therefore, DOE should repair any obvious signs of facility degradation. However, such degradation can provide insights into potential long-term facility performance. NRC staff should also discuss any maintenance activities that are performed at the disposal facility (e.g., repairs to engineered surface barriers) with SCDHEC. This monitoring activity is expected to remain open indefinitely.

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APPENDIX A
CROSSWALK OF CONSULTATIVE RECOMMENDATIONS TO MONITORING FACTORS LISTED IN THIS PLAN

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
MA 1, "Inventory"					
1	10 CFR 61.41 10 CFR 61.42	In the FTF and HTF TERs, NRC recommended that DOE sample each tank following waste retrieval operations for the purpose of developing a final inventory.	Factors 1.1—Final Inventory and Risk Estimates Factor 1.2—Residual Waste Sampling	Medium to High Risk Medium Difficulty As tanks are cleaned and sampled	FTF TER pgs. 107, 178 HTF TER pgs. xx, 4-36, 4-168
2	10 CFR 61.41 10 CFR 61.42 Including ALARA	In the FTF TER, NRC recommended that DOE better explain intratank waste variability that influences waste characterization and uncertainty evaluation. NRC's comments were expressed in the context of Tank 18F sampling, but also pertain to future characterization of other tanks. Specifically, NRC commented on (i) lack of explanation regarding differences between past and current sample variability, (ii) potential lack of consideration and explanation of the unexpectedly high tank wall concentrations for Pu-238, and (iii) lack of basis for assumptions regarding normality of sample concentrations and volume estimates when calculating inventory multiplier to be used in the probabilistic analysis.	Factor 1.2—Residual Waste Sampling (This recommendation is also related to Factor 6.2, Model and Parameter Support)	Medium Risk Medium Difficulty As tanks are sampled and special analyses are prepared	FTF TER pgs. 46, 47, 48, 127
3	10 CFR 61.41 10 CFR 61.42	In the TERs for FTF and HTF, NRC staff recommended that DOE continue to evaluate its HRR list and provide sufficient justification for any changes as additional information becomes available. The HRR list should be evaluated especially where it is used to inform decisions, such as the selection of radionuclides characterized in residual waste, selection of treatment technologies, and the screening of radionuclides for the purpose of detailed PA calculations.	Factor 1.1 – Final Inventory and Risk Estimates Factor 1.2—Residual Waste Sampling	Low to Medium Risk Low Difficulty When developing HRR list and when characterizing residuals	FTF TER pg. 51 HTF TER pgs. xvii, 3-20, 3-30, 3-31, 3-55
4	10 CFR 61.41 10 CFR 61.42 Including ALARA	In the FTF TER, NRC recommended that DOE consider improvements to residual material mapping and consideration of uncertainty in volume estimates.	Factor 1.3—Residual Waste Volume	Medium Risk Medium Difficulty 1 to 5 Years	FTF TER pgs. 43, 48, 79 HTF TER pgs. xvii, 3-21, 3-25, 3-55

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		In the HTF TER, NRC staff repeated recommendations related to volume estimations from the Inventory TRR (ML13085A291) for FTF Tanks 5F and 6F (see Table B–1).		Next tank mapping	
5	10 CFR 61.41 10 CFR 61.42	In the HTF TER, the NRC staff repeated recommendations from the Inventory TRR (ML13085A291) for Tanks 5F and 6F related to sampling.	Factor 1.2—Residual Waste Sampling	Low to Medium Risk Low Difficulty When characterizing residuals	HTF TER pg. 3-26
6	10 CFR 61.41 10 CFR 61.42 Including ALARA	DOE indicates, in response to NRC comment (SRR–CWDA–2009–00054, Rev. 0), its intent to verify PA assumptions regarding transfer line inventories consistent with Section 8.2, “Further Work,” in DOE’s PAs (SRS–REG–2007–00002, Rev. 1 and SRR–CWDA–2010–00128, Rev. 1).	Factor 1.4—Ancillary Equipment Inventory	Low to Medium Risk Low Difficulty 1 to 5 Years	FTF TER pg. 49 HTF TER pg. 3-24
7	10 CFR 61.41 10 CFR 61.42	In the HTF TER, NRC staff recommended that DOE revise its annulus inventory assumptions in the HTF PA if plans to clean the annuli of Tanks 9H, 10H, and 14H change.	Factor 1.1—Final Inventory and Risk Estimates	Low to Medium Risk Low Difficulty	HTF TER pg. 3-24
8	Criterion 2—Removal to the Maximum Extent Practical 10 CFR 61.41 ALARA	In the FTF TER, NRC recommended DOE more fully evaluate costs and benefits of additional HRR removal, including (i) consideration of benefits of additional HRR removal over longer performance periods (and considering uncertainty in the timing of peak doses), (ii) justification for assumptions regarding alternative cleaning technology effectiveness, and (iii) comparison of costs and benefits of additional HRR removal to similar DOE activities. In the HTF TER, NRC indicated that DOE provide a clear linkage between the Criterion 2 evaluation and the PA results, including consideration of the long-term risks associated with the HTF facility, and indicated	Factor 1.5—Waste Removal As It Pertains to ALARA	Medium Risk Medium Difficulty As tanks are cleaned	FTF TER pgs. 80, 81 HTF TER pgs. xviii, 3-52, 3-56

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	Performance Objective	Recommendation or Comment	Monitoring Factor†	Risk, Difficulty, and Timing Ranking	TER Page No.
		that sufficient detail was not provided in the waste determination to ensure consistent format and appropriate content for future cost-benefit analyses.			
9	Criterion 2—Removal to the Maximum Extent Practical 10 CFR 61.41 ALARA	In the HTF TER, NRC staff indicated that it does not have confidence that DOE has adequately evaluated the risk associated with the projected inventory of the Tank 16H annulus. The NRC staff recommended that DOE evaluate a waste release scenario due to groundwater in-leakage into and out of the annular region and contacting the high-solubility waste in the annuli of those tanks.	Factor 1.5—Waste Removal As It Pertains to ALARA		HTF TER pgs. 3-51, 3-54
MA 2, "Waste Release"					
10	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC recommended DOE perform experiments to verify validity of Geochemist's Workbench calculations used to determine solubility-limiting phases, solubility limits, and chemical transition times. These experiments should study (i) pH and Eh evolution of the grout pore water over time, (ii) controlling solubility-limiting phases, and (iii) static and dynamic leach tests to study the mobility of HRRs, including consideration of alteration of tank residuals following chemical cleaning with reagents, such as oxalic acid. In the HTF TER, NRC staff reiterates its FTF recommendation that DOE conduct waste release experiments to (i) distinguish between releases from high solubility compounds and low solubility compounds via semi-dynamic leach tests and (ii) determine constant concentrations of elements of concern under conditions of exposure to local groundwater and grout leachate via static tests.	Factor 2.1—Solubility-Limiting Phases/Limits and Validation Factor 2.2—Chemical Transition Times	High Risk Medium to High Difficulty Short to Intermediate Term	FTF TER pgs. 134, 178 HTF TER pgs. xx, 4-22, 4-84, 4-157, 4-167
11	10 CFR 61.41 10 CFR 61.42	The NRC staff recommends that DOE include dissolved oxygen concentrations in its modeling that are consistent with measurements of unimpacted groundwater across SRS or collect additional dissolved	Factor 2.2—Chemical Transition Times and Validation	Medium to High Risk Low to Medium Difficulty	HTF TER pg. 4-76

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		oxygen measurements within the HTF at locations and elevations that are in closer proximity to the tanks.		Intermediate Term	
		MA 3, “Cementitious Material Performance”			
12	10 CFR 61.41 10 CFR 61.42	In the HTF TER, NRC staff indicated that DOE should conduct a more comprehensive analysis of contaminant release from the annular regions of Types I and II tanks. Dose projections from the potential release of the radionuclides in the annuli and sand pads are likely to be very sensitive to several key assumptions, which should be well supported. These assumptions include, but are not limited to, (i) the assumed release scenario; (ii) the chemical composition of the infiltrating water; (iii) the volumetric flow rate through grouted tanks, including shrinkage gaps and cracks; and (iv) the solubility of the annulus and sand pad waste. NRC staff also indicated that if the possibility of rise and fall of the water table in the vicinity of the Types I and II tanks cannot be excluded, DOE should evaluate a scenario where water drains from any gaps in the annulus and sand pad regions.	Factor 3.1—Hydraulic Performance of Concrete Vault and Annulus (As it Relates to Steel Liner Corrosion and Waste Release) Factor 3.2—Groundwater Conditioning via Reducing Grout Factor 3.3—Shrinkage and Cracking of Reducing Grout Factor 3.5—Vault and Annulus Sorption	Medium to High Risk Significance Medium Difficulty Short and Intermediate Term	HTF TER pgs. xx, 4-75, 4-82, 4-85, 4-168, 5-1
13	10 CFR 61.41 10 CFR 61.42	In the FTF and HTF TERs, NRC staff recommended that DOE consider uncertainty in initial conditions and performance lifetime of concrete vaults, because they impact uncertainty in the calculated steel liner failure times.	Factor 3.1—Hydraulic Performance of Concrete Vault and Annulus (as it relates to steel liner corrosion and waste release)	Medium to High Risk Medium Difficulty Long-Term Activity (need contingent on other factors)	FTF TER pgs. 120–128 HTF TER pg. 4-58
14	10 CFR 61.41 10 CFR 61.42	In the FTF and HTF TERs, NRC recommended DOE obtain greater support for its assumption regarding flow through the tank grout (i.e., fracture versus matrix) flow as it impacts the timing of chemical transition or time to release of HRRs at risk-significant solubility. If found to be risk significant, DOE should consider the appropriateness of using moisture characteristic curves for matrix	Factor 3.2—Groundwater Conditioning via Reducing Grout Factor 3.3—Shrinkage and Cracking of Reducing Grout	Medium to High Risk Medium to High Difficulty Intermediate to Long-Term (need contingent on other factors)	FTF TER pgs. 126–127 HTF TER pgs.4-62, 4-75–4-76

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		materials to simulate fracture flow. In the HTF TER, NRC staff recommended that DOE provide more support for the assumption that the engineered system will not interfere with the ability of the overlying grout to sufficiently condition the infiltrating water for the fully and partially submerged tanks.			
MA 3, "Cementitious Material Performance"					
15	10 CFR 61.41 10 CFR 61.42	In the FTF and HTF TERs, NRC staff commented that given the wide range of values in the literature, NRC recommends DOE obtain additional support for basemat K_ds for Pu and Np, including consideration of solubility affects from previous evaluations and representativeness of experimentally derived values for aged concrete. DOE should continue to evaluate the appropriateness of selected transport parameters (e.g., cementitious material and soil K_ds) and the selection of sorption models during the monitoring period.	Factor 3.5—Vault and Annulus Sorption	Medium to High Risk Medium to High Difficulty Intermediate Term	FTF TER pgs. 128, 178 HTF TER pgs. xx,4-79, 4-83, 4-85, 4-168
MA 4, "Natural System Performance"					
16	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC recommended DOE evaluate appropriateness of averaging K_ds of multiple oxidation states to simulate the transport of Pu in the natural system. Consistent with the recommendation in the FTF TER, in the HTF TER, NRC staff indicated that a more accurate representation of the transport of multivalent plutonium would be to treat the two species separately, assuming the oxidation state distribution could be reasonably quantified. In the HTF TER, NRC staff also questioned the basis for the sandy sediment K_d for plutonium of 650 mL/g derived from SRNL–	Factor 4.1—Natural Attenuation of Key Radionuclides	Medium to High Risk Short-Term Intermediate Term	FTF TER pg. 129 HTF TER pgs. xx, 4-80, 4-114

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		STI–2011–00672, as well as the cement leachate factors that were derived based on Hanford data (SRNL–STI–2009–00473)..			
17	10 CFR 61.41 10 CFR 61.42	In the FTF and HTF TERs, NRC recommended that DOE continue to evaluate significance of calcareous zone dissolution on FTF flow and transport, including conduct of tracer studies and field mapping of seepage locations along Upper Three Runs Creek. Site-specific K_ds may also need to be developed for the UTRA-LZ.	Factor 4.2—Calcareous Zone Characterization Factor 6.2—Model and Parameter Support	Medium Risk Low to Medium Difficulty Next PA Updatem (Long Term)	FTF TER pgs. 146, 147, 149, 150, 178 HTF TER pgs. 4-115, 4-105
MA 5, "Closure Cap Performance"					
18	10 CFR 61.41 10 CFR 61.42 10 CFR 61.44	In the FTF and HTF TERs, NRC recommended DOE provide additional model support for (i) the long-term hydraulic conductivity of the upper foundation layer and lateral drainage layer and (ii) the long-term erosion of the topsoil layer.	Factor 5.1—Long-Term Hydraulic Performance of the Closure Cap Factor 5.2—Long-Term Erosion Protection Design	Low to Medium Risk Medium Difficulty Long-Term Activity	FTF TER pgs. 104, 105 HTF TER pg. 4-33
19	10 CFR 61.41 10 CFR 61.42 10 CFR 61.44	In the FTF and HTF TERs, NRC recommended DOE conduct a preliminary evaluation of erosion protection designs (e.g., assessment of an acceptable rock source, and the ability of an integrated drainage system to accommodate design features) prior to completing the final closure cap design.	Factor 5.1—Long-Term Hydraulic Performance of the Closure Cap Factor 5.2—Long-Term Erosion Protection Design	Low to Medium Risk Low Difficulty Intermediate to Long-Term Activity	FTF TER pgs. 104, 105 HTF TER pg. 4-34
MA 6, "Performance Assessment Maintenance"					
20	10 CFR 61.41 10 CFR 61.42	As documented in the FTF TER, DOE will explain the differences in the inventory lists for tanks versus ancillary equipment in future PA documentation. DOE made this commitment in an NRC/DOE teleconference on the FTF RAIs held on June 28, 2011 (ML111920367).	Factor 6.2—Model and Parameter Support	Low Risk Low Difficulty Next PA Update	FTF TER pg. 49
21	10 CFR 61.41 10 CFR 61.42	In the HTF TER, NRC staff repeated an FTF technical review report (ML13273A299) comment indicating that DOE should provide a stronger technical basis for the projected inventory multipliers used in the probabilistic analysis. Given the significant fraction of the Tank 5F and 6F radionuclide inventories that	Factor 6.2—Model and Parameter Support	Low Risk Low Difficulty Next PA Update	HTF TER pgs. 3-21

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		were underestimated, it was not clear to the NRC staff that the inventory multipliers should be biased at 100 times less and only 10 times higher. NRC staff went on to state that DOE should analyze trends in projections versus actual inventories by radionuclide to update the multiplier assumptions for the probabilistic analysis.			
22	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC staff recommended DOE perform a systematic scenario analysis in which FEPs are identified, screened, and dispositioned using transparent and traceable documentation of the FEPs considered, the screening arguments, and how FEPs are implemented in the models to support future waste determination efforts. DOE performed a FEPs analysis to support the final waste determination for FTF. NRC staff reviewed the FEPs analysis and documented the results of its review in a technical review report (ML13277A063; see also Table B–1) In the HTF TER, similar to the findings in the technical review report for FTF, NRC staff recommended that DOE include subject matter experts on the screening team in the specific engineering and scientific disciplines that are pertinent to the professional judgments being made. NRC staff noted that the screening documentation could be more transparent. The NRC staff also recommended that DOE improve the transparency and traceability of its implementation of FEPs to ensure comprehensive, accurate, and traceable links to clear descriptions of how included FEPs are actually implemented in the HTF PA.	Factor 6.1—Scenario Analysis	Low to Medium Risk Medium Difficulty Next PA Update	FTF TER pgs. 12, 14, 92, 93, 95, and 178 HTF TER pgs. 4-18–4-21, and 4-24
23	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC staff recommended DOE consider uncertainty in steel liner performance, including more aggressive service conditions and corrosion mechanisms	Factor 6.2—Model and Parameter Support	Medium to High Risk Medium to High Difficulty	FTF TER pg. 121 HTF TER pgs. 4-58, 4-60

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		than assumed in the PA, as well as a patch model for waste release, if deemed to be risk significant. In the HTF TER, similar to previous FTF consultative comments, NRC staff also questioned DOE's assumed time-invarient oxygen diffusivity of 10^{-6} cm^2/s given expected degradation of concrete vaults over time and potential presence of bypassing pathways through the system.		Long-Term Activity (need contingent on other factors)	
24	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC recommended DOE obtain additional support for probabilistic parameter distributions, including solubility limiting phases, cement K_ds (based on sediment variability), chemical transition times, basemat bypass, and configuration probability. In the HTF TER, NRC staff recommended DOE incorporate in probability distributions "pessimistic" values that exceed base case solubility limits and that DOE obtain support for the solubilities and probability assignments.	Factor 6.2—Model and Parameter Support	Medium Risk Medium to High Difficulty Intermediate-Term	FTF TER pgs. 130–132 HTF TER pg. 4-73
25	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC recommended DOE acquire FTF specific data to support material property assignments, including hydraulic conductivity, moisture characteristic curves, and K_ds.	Factor 6.2—Model and Parameter Support	Low to Medium Risk Medium Difficulty Long-Term	FTF TER pgs. 128–129
26	10 CFR 61.41 10 CFR 61.42 10 CFR 61.44	In the HTF TER, NRC staff recommended that DOE provide additional model support to understand the effects of perimeter infiltration and focused infiltration in the drainage valley between the East and West Caps on near-field and far-field groundwater flow patterns and radionuclide transport. The analysis should include appropriate refinement of the grid cells receiving recharge and a well-supported value for the diversion of flow.	Factor 6.2—Model and Parameter Support	Low Risk Significance Medium Difficulty Prior to final closure	HTF TER pgs. 4-31, 4-33–4-34
27	10 CFR 61.41	In the FTF TER, NRC staff indicated that it	Factor 6.2—Model and	Low to Medium Risk	FTF TER pg. 127

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
	10 CFR 61.42	would monitor DOE’s efforts to study the impact of cement leachate on radionuclide mobility. NRC reviewed cement leachate factors utilized in the HTF PA and listed several technical concerns in the HTF TER, most notably the lack of site-specific information and basis for some of the factors.	Parameter Support	Medium Difficulty Long-Term	HTF TER pg. 4-80
28	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC staff recommended that DOE address the significant amount of dispersion evident in its near-field and far-field PORFLOW models, including evaluation of the need for mesh refinement to ensure that contaminant plumes are not artificially dispersed over the volume of the cells in the far-field model. Nonphysical dispersion may be attributable to large changes in adjacent element size and large differences in element sizes between the vadose zone and far-field models. DOE should evaluate the adequacy of the time discretization of the model(s) for high mobility constituents such as Tc-99.	Factor 6.2—Model and Parameter Support	Medium Risk Low to Medium Difficulty Next PA Update	FTF TER pgs. 149–150
29	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC recommended that DOE evaluate the appropriateness of the assumed level of physical dispersion in the FTF model (i.e., dispersivities).	Factor 6.2—Model and Parameter Support	Medium Risk Low to Medium Difficulty Next PA Update	FTF TER pgs. 149, 178
30	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC staff recommended DOE provide greater transparency and traceability of far-field model calibration, including consideration of more extensive calibration focused strictly on the area of interest. In the HTF TER, NRC staff made recommendations similar to those in the FTF TER, but more strongly indicated that the model may not be sufficiently calibrated local to HTF, and recommended specifically that	Factor 6.2—Model and Parameter Support	Medium Risk Medium to High Difficulty Next PA Update	FTF TER pg. 178 HTF TER pgs. xx, 4-107–111, 4-115, 4-168

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	Performance Objective	Recommendation or Comment	Monitoring Factor†	Risk, Difficulty, and Timing Ranking	TER Page No.
		DOE study uncertainty in calibration targets and provide support for hydraulic conductivity assignments (K_h was artificially lowered in elliptical regions during the calibration process), including consideration of conducting pumping tests to provide support for the model and model parameters.			
31	10 CFR 61.41 10 CFR 61.42	NRC staff indicated in the FTF TER that Gordon Aquifer concentrations should not be used to demonstrate compliance with the POs if higher concentrations are observed in another aquifer that can support groundwater-dependent pathways. These statements were repeated in the HTF TER.	Factor 6.2—Model and Parameter Support	Medium Risk Low Difficulty Next PA Update	FTF TER pgs. 147–148 HTF TER pg. 4-113
32	10 CFR 61.41 10 CFR 61.42	In the HTF TER, NRC staff recommended that DOE evaluate the compliance boundary and loading of the contaminant source cells (i.e., tank cells in the far-field model) to ensure that the dose estimates are not significantly underestimated.	Factor 6.2—Model and Parameter Support	Low to Medium Risk Low Difficulty Next PA Update	HTF TER pg. 4-115
33	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC recommended DOE evaluate plant transfer factor uncertainty in future updates to its PA. DOE should consider the appropriateness of excluding common vegetable types in its assignment of plant transfer factors (DOE only considers root vegetable data) based on production data rather than household data that might be more appropriate for a resident gardener. In the HTF TER, NRC staff indicated that DOE addressed the use of root vegetable transfer factors; however, uncertainty in plant transfer factors was not addressed.	Factor 6.2—Model and Parameter Support	Low to Medium Risk Medium difficulty Next PA Update	FTF TER pg. 153 HTF TER pg. 4-117
34	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC staff recommended that DOE evaluate the appropriateness of assumptions related to drinking water consumption in future updates to its PA, such as partitioning consumption rates based on use of both bottled and community water. Biosphere parameters should be reasonably	Factor 6.2—Model and Parameter Support	Low to Medium Risk Low Difficulty Next PA Update	FTF TER pgs. 153–154 HTF TER pg. 4-117

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		conservative and reflect the behavior of the average member of the critical group. NRC staff reiterated the FTF TER recommendation in the HTF TER.			
35	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC staff indicated that DOE better assess uncertainty in the timing of peak dose, given the inherent level of uncertainty associated with predicting doses over tens of thousands of years. Additionally, NRC staff indicated that key parameters, such as steel liner failure times and chemical transition times, may be overly constrained.	Factor 6.2—Model and Parameter Support	Medium to High Risk Medium Difficulty Next PA Update	FTF TER pgs. 167, 168, 169
36	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC staff recommended DOE provide additional support for the likelihood of its base case or expected Case A. In the HTF TER, NRC staff went on to state the NRC staff thinks that additional information is needed to support the compliance case, Case A. Ideally, supporting information would be in the form of additional experimental or field data, natural analogs, peer review, expert elicitation, and other forms of model support. NRC staff stated that without this additional model support, it would be difficult to argue the relative likelihood of the base case compared to alternative cases. Additionally, NRC staff indicated that the uncertainty analysis results not be used to demonstrate compliance with the POs because (i) there is limited support for the base case and (ii) there is limited support for the assignment of the likelihood of alternative cases and consequently, the averaging of alternative cases in the “All Cases” model. NRC staff recommended that DOE present the results of alternative cases individually and provide qualitative information regarding the likelihood of alternative cases.	Factor 6.2—Model and Parameter Support	Medium to High Risk Medium to High Difficulty Next PA Update	FTF TER pgs. 167, 168, 170 HTF TER pgs. 4-157, 4-161

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		Finally, NRC staff indicated that DOE should use the results of its probabilistic analysis to inform areas where additional model support is needed.			
37	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC staff recommended DOE improve transparency and documentation of its benchmarking process. NRC recommends DOE apply a more methodical and systematic approach to the benchmarking process in future updates to its PA. In the HTF TER, NRC staff also noted that DOE could improve its benchmarking process.	Factor 6.2—Model and Parameter Support	Medium Risk Medium Difficulty Next PA Update	FTF TER pg. 171 HTF TER pg. 4-166
38	10 CFR 61.42	In the HTF TER, NRC staff noted that due to significant differences between the GoldSim™ and PORFLOW™ modeling results, the NRC staff plans to continue to evaluate the PORFLOW™ modeling assumptions and results for the compliance case (Case A) during the monitoring period to provide confidence that the timing of peak dose is not artificially delayed. This applies to the inadvertent intruder analysis.	Factor 6.2—Model and Parameter Support	Medium Risk Medium Difficulty Next PA Update	HTF TER pg. 4-125
39	10 CFR 61.41 10 CFR 61.42	In the FTF TER, NRC staff suggested that DOE consider consistency between the plotting interval and calculation time step size. DOE should also correct errors in its probabilistic assessment (e.g., porosity of 1 × $^{-20}$).	Factor 6.2—Model and Parameter Support	Low to Medium Risk Low Difficulty Next PA Update	FTF TER pgs. 147–148
40	10 CFR 61.41 10 CFR 61.42	NRC made a general comment that DOE could improve its parameter distribution assignments, hybrid modeling approach, benchmarking process, and evaluation and interpretation of probabilistic modeling results. With respect to parameter distributions, NRC included several items in its open items database (see Appendix B in ML12212A192), most of which are listed in other recommendations, with the exception of probability of basemat bypass flow.	Factor 6.2—Model and Parameter Support	Medium Risk Medium Difficulty Next PA Update	FTF TER pg. 177

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
MA 7, "Protection of Individuals During Operations"					
41	10 CFR 61.43	DOE can demonstrate compliance with protection of individuals during operations. DOE provides adequate information that individuals will be protected during operations.	Factor 7.1—Protection of Workers During Operations Factor 7.2—Air Monitoring	Low Risk Low to Medium Difficulty Ongoing	FTF TER pg. 174 HTF TER pg. 4-161
MA 8, "Site Stability"					
42	10 CFR 61.44	In the FTF and HTF TERs, NRC staff recommended DOE continue to evaluate closure cap settlement and stability, including consideration of (i) increased overburden from the tank grout and closure cap on settlement and (ii) potential for subsidence associated with ongoing dissolution of calcareous sediment in the Santee Formation.	Factor 8.1—Settlement	Medium Risk Medium to High Difficulty Intermediate-Term	FTF TER pg. 176 HTF TER pg. 4-164
43	10 CFR 61.41 10 CFR 61.42 10 CFR 61.44	In the FTF and HTF TERs, NRC staff concluded that assumed long-term compressive strength of the grout monolith is not adequately supported and may be optimistic based on observations of vault cracks, discussed in TER Section 4.2.9.1 (ML112371751). While cracking of the vault concrete and tank grout is not expected to result in significant structural tank collapse, the integrity of the vault concrete and tank grout is important to steel liner performance and waste release.	Factor 8.1—Settlement	Medium Risk Medium to High Difficulty Intermediate-Term	FTF TER pg. 175 HTF TER pg. 4-163
Other TER Recommendations					
44	Criterion 2—Technology Selection	In the FTF TER, NRC staff recommended DOE specifically consider and evaluate HRR removal in its technology selection and effectiveness evaluations consistent with the NDAA. In the HTF TER, NRC staff recommended that DOE provide more emphasis on removal of HRR in its technology selection process and provide a clear linkage between the HTF PA results, including information regarding the	TER Recommendation Only	NA	FTF TER pgs. 55, 56, 79 HTF TER pg. xviii HTF TER pgs. 3-55, 3-38

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		long-term risks associated with the HTF facility, and the demonstration that HRRs have been removed to the MEP per Criterion 2.			
45	Criterion 2—Technology Selection	In the FTF TER, NRC staff recommended DOE continuously evaluate new technologies, participate in technology exchanges, and not default to previous evaluations for technology selection. In the HTF TER, NRC staff recommended that DOE continue evaluating new technologies for future use as tank closure progresses, especially if previously used technologies are no longer practical to use. Furthermore, for those tanks in which conditions are dissimilar (e.g., Tank 48), the NRC staff would expect DOE to reevaluate technologies as opposed to relying on previously performed technology evaluations. The NRC staff also recommended that DOE continue its efforts to participate in technology exchanges so that it can stay informed of potential new cleaning technologies. New technologies or improvements to current technologies should be fully considered in the selection process for future tank cleaning. DOE should try to optimize operational parameters for existing technologies and technologies to be developed in the future to ensure that removal of HRRs is not hampered or made more difficult because of poor planning or lack of investment in waste characterization.	TER Recommendation Only	NA	FTF TER pgs. 77, 78, 79 HTF TER pgs. xviii, 3-55, 3-37, 3-38, 3-49, 3-51, 3-52
46	Criterion 2 – Technology Implementation and Optimization	In the HTF TER, NRC staff indicated that DOE's approach to optimization of technology through sampling and monitoring during cleaning should be documented. The NRC staff also recommended that DOE	TER Recommendation Only	NA	HTF TER pgs. 3-49, xviii, 3-56

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		consider how it might better assess and optimize the effectiveness of selected technologies (e.g., obtain better baseline information).			
47	Criterion 2 – Technology Implementation and Optimization	In the HTF TER, NRC staff noted that, although the results from mapping contain uncertainties, performing the tank mapping methodology during multiple cleaning phases will provide additional information on the effectiveness of specific technologies. As such, the NRC staff recommended that DOE perform the tank mapping consistently and as frequently as practical throughout the cleaning process.	TER Recommendation Only	NA	HTF TER pg. 3-49
48	Criterion 2 – Technology Implementation and Optimization	In the HTF TER, NRC staff recommended that DOE should obtain better baseline information from which it could better assess oxalic acid effectiveness.	TER Recommendation Only	NA	HTF TER pgs. 3-49, 3-51
49	Criterion 2 – Technology Implementation and Optimization	In the HTF TER, NRC staff supported DOE's efforts to re-evaluate oxalic acid cleaning against downstream impacts to determine the future role of oxalic acid cleaning, as opposed to relying on previous evaluations of oxalic acid technology.	TER Recommendation Only	NA	HTF TER pg. 3-51
50	Criterion 2 – Technology Implementation and Optimization	In the HTF TER, NRC staff noted that each final characterization should be accompanied by a Technical Task Request and a Quality Assurance and Quality Control Plan.	TER Recommendation Only	NA	(HTF TER pg. 3-51)
51	Criterion 2 – Technology Implementation and Optimization	In the HTF TER, NRC staff indicated that to help overcome the limitations encountered with cleaning Tanks 5F and 6F for the cleaning of future tanks, the NRC staff recommends that DOE evaluate the effectiveness of the SMPs with respect to bulk sludge removal versus residual heel removal. The NRC staff also recommends that DOE compare the efficiency and effectiveness of the SMP to previously used technologies or readily available technologies.	TER Recommendation Only	NA	HTF TER pg. 3-50
52	Criterion 2— Removal to the	In the FTF TER, the NRC staff recommended that DOE include more specificity in its	TER Recommendation Only	NA	FTF TER pgs. 77, 79–80

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	Performance Objective	Recommendation or Comment	Monitoring Factor†	Risk, Difficulty, and Timing Ranking	TER Page No.
	Maximum Extent Practical Criterion 2 – Technology Implementation and Optimization	process for determining HRRs are removed to the maximum extent practical, including (i) defining the term end states versus removal goals and (ii) clarifying when conditions are sufficiently similar to warrant use of a previous technology evaluation. NRC staff also recommended that DOE continue to better define the documented process to be used to demonstrate removal to the MEP to ensure consistent (nonarbitrary) application of the criterion. In the HTF TER, NRC staff noted that Appendix B of the draft basis for the waste determination for HTF (DOE/SRS–WD–2013–001, Rev. 0) outlines a general approach to demonstrate that the HRRs will be removed to the MEP. However, DOE could still improve the standardization of metrics for determining that the anticipated end states have been reached.			HTF TER pgs. xviii, 3-51
53	Criterion 2—Removal to the Maximum Extent Practical	In the HTF TER, NRC staff noted that if oxalic acid is not available to be used for cleaning future tanks and a technology with similar proven effectiveness is not used as an alternative, DOE may need to reconsider the validity of assuming that the cooling coil and tank wall surface inventory is negligible.	TER Recommendation Only	NA	HTF TER pgs. 3-21, 3-56
54	Criterion 3—Waste Classification	In the HTF TER, NRC staff recommended that DOE should develop separate site-specific factors for risk-significant annular waste versus tank waste sources in the future. Annular and tank sources would then be separately compared to adjusted waste classification concentration limits to determine the classification of HTF components.	TER Recommendation Only	NA	HTF TER pg. 4-7
55	Criterion 2—Removal to the Maximum Extent Practical	In the FTF TER, NRC recommended DOE more fully evaluate or document its consideration of alternatives to additional HRR removal, including (i) modifications to existing technologies (e.g., upgraded Mantis	TER Recommendation Only	NA	FTF TER pgs. 79, 81

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	**Performance Objective**	**Recommendation or Comment**	**Monitoring Factor†**	**Risk, Difficulty, and Timing Ranking**	**TER Page No.**
		or enhanced chemical cleaning); (ii) modification to tank system components (e.g., installation of new risers or removal of equipment from existing risers); (iii) sequential cleaning (e.g., sequencing of mechanical and chemical technologies in Tank 18F); and (iv) alternative cleaning technologies (e.g., alternative reagents to leach HRRs out of residual heels).			
56	Criterion 2—Removal to the Maximum Extent Practical Criterion 2 – Technology Implementation and Optimization	In the FTF TER, NRC recommended that DOE better quantify technology effectiveness. For example, DOE should better characterize waste and residual tank inventory prior to deployment of cleaning technologies to better assess effectiveness. In the HTF TER, NRC staff recommended that, to the extent practical, DOE consider obtaining data on HRR inventories prior to and following major cleaning campaigns (e.g., before and after treatment of Type I tanks with oxalic acid) to provide effectiveness measurements for chemical cleaning and mechanical feed-and-bleed.	TER Recommendation Only	NA	FTF TER pgs. 77, 79 HTF TER pg. 3-51
57	Criterion 2—Removal to the Maximum Extent Practical	In the HTF TER, NRC staff noted that given the potential risk significance of the waste remaining in the Tank 16H annulus, the NRC staff recommends that DOE more fully evaluate the practicality of additional radionuclide removal from the Tank 16H annulus versus the long-term benefit of reduced risk considering uncertainty in the releases of radionuclides from the Tank 16H annulus. While DOE's HTF PA demonstrates that the risk from waste remaining in the annulus is reasonable, alternative waste release models may lead to higher risk estimates. NRC staff went on to note that at this stage, DOE has provided a rough order of	TER Recommendation Only		HTF TER pgs. xviii, 3-56

Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*

ID	Performance Objective	Recommendation or Comment	Monitoring Factor†	Risk, Difficulty, and Timing Ranking	TER Page No.
		magnitude cost-benefit analysis of additional HRR removal from the Tank 16H annulus to the NRC staff (U–ESR–H–00107, Rev. 0). The NRC staff acknowledges that DOE is still preparing the final removal report and recommends that DOE provide a more detailed cost benefit analysis to support the Criterion 2 demonstration for Tank 16H in the final removal report. NRC staff indicated that it would like to obtain a copy of the final removal report when it is complete.			
58	Criterion 2 – Technology Implementation and Optimization	In the HTF TER, NRC staff noted that DOE improved the operating plan for Tank 12H by requiring the availability of the transfer receipt tank to be confirmed prior to acid addition. The NRC staff encourages DOE to continue to analyze the lessons learned from these prior cleaning campaigns to prevent limitations of the liquid waste system from unexpectedly influencing the effectiveness of future cleaning campaigns.	TER Recommendation Only		HTF TER pgs. xviii, 3-52

*The table is organized by Monitoring Area. The crosswalk from the consultative recommendation/comment to MFs is provided in the column "Monitoring Factor."

†NRC notes that NRC monitoring pertains to assessment of compliance with the POs in 10 CFR Part 61, Subpart C. Thus, comments or recommendations related to the NDAA criterion that waste has had HRR removed to the maximum extent practical or what NRC refers to as Criterion 2 under the NDAA is only monitored if the same comment or recommendation applies to the ability of the disposal facility to meet Criterion 3: compliance with the POs in 10 CFR Part 61, Subpart C, including the ALARA requirements found in 10 CFR 61.41 and 61.43. If Criterion 2 recommendations in NRC's TER are not tied to Criterion 3, such as ALARA, then the TER recommendations are not carried forward into monitoring.

ALARA–As Low As Is Reasonably Achievable, CFR–Code of Federal Regulations, DOE–The U.S. Department of Energy, FEP–Features, Events and Processes, FTF–F-Tank Farm, HRR–Highly Radioactive Radionuclide, HTF–H-Tank Farm, K_d–Distribution Coefficient, K_h–Hydraulic Conductivity, MEP–Maximum Extent Practical, NDAA–Ronald Reagan National Defense Authorization Act of 2005, NRC–The U.S. Nuclear Regulatory Commission, PA–Performance Assessment, PO–Performance Objective, RAI–Request for Additional Information, SMP–Submersible Mixing Pump, SRS–Savannah River Site, TER–Technical Evaluation Report, TRR–Technical Review Report, UTRA–Upper Three Rivers Aquifer,

References:

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Table A–1. Crosswalk Between Consultative Review Comments, Recommendations, and Monitoring Areas/Factors*					
ID	Performance Objective	Recommendation or Comment	Monitoring Factor†	Risk, Difficulty, and Timing Ranking	TER Page No.

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Table A–2. Crosswalk of DOE's Performance Assessment Maintenance Items to Monitoring Factors in This Plan		
DOE PA Maintenance Program Section (s)	**DOE PA Maintenance Program Title**	**Monitoring Factor**
3.1.1 4.1.1	Maintain F- and H-Area Tank Farm Performance Assessment Control through Unreviewed Waste Management Question Process	This general technical support activity can support any monitoring factor listed in this plan but is not specific to any single monitoring factor or set of monitoring factors.
3.1.2 4.1.2	Prepare Annual Performance Assessment Maintenance Program Implementation Plan	This general technical support activity can support any monitoring factor listed in this plan but is not specific to any single monitoring factor or set of monitoring factors.
3.1.3 4.1.3	Provide General Technical Support on F-and H-Area Tank Farm Performance Assessment Issues	This general technical support activity can support any monitoring factor listed in this plan but is not specific to any single monitoring factor or set of monitoring factors.
3.1.4 4.1.4	Develop and Maintain Performance Assessment Model Archive and Revision Control	Facilitates NRC staff's review of the PAs.
3.2.2 4.2.2	F- or H-Area Tank Farm Special Analyses	Monitoring Factor 1.1, Final Inventory and Risk Estimates Monitoring Factor 1.4, Ancillary Equipment Inventory
3.2.1 4.2.3	Prepare Out-Year F- or H-Area Tank Farm Performance Assessment Revisions	Monitoring Factor 6.1, Scenario Analysis Monitoring Factor 6.2, Model and Parameter Support Monitoring Factor 6.3, F-Tank Farm Performance Assessment Revisions
3.3.2 4.3.1	To Be Determined Out-Year HTF Testing & Research Activities	No specific plans listed in SRR–CWDA–2014–00108), but could include: Monitoring Factor 2.2, Chemical Transition Times Monitoring Factor 3.2, Groundwater Conditioning via Reducing Grout Monitoring Factor 3.3, Shrinkage and Cracking of Reducing Grout Monitoring Factor 3.5, Vault and Annulus Sorption Monitoring Factor 4.1, Natural Attenuation of Key Radionuclides Monitoring Factor 4.2, Calcareous Zone Characterization Monitoring Factor 5.1, Long-Term Hydraulic Performance Monitoring Factor 5.2, Long-Term Erosion Protection Design Monitoring Factor 6.1, Scenario Analysis Monitoring Factor 6.2, Model and Parameter Support Monitoring Factor 8.1, Settlement
3.3.1.1	Waste Release Studies	Monitoring Factor 2.1, Solubility Limiting Phases/Limits and Validation
2.3.1.1	Measurement of Distribution Coefficients in SRS Subsurface Sediments	Monitoring Factor 4.1, Natural Attenuation of Key Radionuclides Monitoring Factor 6.2, Model and Parameter Support

Table A–2. Crosswalk of DOE's Performance Assessment Maintenance Items to Monitoring Factors in This Plan		
DOE PA Maintenance Program Section (s)	**DOE PA Maintenance Program Title**	**Monitoring Factor**
2.3.2.2	Long-Term Radiological Lysimeter Program	Monitoring Factor 3.5, Vault and Annulus Sorption Monitoring Factor 4.1, Natural Attenuation of Key Radionuclides
2.3.2.1	Measurement of Unsaturated Permeability of Fractured Saltstone	Monitoring Factor 3.2, Groundwater Conditioning via Reducing Grout Monitoring Factor 3.3, Shrinkage and Cracking of Reducing Grout
2.3.2.3	Studies Related to Cementitious Materials Degradation Due to Radiation Damage	Monitoring Factor 3.4, Grout Performance
2.3.2.4	Closure Cap Drainage Layer Long-Term Performance	Monitoring Factor 5.1, Long-Term Hydraulic Performance of the Closure Cap Monitoring Factor 5.2, Long-Term Erosion Protection Design Monitoring Factor 5.3, Closure Cap Functions That Maintain Doses ALARA
ALARA–As Low As Is Reasonably Achievable, DOE–U.S. Department of Energy, PA–Performance Assessment, HTF–H-Tank Farm, NRC–U.S. Nuclear Regulatory Commission Reference: SRR–CWDA–2014–00108, Rev. 0. "Savannah River Site Liquid Waste Facilities Performance Assessment Maintenance Program, FY2015 Implementation Plan." Aiken, South Carolina: Savannah River Remediation, Savannah River Site. January 2015.		

APPENDIX B
CROSSWALK BETWEEN TECHNICAL REVIEW REPORTS AND MONITORING FACTORS

Table B–1. Crosswalk Between Technical Review Report Findings and Monitoring Factors

ID	Technical Review Report (TRR) Finding	TRR Monitoring Factor	Related Monitoring Factor	New Monitoring Factor
	Tanks 18F and 19F Special Analysis (ML13100A230)			
1	Although the Tanks 18F and 19F Special Analysis presented useful information on the impact of changes to solubility and K_d on the results of the analysis, the uncertainty and sensitivity analysis was not comprehensive and primarily focused on factors that served to decrease the risk. For example, the impact of preferential flow through cracks and fractures resulting in faster chemical transition times, water table rise,[1] and existence of more mobile forms of Pu were not considered in the analysis. DOE should provide sufficient information to support its base case (or rule out these processes) or provide adequate representations of these processes in performance assessment calculations used to support the compliance demonstration. Furthermore, updated geochemical modeling for Pu showed that Pu could be released much earlier than assumed in the FTF PA, upon transition to Oxidized Region II. Experimental support for updated solubility modeling is also needed. The TRR also expressed potential issues with the Pu K_d analysis, SRNL–STI–2011–00672. Issues with the Pu K_d analysis were more fully discussed in the HTF TER (ML14094A496).	Monitoring Factor 1.1, “Final Inventory and Risk Estimates”	Monitoring Factor 2.1, “Solubility Limiting Phases/Limits and Validation” Monitoring Factor 2.2, “Chemical Transition Times” Monitoring Factor 3.1, “Hydraulic Performance of Concrete Vault and Annulus” Monitoring Factor 3.2, “Groundwater Conditioning via Reducing Grout” Monitoring Factor 3.3, “Shrinkage and Cracking of Reducing Grout” Monitoring Factor 4.1, “Natural Attenuation of Key Radionuclides”[2] Monitoring Factor 4.3, “Environmental Monitoring”	
	Tanks 5F and 6F Special Analysis (ML13273A299)			
2	DOE should evaluate whether it has appropriately managed inventory uncertainty. DOE should provide a stronger technical basis for projected inventory multipliers. Additional information related to the Niobium distribution coefficient, or K_d, is needed to have reasonable assurance that DOE disposal actions at the FTF will meet the POs in 10 CFR Part 61, Subpart C.	Monitoring Factor 1.1, “Final Inventory and Risk Estimates”	Monitoring Factor 4.1, “Natural Attenuation of Key Radionuclides”[2] See Monitoring Factors listed under ID 1	Old Monitoring Factor 4.1, “Natural Attenuation of Pu” will be expanded to include natural attenuation or K_d for Nb and other key radionuclides.

[1]With respect to water table rise, NRC staff was concerned with both (i) accelerated corrosion of the steel liner and (ii) early release from Tank 18. Accelerated corrosion from water table rise is considered in Monitoring Factor 3.1, “Concrete Vault Performance.” Early release from the tanks due to water table rise is considered under Monitoring Factor 3.2, “Groundwater Conditioning.”

[2] MF 4.1 in the FTF Monitoring Plan was named, “Natural Attenuation of Pu”. MF 4.1 has been broadened to include other key radionuclides.

Table B–1. Crosswalk Between Technical Review Report Findings and Monitoring Factors				
ID	**Technical Review Report (TRR) Finding**	**TRR Monitoring Factor**	**Related Monitoring Factor**	**New Monitoring Factor**
	Finally, technical concerns identified in the NRC staff's review of the Tanks 18F and 19F Special Analysis (ML13100A230) are also applicable to the Tanks 5 and 6 Special Analysis and are not repeated in this report.			
Tanks 5F and 6F Final Inventory Development (ML13085A291)				
3	With regard to sample analysis, NRC staff identified the following issues: □DOE should consider, in its tank sampling design, historical information on tank waste receipts and information related to the alteration and redistribution of waste due to cleaning operations that may impact horizontal and vertical waste heterogeneity. □ DOE should evaluate the option to composite samples within segments (or strata) to preserve information about segment (or strata) variance. □ DOE should evaluate and present information on the relative contributions of various forms of uncertainty in its estimation of mean tank concentrations. □ DOE should clarify the statistical approach used to estimate the UCL95 (e.g., treatment of all nine measurements as independent when computing the UCL95). □ DOE should also consider how it can better assure sample representativeness by improving tank sampling designs, collection tools, and instructions. Alternatively, DOE could manage sampling and analysis uncertainty through use of estimates that clearly err on the side of higher inventories. These technical concerns do not need to be addressed until the next tank sampling effort is conducted. Ancillary equipment inventory verification and support for changes to the HRR list were also mentioned. *Tanks 5F and 6F Final Inventory Development (continued')* With regard to volume estimation, NRC staff identified the following issues: □ DOE should better understand the accuracy of mapping team height estimates through additional field validation activities for a range of solid material heights.	Monitoring Factor 1.2, "Residual Waste Sampling" Monitoring Factor 1.3, "Residual Waste Volume"	Monitoring Factor 1.1, "Final Inventory and Risk Estimates" Monitoring Factor 1.4, "Ancillary Equipment Inventory"	Issues in red text in column 2 are incorporated into Monitoring Factor 1.2, "Residual Waste Sampling," or Monitoring Factor 1.3, "Residual Waste Volume." These issues are also discussed in the HTF TER.

Table B–1. Crosswalk Between Technical Review Report Findings and Monitoring Factors				
ID	**Technical Review Report (TRR) Finding**	**TRR Monitoring Factor**	**Related Monitoring Factor**	**New Monitoring Factor**
	□ DOE should clearly communicate how it determines the size of areas to be mapped and how it manages uncertainty related to height estimates for discretized areas in its deterministic analysis. Likewise, DOE should clarify how it represents uncertainty in the assignment of high and low end heights to these areas (e.g., does it use a height that is clearly below/above the nonuniform surface of the delineated areas?). □ DOE should consider uncertainty in the volume estimates resulting from the transfer of data from photographic and video evidence to hand-contoured maps (and then to Excel spreadsheets with a finer discretization). □ DOE should be more transparent with respect to its approach to (i) mapping annular volumes including use of a crawler to inspect internal surfaces and (ii) estimating residual waste volumes in ventilation ducts. DOE should consider uncertainty in annulus volume estimates. Alternatively, volume mapping uncertainty could be managed through use of estimates that clearly err on the side of higher volumes. NRC staff will monitor DOE's visual inspection of internal surfaces to ensure no significant inventory is overlooked (e.g., Pu-238 on the walls of Tank 18F).			
Cost Benefit Analysis for Tanks 18F and 19F (ML13080A401)				
4	□ NRC staff notes that many additional costs were due to the length of time that had passed between the decision to cease removal activities and the time at which the cost-benefit analysis was performed. DOE does not expect this lapse in time for future cost-benefit analysis for other tanks. □ NRC staff also noted issues with the collective dose comparison, which only included 1 person for 50 years, although NRC also noted problems with use of collective dose. □ NRC staff questioned DOE's criteria that additional waste removal be more cost beneficial than other similar DOE activities. □ NRC staff also questioned DOE's separate consideration of cost and benefit uncertainty in its sensitivity analysis (cumulative impact of uncertainty in the costs and benefits was not	Monitoring Factor 1.5, "Waste Removal (As It Impacts ALARA)"		NRC staff has been reviewing closure module documentation early on in the process, alleviating concerns with escalation of costs due to timing of the analysis. NRC will continue to monitor DOE documentation that supports ALARA criteria.

Table B–1. Crosswalk Between Technical Review Report Findings and Monitoring Factors				
ID	**Technical Review Report (TRR) Finding**	**TRR Monitoring Factor**	**Related Monitoring Factor**	**New Monitoring Factor**
	considered). Additionally, higher removal rates (e.g., 75 percent) could have been evaluated in sensitivity analysis. Finally, NRC staff inquired about DOE plans to perform cost-benefit analyses in the future. NRC will continue to monitor DOE's process for optimizing waste removal as it impacts the ALARA criteria in 10 CFR 61.41, as tank farm closure progresses.			
Waste Release and Solubility Documentation (ML12272A082)				
5	Given the risk significance of the solubility of plutonium and consistent with previous NRC recommendations, as well as recommendations made by DOE's plutonium solubility peer review group (Cantrell, et al., 2011) and other DOE experts, NRC continues to believe that experimental verification of modeled plutonium solubility under a range of chemical conditions potentially relevant to the contaminated zone should be undertaken. NRC staff identified two follow-up actions: DOE should provide additional information to support assumptions regarding longevity of reducing conditions in the contaminated zone. Recent studies (Cantrell and Williams, 2012) suggest that the reducing capacity of the tank grout could be depleted much earlier than assumed in the FTF PA (SRS–REG–2007–00002) and in more recent Pu solubility modeling performed for Tank 18F (Denham, 2012). Uncertainty in the normative mineralogy assumed in geochemical modeling should be considered under this action. DOE should provide additional support for the assumption that the Eh of infiltrating water will remain below a critical threshold at which Pu solubility will increase to a risk-significant value (e.g., updated geochemical modeling indicates a dramatic increase in Pu solubility occurs at Eh greater than +0.45 V). Uncertainty in the critical threshold and the Eh of infiltrating groundwater should be considered under this action.	Monitoring Factor 2.1, "Solubility Limiting Phases/Limits" Monitoring Factor 2.2, "Chemical Transition Times"		Issues in red text in column 2 are incorporated into Monitoring Factor 2.1, "Solubility Limiting Phases/Limits and Validation," and Monitoring Factor 2.2, "Chemical Transition Times"
Tanks 18F and 19F Grout Documentation (ML13269A365)				

Table B–1. Crosswalk Between Technical Review Report Findings and Monitoring Factors				
ID	**Technical Review Report (TRR) Finding**	**TRR Monitoring Factor**	**Related Monitoring Factor**	**New Monitoring Factor**
6	DOE has not provided sufficient information to rule out preferential pathways in its reference case. NRC staff expects DOE to provide additional information related to the extent and performance impact of shrinkage. During the review of the tank grouting video, NRC staff has observed potential segregation of tank grout that could enhance the extent of shrinkage along the periphery of the Type IV tanks (i.e., along the tank walls). NRC staff also expects DOE to provide additional information on the potential for thermal cracking of the grout monolith for Tanks 18F and 19F. The NRC staff will continue to evaluate the potential for shrinkage- and cracking-induced preferential flow through the tank grout under Monitoring Factor 3.3, "Shrinkage and Cracking" (see ML12212A192). NRC also continues to monitor the potential for segregation of emplaced grout and its impacts on flow through the grout monolith and waste release under Monitoring Factor 3.4, "Grout Performance."[3] The NRC staff will also continue to monitor void volumes in the emplaced grout to the extent information is available (Monitoring Factor 3.4, "Grout Performance"),[4] the importance of alkali-silica reactivity on cementitious material degradation (Monitoring Factor 3.3, "Shrinkage and Cracking"), and the impact of limestone additions to the grout mix on pH buffering of water contacting the emplaced grout (Monitoring Factor 3.4, "Grout Performance").[5]	Monitoring Factor 3.3, "Shrinkage and Cracking fo Reducing Grout," and Monitoring Factor 3.4, "Grout Performance"	Monitoring Factor 3.2, "Groundwater Conditioning via Reducing Grout" Monitoring Factor 8.1, "Settlement" Monitoring Factor 2.2, "Chemical Transition Times"	Issues in red text in column 2 are incorporated into Monitoring Factor 3.2, "Groundwater Conditioning via Reducing Grout," Monitoring Factor 8.1 "Settlement," and Monitoring Factor 2.2, "Chemical Transition Times"
Tanks 5F and 6F Grout Documentation (ML14342A784)				
7	DOE has not provided sufficient information and testing to exclude from its reference case preferential flow through the tank grout monolith. During its review of tank grouting video, NRC staff observed potential bleedwater segregation of tank grout during placement	Monitoring Factor 3.3, "Shrinkage and Cracking of Reducing Grout," and Monitoring Factor 3.4, "Grout Performance"	Monitoring Factor 3.2, "Groundwater Conditioning via Reducing Grout" Monitoring Factor 8.1, "Settlement"	Issues in red text in column 2 are incorporated into Monitoring Factor 3.2, "Groundwater Conditioning via

[3]The impact of segregation on the flow through the monolith is also closely related to Monitoring Factor 3.2, "Groundwater Conditioning."
[4]Void volume is also important for site stability (Monitoring Factor 8.1, "Settlement").
[5]Limestone addition is also important to chemical transition times (Monitoring Factor 2.2, "Chemical Transition Times").

Table B–1. Crosswalk Between Technical Review Report Findings and Monitoring Factors				
ID	**Technical Review Report (TRR) Finding**	**TRR Monitoring Factor**	**Related Monitoring Factor**	**New Monitoring Factor**
	that could result in inhomogeneity of the monolith, which can affect flow patterns. [6] The NRC staff will continue to evaluate the potential for shrinkage- and cracking-induced preferential flow through the tank grout under Monitoring Factor 3.3, "Shrinkage and Cracking." The NRC staff will also continue to monitor void volumes in the waste tanks to the extent that information is available (Monitoring Factor 3.4, "Grout Performance"); [7] the importance of alkali–silica reactivity on cementitious material degradation (Monitoring Factor 3.3, "Shrinkage and Cracking"); and the impact of limestone additions to the grout mix on pH buffering of water contacting the emplaced grout (Monitoring Factor 3.4, "Grout Performance"). [8]		Monitoring Factor 2.2, "Chemical Transition Times"	Reducing Grout," Monitoring Factor 8.1 "Settlement," and Monitoring Factor 2.2, "Chemical Transition Times"
Environmental Monitoring (ML12272A124)				
8	NRC staff concluded the following: 1. DOE has performed environmental monitoring at the FTF that provides useful information on the hydrogeological system at FTF. This information can also be used to better understand contaminant flow and transport and validate DOE Performance Assessment models. 2. Uncertainty exists in the source of contaminant plumes detected via the FTF monitoring well network. Reducing this uncertainty will be important to better understanding contaminant flow and transport processes operable at the FTF. 3. Progress has been made on development of cement leachate factors used to account for the impact of cement leaching on natural system sorption; however, additional information is needed to support factors for key radio-elements such as Neptunium (Np), Plutonium (Pu), and Uranium (U). 4. Progress has been made on development of site-specific K_ds for Niobium (Nb); however, additional information is needed to	Monitoring Factor 4.1, "Natural Attenuation of Key Radionuclides," and Monitoring Factor 4.3, "Environmental Monitoring"		Issues in red text in column 2 are incorporated into Monitoring Factors 4.1, "Natural Attenuation of Key Radionuclides," and 4.3 "Environmental Monitoring"

[6]The impact of segregation on the flow through the monolith is also closely related to Monitoring Factor 3.2, "Groundwater Conditioning."
[7]Void volume is also important for site stability (Monitoring Factor 8.1, "Settlement").
[8]Limestone addition is also important to chemical transition times (Monitoring Factor 2.2, "Chemical Transition Times").

Table B–1. Crosswalk Between Technical Review Report Findings and Monitoring Factors				
ID	**Technical Review Report (TRR) Finding**	**TRR Monitoring Factor**	**Related Monitoring Factor**	**New Monitoring Factor**
	support K_d values used in performance assessment calculations. 5. Little progress has been made to address the technical issue associated with the Pu K_d averaging approach used in tank farm performance assessment calculations. DOE should address this technical issue in the future. Follow-up actions include the following: 1. The NRC staff will continue to monitor the ability of the tank farm monitoring well network to detect releases from the tank farm facilities following closure. DOE could (i) evaluate the monitoring well network by performing an analysis of the centerline of plumes emanating from tank sources should releases occur in the future and (ii) provide input on optimal well locations to ensure that future releases from the tank farm facility would be detected. 2. The NRC staff will continue to evaluate the source of elevated Technetium (Tc)-99 levels in well FTF 28. It is not clear that releases from the F-Area Inactive Process Sewer Line could migrate vertically to the lower zone of the Upper Three Runs Aquifer in such a short distance from the source. This evaluation is important to ensure that the hydrogeological system at FTF is well understood and that releases from the tanks could be detected by the monitoring well network. DOE could provide additional support for the source of contamination detected at well FTF 28 by performing particle tracking to better understand contaminant plume trajectories. DOE could also perform a more formal statistical analysis of FTF and Western Groundwater Operable Unit well data to correlate contaminant concentrations associated with various sources. 3. The NRC staff will continue to monitor the K_d averaging approach used to simulate Pu transport in the natural system at FTF. DOE could address the issue by modeling explicitly more mobile and less mobile forms of Pu in future performance assessment calculations. 4. The NRC staff will continue to monitor support for cement leachate factors developed for Pu (and other constituents). DOE could provide support for cement leachate factors by performing site-specific analyses. 5. The NRC staff will continue to monitor the basis for selection of the Nb distribution coefficient or K_d value of 160 L/kg used in the Tanks 5F and 6F Special Analysis. DOE could address the			

Table B–1. Crosswalk Between Technical Review Report Findings and Monitoring Factors

ID	Technical Review Report (TRR) Finding	TRR Monitoring Factor	Related Monitoring Factor	New Monitoring Factor
	technical issues by verifying the batch experiments did not exceed solubility limits and are representative of conditions at FTF (e.g., plot solid phase versus aqueous phase concentration or K*d* versus concentration; evaluate K*d* for FTF aquifer soils) or perform additional experiments to verify the Nb K*d*.			
	Review of Features, Events, and Processes (ML13277A063)			
9	The NRC staff's review of the DOE screening methodology finds that DOE properly focused on likelihood and impact as criteria for screening, but identifies several concerns with DOE's screening of FEPs, including the membership of the FEPs screening team and the documentation of each subject matter expert's basis for judgment. The NRC staff's review also identifies questions with the screening process for selected FEPs. Finally, the NRC staff's review finds that DOE's crosswalk of included FEPs has the potential to enhance transparency and traceability, while NRC staff identifies multiple examples where transparency and traceability are reduced, which results in a loss of confidence that all relevant FEPs are adequately considered in the FTF Performance Assessment.	Monitoring Factor 6.1, "Scenario Analysis"		Issues in red text in column 2 are incorporated into Monitoring Factor 6.1, "Scenario Analysis"

ALARA–As Low As Is Reasonably Achievable, CFR–Code of Federal Regulations, DOE–U.S. Department of Energy, E_h–Oxidation-Reduction Potential, FEP–Features, Events, and Processes, FTF–F-Tank Farm, HRR–Highly Radioactive Radionuclides, K*d*–Distribution Coefficient, NRC–U.S. Nuclear Regulatory Commission, PA–Performance Assessment, pH–Hydrogen Ion Activity, PO–Performance Objective, TER–Technical Evaluation Report, TRR–Technical Review Report, UCL95–95th Percentile Upper Confidence Limit.

References:

ML12212A192. "U.S. Nuclear Regulatory Commission Plan for Monitoring Disposal Actions Taken by the U.S. Department of Energy at the Savannah River Site F-Area Tank Farm Facility in Accordance With the National Defense Authorization Act for Fiscal Year 2005." Washington DC: U.S. Nuclear Regulatory Commission. 2013.

ML13080A401. "Technical Review Updated Cost-Benefit Analysis for Removal of Additional Highly Radioactive Radionuclides from Tank 18." Memorandum from L. Parks (NRC) to G. Suber (NRC) thru C. McKenney (NRC). Washington, DC: U.S. Nuclear Regulatory Commission. March 2013.

ML13100A230. "Technical Review of Tank 18 and 19 Special Analysis for the Performance Assessment for the F-Tank Farm at the Savannah River Site, SRR-CWDA-2010-00124, Rev. 0, February 2012 (DOCKET NO. PROJ0734)." Memorandum from C. Barr (NRC) to G. Suber (NRC) thru C. McKenney (NRC). Washington, DC: U.S. Nuclear Regulatory Commission. April 2013.

ML12272A082. "Technical Review: Waste Release and Solubility Related Documents Prepared by United States Department of Energy to Support Final Basis Section 3116 Determination for the F-Area Tank Farm Facility at Savannah River Site." Memorandum from G. Alexander (NRC) to J. Jesse (NRC) thru C. McKenney (NRC). Washington DC: U.S. Nuclear Regulatory Commission. May 2013.

Table B–1. Crosswalk Between Technical Review Report Findings and Monitoring Factors

ID	Technical Review Report (TRR) Finding	TRR Monitoring Factor	Related Monitoring Factor	New Monitoring Factor
ML13085A291. “Tehnical Review of Final Inventory Documentation for Tanks 5 and 6 at F-Tank Farm, Savannah River Site, (Project No. PROJ-0734).” Memorandum from C. Barr (NRC) to G. Suber (NRC) thru C. McKenney (NRC). Washington, DC: U.S. Nuclear Regulatory Commission. September 2013.				
ML13273A299. “Technical Review of Tanks 5 and 6 Special Analysis at F-Tank Farm Facility, Savannah River Site (Project No. PROJ0734).” Memorandum from C. Barr (NRC) to G. Suber (NRC) thru C. McKenney (NRC). Washington, DC: U.S. Nuclear Regulatory Commission. October 2013.				
ML13269A365. “Technical Review: U.S. Department of Energy Documentation Related to Tanks 18F and 19F Final Configurations with an Emphasis on Grouting from Recommendations and Testing to Final Specifications and Procedures (Project No. PROJ0734).” Memorandum from C. Grossman (NRC) to G. Suber (NRC) thru C. McKenney (NRC). Washington, DC: U.S. Nuclear Regulatory Commission. October 2013.				
ML14342A784. “Technical Review: U.S. Department of Energy Documentation Related to Tanks 5F and 6F Final Configurations with an Emphasis on Grouting from Recommendations and Testing to Final Specifications and Procedures (Project No. PROJ0734)”. Memorandum from L. Parks (NRC) to G. Suber (NRC) thru C. McKenney (NRC). Washington, DC: U.S. Nuclear Regulatory Commission. December 2014.				
ML13277A063. “Technical Review: U.S. Department of Energy Documentation Related to Features, Events, and Processes in the F-Area Tank Farm Performance Assessment.” Memorandum from C. Grossman (NRC) to G. Suber (NRC) thru C. McKenney (NRC). Washington, DC: U.S. Nuclear Regulatory Commission. April 2014.				
ML12272A124. “Technical Review of Environmental Monitoring and Site-Specific Distribution Coefficient Reports.” Memorandum from C. Barr (NRC) to G. Suber (NRC) thru C. McKenney (NRC). Washington, DC: U.S. Nuclear Regulatory Commission. March 2015.				

APPENDIX C
MA 2, “WASTE RELEASE”

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The DOE relies on solubility controls in the residual waste to constrain aqueous phase concentrations of HRRs released from the residual waste remaining in the primary liners of the waste tanks and associated groundwater doses to a potential receptor. In DOE's FTF and HTF PAs, solubility-limiting phases and the resulting solubility limits are often a function of the chemical environment in the contaminated zone. The chemical environment of the contaminated zone is affected by chemical conditioning afforded by the overlying reducing grout used to fill the tanks following closure, which is intended to ensure a relatively high pH and low Eh chemical environment in the contaminated zone for thousands to tens of thousands of years, thereby delaying significant release of key HRRs beyond the 10,000-year compliance period.[1]

In its TERs (ML112371751, ML14094A496) the NRC staff presented a number of observations and recommendations. NRC staff's primary recommendation related to Criterion 3, as stated in the FTF TER[2] Executive Summary, is as follows:

> NRC staff recommends DOE conduct waste release experiments to increase support for key modeling assumptions related to (i) the evolution of pH and Eh in the grouted tank system over time, (ii) identification of HRR association with solid phases comprising the residual wastes, and (iii) expected solubility of HRRs under a range of environmental or service conditions that the residual wastes in the contaminated zone are expected to be exposed to over time. Implementation of this recommendation is deemed crucial for NRC staff to have reasonable assurance that the POs in 10 CFR Part 61, Subpart C, can be met.

As a result, NRC staff has identified the following MFs related to waste release:

- MF 2.1 "Solubility-Limiting Phases/Limits and Validation" (see Section 3.2.1)

- MF 2.2 "Chemical Transition Times" (see Section 3.2.2)

Because chemical transitions to risk-significant solubilities for HRRs could lead to exceedance of the 0.25 mSv/yr [25 mrem/yr] 10 CFR 61.41 dose standard (or 5 mSv/yr applied dose standard for 10 CFR 61.42) during the compliance period, the timing of chemical transitions could be important to compliance. Therefore, both (i) the nature of flow through the tank grout (e.g., fracture versus matrix flow) that dictates the reactive surface area and amount of grout available to condition infiltrating water and (ii) the assumed rate of change of Eh and pH[3] may

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[1]In contrast to the FTF PA and based on updated solubility modeling, the HTF PA assumes that solubility of many HRRs remains at non-risk-significant values into perpetuity. DOE evaluates the impact of higher HRR solubility upon transition to Oxidized Regions II or III in uncertainty and sensitivity analysis in the HTF PA.
[2]In HTF TER, the NRC staff reiterated the FTF recommendation that DOE conduct waste release experiments.
[3]In the FTF PA, a risk-significant increase in solubility of Tc and Pu occurred upon transition to Oxidized Region III. In the Tanks 18F and 19F Special Analysis and HTF PA reference cases, DOE assumes that Pu solubility remains at non-risk-significant values for all chemical states; or assumes Pu solubility increases to a risk-significant value upon transition to Oxidized Region II in sensitivity analysis cases. In the HTF PA, DOE assumes that Tc remains at a low solubility phase for all chemical conditions or increases to a risk-significant value upon transition to Oxidized Regions II or III in sensitivity analysis. In general, the updated geochemical modeling results in the HTF PA indicate that HRR solubility is generally not sensitive to the transition from Oxidized Region II to Oxidized Region III. However, if future revisions to the HTF PA and updated geochemical modeling indicate that the solubility of certain

also be important to the compliance demonstration. Uncertainty related to flow through the tank grout is considered under MA 3, “Cementitious Material Performance,” and MF 3.2, “Groundwater Conditioning via Reducing Grout,” which is concerned with the hydraulic (rather than the chemical) performance of cementitious materials mitigating tank farm releases and doses.

Other NRC staff TER recommendations related to waste release are binned under PA maintenance activities under MA 6 until overall facility performance is better understood and constrained. Should the results of the experiments indicate less than favorable performance, NRC staff expects DOE to assess the impact on the results of the PAs. NRC staff also will assess the need for additional experiments, data collection, and modeling to provide support for key barriers in DOE’s PAs that might serve to mitigate underperformance of chemical barriers. If the results of the experiments show that key radionuclides are strongly retained in the residual waste, NRC staff expects other MAs or MA components will become less important and may be closed as monitoring progresses.

Since preparation of the FTF PA, DOE performed additional analysis to study potential solubility of Pu in Tank 18 to support the final waste determination and closure of the tank (SRNL–STI–2012–00404). The analysis indicates that Pu may be present in the tank waste waters at risk-significant concentrations for what DOE describes as “conservative” or higher Eh conditions, or that Pu also can be relatively insoluble at what DOE describes as more “realistic” or lower Eh conditions. These results are important, as they show that peak doses could either be similar to those doses reported in DOE’s FTF PA (i.e., hundreds of mrem/yr) or that the peak doses from Pu could be insignificant. However, only through additional analyses and experimental validation can DOE confirm the geochemical modeling results and present a more accurate measure of risk. It also is important to note that if higher Eh conditions prevail, DOE models predict releases from the tanks much earlier in time. In Figure 3-5, a green dashed line that dissects the tank grout and contaminated zone chemical barriers[4] at around 10,000 years for Type IV FTF tanks (including Tank 18)[5] marks the first chemical transition from reducing to oxidizing conditions, corresponding to the time at which Pu is expected to be released at risk-significant rates based on DOE’s updated solubility modeling. Potential risk-significant release of Pu-239 at higher solubility may occur much earlier in time based on results of the updated solubility modeling compared to what was assumed in DOE’s FTF PA (i.e., Pu-239 was previously assumed to be released at risk-significant rates only after the second chemical transition to lower pH marked with a red dashed line after 30,000 years in Figure 3-5). If performance of the tank grout, steel liner, or basemat is slightly less than assumed in DOE’s base case scenario, then release of Pu-239 into the surrounding environment could occur within the 10,000-year period of performance.

In 2011, NRC staff recommended in its FTF TER (ML112371751) that DOE initiate discussions with NRC staff regarding implementation of waste release experiments for Tank 18F as soon as practical, given the overall risk-significance of the tank in the FTF PA and DOE’s plans to close Tank 18F in CY 2012. After issuance of NRC staff’s FTF TER, DOE convened a peer review group, which documented its recommendations with respect to Pu solubility experiments in LA–UR–2012–00079. In the report, the peer review group recommended, consistent with NRC

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radionuclides is sensitive to pH, DOE may need to provide additional support for the chemical transition times to Oxidized Region III conditions.

[4]Tank grout and contaminated zone chemical barriers are combined and shown in purple in Figure 3-5.

[5]Type IV tanks are illustrated in the bottom set of three panels in Figure 3-5.

staff's TER recommendations, that DOE update its geochemical modeling and validate modeling results with follow-up experiments. The peer review report, however, suggested that validation experiments could occur after tank grouting had been completed. Consistent with the peer review group recommendation, DOE decided to grout the tanks and perform follow-up experiments to study waste release later (SRR–CWDA–2012–00020). DOE developed an experimental plan to provide additional information and model support for the closure of Tank 18F. The task is intended to provide additional information regarding the residual waste solubility assumptions used in the FTF and HTF PA waste release models. DOE plans to perform the task in two phases. The first phase involved development of a test plan and methods, which are documented in SRNL–RP–2013–00203, as updated in SRNL–RP–2013–00203 and the second phase involves experiments with actual Tank 18F waste residuals. NRC staff commented on (ML15153A384) DOE's experimental plan (SRNL–RP–2013–00203) and discussed the research with DOE at the March 2014 Onsite Observation Visit (ML14106A573). The research is ongoing with testing currently limited to surrogate samples (SRNL–STI–2014–00456). One of the key findings of this research is that the pore-water Eh in these studies is inconsistent with the values assumed in the PA waste release modeling. This may be an experimental artifact (e.g., insufficient equilibration time). NRC staff commented that the assumed Eh and pH values in the field are uncertain and that this uncertainty should be considered in the design of the experiments (i.e., pH and Eh endpoints should be investigated in the experiments to determine whether the HRRs could be at a risk-significant solubility; if the solubility at the endpoint is risk significant, then DOE should investigate the critical threshold where solubility increases to risk-significant values).

Monitoring Factor 2.1—Solubility-Limiting Phases/Limits and Validation

The key radio-elements that are expected to significantly contribute to receptor dose and are sensitive to solubility limits are Tc, Np, and Pu. As discussed in the NRC staff's TERs (ML112371751, ML14094A496), DOE models solubility limits for these elements in the DOE PAs for pure phases and, in some cases,[6] as coprecipitates with iron oxyhydroxide minerals in the residual waste. NRC staff will, therefore, emphasize these elements in monitoring how DOE treats its concentration-limited release in the PAs.

As mentioned previously, NRC staff's primary recommendation in its TERs (ML112371751, ML14094A496) was that DOE conduct waste release experiments to increase support for key modeling assumptions. Accordingly, NRC staff will monitor experiments conducted by DOE to address the primary recommendation. With respect to the experiments, DOE should develop a plan to analyze key radio-elements that rely on solubility for control, such as Pu, Tc, and Np. The experiments should consider the effects of reagents (e.g., oxalic acid) used to remove radionuclides from the tank residue, including formation of new compounds that may alter leachability of key radionuclides. DOE should determine the number of samples to be analyzed from each waste tank based on characterization results that show the homogeneity or lack thereof of residual waste remaining in the tanks.

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[6]In the FTF PA, iron coprecipitation is used to calculate solubility limits for uranium (U), Tc, and Pu in both the deterministic and probabilistic models. In the HTF PA, iron coprecipitation is used to calculate solubility limits for Tc in both the deterministic and probabilistic models. For U, Np, and Pu, the iron coprecipitation model is not used to calculate solubility limits in the HTF PA deterministic models, but it is used to calculate solubility limits for establishing probability distributions and also used in sensitivity analyses.

In the FTF TER, NRC staff recommended DOE perform experiments for residual waste from Tank 18F in the short term and, based on the results of the first set of experiments and expected intertank variability, determine the need for additional experiments for remaining tanks. Decisions on additional experiments should be based on expected tank risk; HRRs targeted for these studies should be those that are the largest risk drivers and for which the reliance on chemical retention is greatest. The experiments should be representative of the final chemical and physical form of the waste (e.g., should reflect postchemical treatment for those tanks where chemical cleaning is selected as the preferred technology).

DOE should conduct tests recommended by the peer review group (LA–UR–2012–00079) using archived samples of Tank 18F heels or additional samples that were obtained before grouting commenced. As mentioned earlier, DOE has developed an experimental plan to provide additional information and model support for the closure of Tank 18F. The proposed task is intended to provide additional information regarding the residual waste solubility assumptions used in the FTF and HTF PA waste release models. The need for this information is important, especially when considering waste reactions with water and the subsequent interactions of this leachate with soil underlying the tanks.

The remainder of this section will address, in turn, each of the three elements for which waste release is most significant to calculated dose. The Pu section exceeds the others in length mainly because recent information has become available that warrants discussion; the DOE efforts that led to much of the new information were expanded in the HTF PA (i.e., updated geochemical modeling) and provide relevant data for Tc and Np.

Technetium

In the FTF PA, solubility limits of Tc are controlled by coprecipitation with iron oxides for Reduced Region II and Oxidized Region II; however, no solubility limit is placed on Tc under Oxidized Region III. In the HTF PA, technetium coprecipitates with iron oxides, which limits its solubility in all chemical conditions modeled. NRC staff still has questions regarding the applicability of the iron coprecipitation model for Tc. It appears these concerns will be moot if the tank Tc-99 inventories are reduced enough by cleaning, such that the Tc solubility limit is not risk significant. If Tc-99 tank inventories continue to be sufficiently low, NRC staff may not need to monitor Tc solubility limit issues.

Neptunium

NRC staff's FTF TER (ML112371751) observed that Np pure-phase solubilities used in the PA appeared reasonable. These solubility values have the potential to be risk-significant if release and chemical transitions occur before 10,000 years. In the HTF TER, (ML14094A496) NRC staff observed that while the solubilities used in the HTF PA were considerably lower than in the FTF PA,[7] they appeared reasonable considering that DOE uses a thermodynamic database based on the well-established Nuclear Energy Agency (NEA) data compilation. However, DOE model results in Figure 24 of SRNL–STI–2012–00404 show that the neptunium solubility limit is

[7]Np solubility limits range from 2×10^{-6} to 1×10^{-9} mol/L in the HTF PA (SRR–CWDA–2010–00128, Table 4.2-11) compared to 1.1×10^{-4} mol/L to 1.6×10^{-9} mol/L in the FTF PA (SRS–REG–2007–00002, Table 4.2-10).

sensitive to Eh for Oxidized Regions II and III. The solubility value of over an order of magnitude higher is possible if Eh is 400 mV rather than 290 mV (i.e., 3×10^{-5} mol/L versus 2×10^{-6} mol/L).

DOE assumes the basemat is quite effective in limiting Np release in its PAs. Accordingly, monitoring activities concerning the Np K_ds in the basemat are discussed under MA 3, "Cementitious Materials Performance," as well as those concerned with by-pass flow through the basemat, which are discussed further under MA 6, "PA Maintenance."

Plutonium

Pu release and, therefore, dose are highly sensitive to the contamination zone solubility limit. The DOE plot seen in Figure C–1 shows that, if timing is disregarded, any Pu solubility limit above 1×10^{-10} mol/L could yield doses that exceed the 10 CFR 61.41 compliance limit at FTF. Independent NRC staff analyses corroborate DOE's sensitivity analysis results and show that peak release rates (and therefore doses) are relatively insensitive to solubility at higher solubility levels but that, at some threshold value, tank waste solubility becomes increasingly controlling with respect to peak release and dose. Because NRC staff remains unconvinced of the timing of release, owing to uncertainty in chemical transition times and potential for tank grout bypass, a solubility limit exceeding 1×10^{-10} mol/L, under any set of chemical conditions, has the potential to lead to an unacceptable dose at FTF within 10,000 years. Because Pu solubility is highly dependent on assumptions regarding any solubility limiting pure Pu phases, recommended waste release studies discussed earlier are particularly critical for Pu.

Table C–1 also shows that a Pu solubility at the source of less than 1×10^{-10} mol/L is not likely to be risk significant for FTF, considering minimal credit for the performance of other FTF barriers [i.e., 1×10^{-12} mol/L could easily be reduced by two orders of magnitude, which is a minimal amount of credit for the performance of engineered and natural FTF barriers (see Table 3-1)]. The concentrations were calculated based on the DOE-calculated pathway dose conversion factor for Pu-239 used in the FTF PA, which provides the dose to groundwater concentration ratio for this key radionuclide.

DOE convened a peer review group to assess recommendations and comments NRC staff made in its FTF TER (ML112371751), specifically with regard to the technical justification for the assumptions and technical bases for modeling Pu release from tank residual wastes. Much of this effort focused on the solid phases of Pu in the waste and the modeling activities associated with assessing solubility of those phases. The peer review group's report points out the DOE analysis of chemistry in the tanks only provides "possible clues as to the potential nature of Pu speciation in the precipitates and residues left in the tank after extensive cleaning" (LA–UR–2012–00079). In addition, the report states, "There is no real understanding of the nature of Pu speciation in tank precipitates" (LA–UR–2012–00079, p. 8). The peer review team's findings are based on several days of discussions with Savannah River Site (SRS) personnel. The peer review report states that, to provide a stronger scientific foundation to justify the use of geochemical modeling in the tank closure PA, validation and verification of the model and assumptions are required.

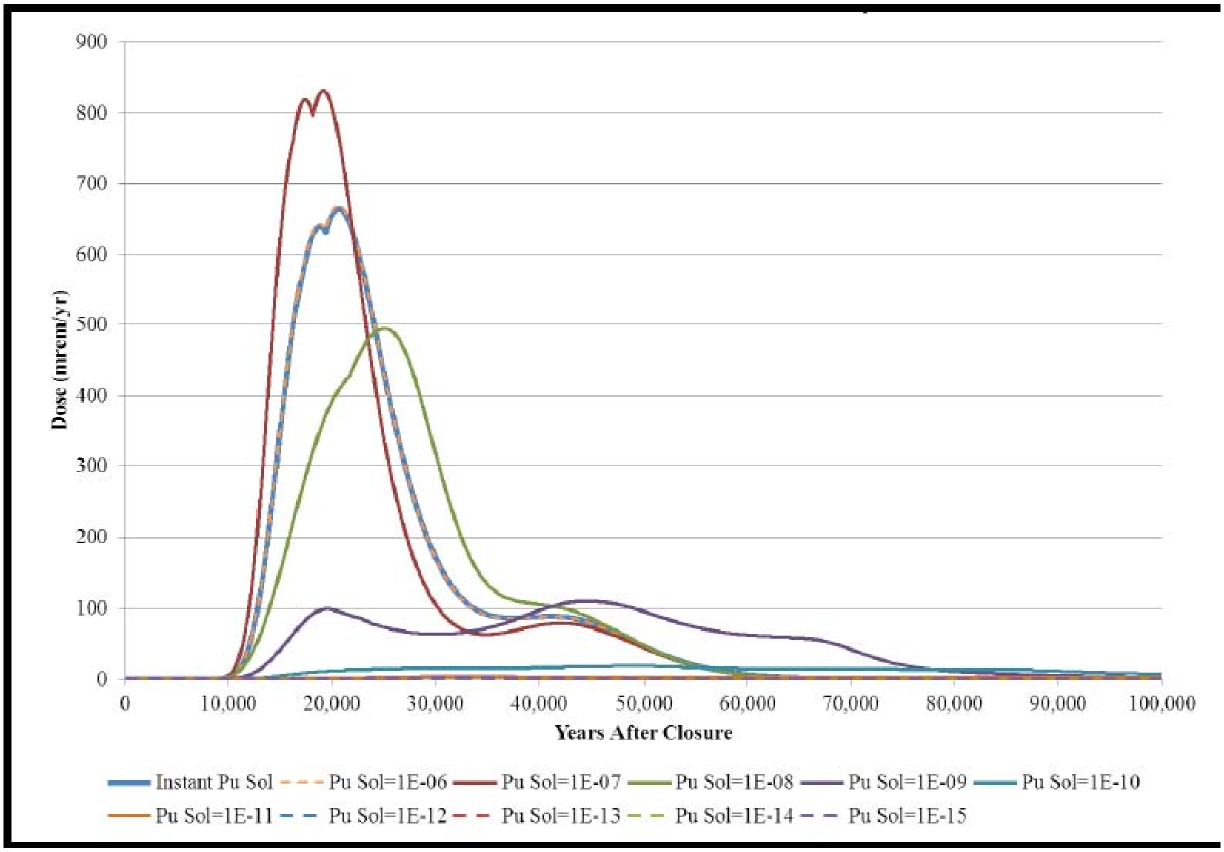

Figure C–1. Revised Tank 18F/Tank 19F Special Analysis (SRR–CWDA–2010–00124, Figure 6.3-23) Showing the Sensitivity of Calculated Dose to the Plutonium Solubility at the Waste Residue

Table C–1. Risk-Significant Concentrations of Pu-239 in the Environment Based on DOE FTF PA Modeling

	Standard	Concentration (pCi/L)	Concentration (mol/L)
Intruder	5 mSv/yr	1,100	7×10^{-11}
Member of the Public	0.25 mSv/yr	55	4×10^{-12}
Pathway Dose Conversion Factor = 4.5×10^{-3} mSv/yr per pCi/L Specific Activity = 0.063 Ci/g 1 pCi/L = 3.7×10^{-02} Bq/pCi PU = Plutonium, DOE = U.S. Department of Energy, FTF F-Area Tank Farm, PA= Performance Assessment			

With respect to tank waste residues, the peer review group recommended:

- Spectroscopic analyses [e.g., Extended X-Ray Absorption Fine Structure or (EXAFS)] of Pu and other metals in the waste residues.

- Leach tests that use leachant solutions representative of aged as well as fresh grout and deionized water. The recommended leach tests would include the following features:

  - Chemical analysis including all major ions, pH, alkalinity, Eh, and appropriate trace components (e.g., Pu, Fe, and sulfide).

  - Solids characterization after leaching, because new phases may have precipitated or some phases may have dissolved completely.

  - Geochemical modeling with the leachate data as input, in order to validate and verify the solubility model and certain assumptions used in the model.

In addition to these peer review group recommendations, SRNL–STI–2012–00106 recommends that if the presence of $PuO(CO_3)$(am,hyd) is confirmed by x-ray absorption analysis, experiments be conducted to determine whether Pu carbonates can be transformed back intoPuO_2(am,hyd) upon contact with grout. This is important because observed Pu concentrations in the Tank 18F were risk significant (1×10^{-8} mol/L) and could lead to peak doses similar to the larger doses in the FTF PA (3–5 mSv/yr [300–500 mrem/yr]).

Many of the tests that were recommended by the peer review group are consistent with NRC's TER (ML112371751) recommendations. DOE has identified an experimental plan and begun testing of surrogate samples, prior to testing actual waste samples, to provide additional information and model support for the closure of Tank 18F (SRNL–RP–2013–00203). The proposed task is intended to provide additional information regarding the residual waste solubility assumptions used in the FTF and HTF PA waste release models. Although DOE has performed some preliminary work, DOE has not yet adequately characterized tank waste residues, especially with respect to the forms and behavior of the transuranic elements, to allow reasonable assurance that releases from the tanks have been appropriately modeled. The complex behavior of Pu and the variety of tank configurations, materials, and potential pathways for water to short-circuit closure conditions suggest DOE should conduct carefully considered leaching studies coupled to site-specific soil interaction analysis. Specifically, DOE should conduct leaching studies to ascertain maximum solubilities and leach rates of key radionuclides from the tank heels. These tests should represent different scenarios of waste-grout interactions that control factors such as pH and speciation. DOE could use leachate from the experiments to define site-specific K_ds values, based on waste-specific releases to support the cement leachate factors derived from the literature (see Section 3.4.1).

SRNL–STI–2012–00106 provides a discussion of the possible solid phases and aqueous species in which Pu may reside in residual SRS tank wastes, based on observations of Tank 18F residues, the tank operational history, and the literature. A variety of metals, including Pu, that precipitate from solution as acidic residues from spent fuel dissolution are made alkaline by addition of NaOH. SRNL–STI–2012–00106 describes three forms that the Pu may take if it co-precipitates with other, much more abundant metals, such as iron and aluminum: (i) Pu substitution for another metal in a crystal lattice, (ii) physical occlusion into a mass of precipitated material without becoming part of the structure, and (iii) adsorption onto surfaces of the material. In each of these cases, Pu would be expected to be uniformly dispersed in the solid. However, recent Scanning Electron Microscopy (SEM) analyses of a single Tank 18F waste sample (SRNL–L3100–2012–00017) show Pu present as discrete, small (<1 μm) particles that are not evenly distributed within the precipitated matrix. The Pu mass represented by these particles seems to be smaller than total Pu in the sample, suggesting that some Pu also is co-precipitated. Perhaps more importantly, the concentrations of Pu in Tank 18F waste liquids (1×10^{-8} mol/L and 3×10^{-8} mol/L) were "well above the predicted solubilities for PuO_2(am,hyd) and co-precipitated Pu(IV)" (less than 2×10^{-9} mol/L) (SRNL–STI–2012–00106).

Further, SRNL-STI-2012-00106 discusses how the speciation of Pu in the waste may be impacted by changes in pH and ingress of CO_2, resulting from continual active ventilation of the tanks to control hydrogen accumulation. The presence of CO_2 gas over a strongly alkaline solution will result in accumulation of carbonates in solution, inducing the formation of $PuO(CO_3)xH_2O_{(solid)}$ or $Pu(OH)_2(CO_3)_{(solid)}$ in the presence of aqueous Pu carbonate species. In fact, carbonate concentrations of about 0.04 mol/L were measured in the aqueous phase of Tank 18F heels. A recent X-Ray Diffraction (XRD) analysis of Tank 18F heels shows the presence of $Na_4UO_2(CO_3)_3$ and calcite at about 10 percent of the crystalline solid phase material (SRNL–L3100–2012–00017). The presence of these solids and the measured aqueous carbonate concentrations strongly suggests that some Pu in the heels is in a carbonate form. These observations have important implications for how Pu solubility is modeled, because the solubility limits for these carbonate phases could differ substantially from the hydrated Pu oxides used in DOE models. If Pu is present as a carbonate solid, then at pH 9.8, Pu solubilities of around 1×10^{-6} mol/L can be expected (SRNL-STI-2012-00106). In addition, these observations mean that at least some of the Pu in the aqueous phase will be negatively charged carbonate complexes, which will have very low K_ds values. Higher solubility and lower K_d could lead to an exceedance of the performance objective within the period of compliance (i.e., increase the magnitude of peak dose and lead to earlier peak doses within the compliance period).

In the recent special analyses for Tanks 18F and 19F (SRR–CWDA–2010–00124), DOE assumes that reaction of Pu carbonate species with the high pH of the grout will convert all Pu to the lower-solubility phases $Pu(OH)_{4(am)}$ or $PuO_{2(am,\ hyd)}$. Presumably, this would take place with free alkaline water released during grout setting or with water that percolated from the surface through the grout. In many release scenarios, water in the system will be alkaline before it contacts the waste residue. This seems reasonable for many situations. However, there are several important processes that may preclude the conditioning of water entering the contamination zone. Based on information presented in the PA, the Pu Peer Review Report, and SRNL-STI-2012-00106, there are potential radionuclide release scenarios that may lead to greater leach rates than expected from the PA.

The recent analysis of one sample of tank residue by SEM and XRD has altered the conceptual model presented in the PA. From SRNL-STI-2012-00106, it is reasonable to think that Pu may be present in at least three forms in the heels, and the higher than expected concentrations of aqueous Pu highlight this point. This illustrates the importance of doing a characterization of the waste, as outlined above. Other radio-elements that cannot be detected by the solid phase analytical techniques may be better characterized by the leach tests. Moreover, release rates of Pu and other related elements as well as their speciation can be used by DOE to validate modeling of this system.

In summary, DOE should characterize tank heels as recommended in NRC's TER (ML112371751) and by the DOE peer review group. These analyses, to be conducted on multiple samples, include: XRD; SEM/Energy Dispersive Spectroscopy (EDS); synchrotron-based studies, such as X-Ray Absorption Near Edge Structure (XANES); synchrotron microprobe; and EXAFS for selected materials. Leach tests need to be conducted under differing environmental conditions. Analyses of the leachates should attempt to determine the aqueous speciation of Pu. Tests need to be conducted to assess the ability of fluids from the grout to transform Pu carbonate solids to $Pu(OH)_{4(am)}$ or $PuO_{2(am,\ hyd)}$.

Monitoring Factor 2.2—Chemical Transition Times

DOE relies on geochemical modeling to estimate the time at which two key chemical transitions take place (i) transition from reduced to oxidized conditions reflected in an increase in Eh and (ii) transition from relatively high to relatively low pH reflected in a decrease in pH. In Section 4.2.9.3 of its TERs (ML112371751; ML14094A496), NRC staff discussed its concerns with the geochemical modeling results, which may be attributable to assumptions such as the solid phases that comprise the tank grout, the characteristics of the infiltrating groundwater, uncertainties in the thermodynamic data used in the modeling, or assumptions regarding the ability of grout components to react with and condition infiltrating groundwater. As illustrated in Figure C–2 (ML112371751, Figure 4-5), NRC staff questioned the shape of the pH vs. time curve generated, using the results of DOE's geochemical modeling. The experimental data presented in Figure C–2 suggest that DOE's conceptual model or modeling results related to chemical transition times may be flawed. DOE acknowledges that the shape of the curve is a limitation of the geochemical model (ML12236A370). As a consequence of this model simplification, the pH is overestimated at some times and underestimated at other times. However, DOE also discusses that the solubility of key radionuclides is not significantly sensitive to these slight variations in pH for the HTF PA. Because of its importance for the FTF PA and because of its potential importance should concerns regarding radionuclide solubility limits discussed under Monitoring Factor 2.1 lead to changes in solubility limits for key radionuclides in the HTF PA, the NRC staff will continue to evaluate information related to chemical transitions and groundwater conditions during monitoring.

Chemical transition times also are dependent on the nature of flow through the grouted tanks. If flow is primarily through cracks, only a small fraction of the total mass of tank grout may come into contact with infiltrating water over time, thereby limiting the effective reductive and buffering capacity of the tank grout and hastening chemical transitions to higher solubility. MF 3.2—Groundwater Conditioning and MF 3.3—Shrinkage and Cracking, discussed in Sections 3.3.2 and 3.3.3 and Appendix D is concerned with the potential for preferential pathways to form that by-pass the tank grout, limit groundwater conditioning, and lead to faster chemical transition times.

In addition to these aforementioned concerns, in a technical review report on waste release ([ML12272A082) and the HTF TER (ML14094A496), the NRC staff discussed various research that raises additional questions regarding the ability of the grout to condition the contaminated zone because of (i) the relative rate of flow versus the rate of chemical reaction, (ii) formation of a passivation layer along the flow paths, and (iii) the potential for the early release of soluble reduced sulfur phases (e.g., CaS). In light of this research, NRC staff identified in a TRR on

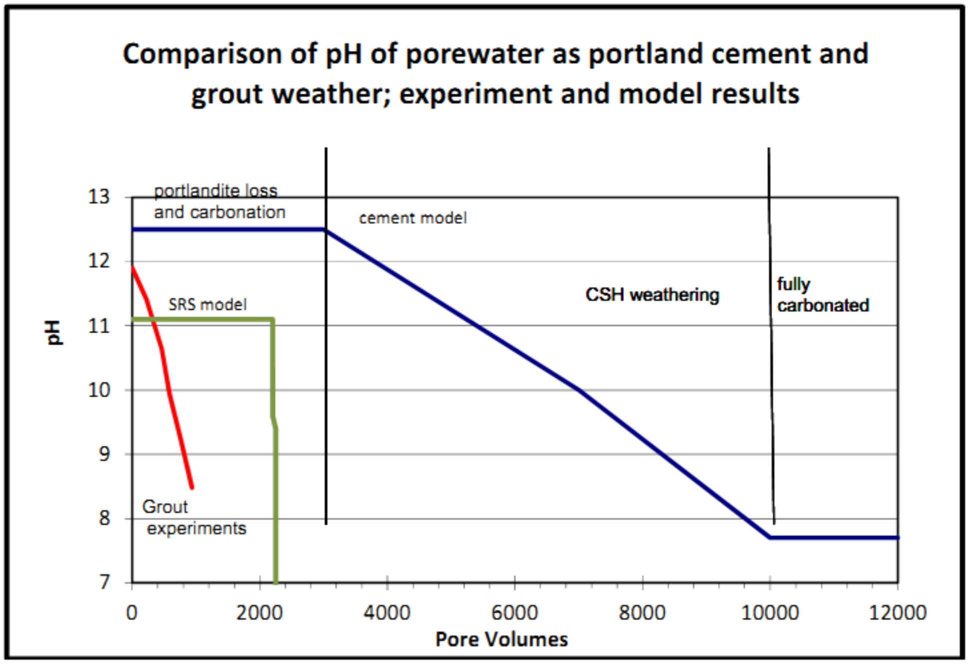

Figure C–2. Experimental Versus Modeled Change in pH Versus Displaced Pore Volumes (Dimensionless Time) (ML112371751, Figure 4-5; BNL-82395)

waste release documentation (ML12272A082) that DOE has not to date provided adequate support for assumptions regarding the longevity of reducing conditions.

For these reasons, NRC staff does not believe a compelling case has been made yet that waste release will be limited to times after the 10,000-year compliance demonstration period. For the purposes of waste release, NRC staff assumes releases and chemical transitions can occur before 10,000 years. Until DOE resolves questions of the timing of release and chemical transitions, the compliance demonstration will depend on whether the highest solubility limits identified as a result of monitoring DOE activities under MF 2.1 will lead to doses that meet or exceed the dose limits in 10 CFR 61.41 and 61.42.

Since preparation of DOE's FTF PA and NRC's FTF TER (ML112371751), DOE has performed additional modeling (SRNL-STI-2012-00404, Rev. 0) that updates the chemical transition times presented in DOE's HTF PA. Table 3-2 of this monitoring plan summarizes the differences in chemical transition times between the FTF and HTF PAs that resulted from DOE's additional modeling. As part of this MF, NRC will review information provided in the updated solubility report as a technical review activity. However, DOE should perform experiments to validate results of the updated geochemical modeling. As NRC staff has expertise in design and implementation of relevant experiments, DOE should discuss with NRC staff its plans to ensure that experiments are designed to optimize their usefulness in supporting the 10 CFR 61.41 compliance demonstration. NRC staff also may observe DOE experiments related to this MF in conjunction with an onsite observation. This MF will be closed when DOE completes experiments to study the evolution of pH and Eh in the tank grout over time to provide more accurate estimates of chemical transition times to higher solubility.

In addition to concerns regarding geochemical modeling results that show the evolution of pH and Eh over time, NRC staff also is concerned that the reducing capacity of the tank grout may not be readily transferable to the waste zone; DOE PA modeling assumes the waste zone remains in a reduced state for thousands of years (see purple barrier to the left of the green dashed line in Figure 3-5), based on conditioning from the overlying grout. NRC will, therefore, monitor the ability of tank grout to maintain reducing conditions in the waste zone through experimentation or other support.

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APPENDIX D
MA 3, “CEMENTITIOUS MATERIAL PERFORMANCE”

MA 3, "CEMENTITIOUS MATERIAL PERFORMANCE"

DOE relies on the cementitious vault materials to (i) limit flow and transport of deleterious species into the vault or key radionuclides out of the vault; (ii) condition the chemistry of the water contacting the residual waste, thereby limiting dissolution of radionuclides associated with the residual waste (see MA 2 for a discussion of dissolution of residual waste); (iii) retard radionuclide transport through the vault via interactions with cementitious grout and vault materials; and (iv) stabilize waste residuals. These capabilities are directly dependent upon the chemical and hydraulic performance of the cementitious materials. The NRC has identified the following MFs related to the capabilities of the cementitious materials to limit or mitigate releases from the tank farms:

- MF 3.1 "Hydraulic Performance of Concrete Vault and Annulus (As It Relates to Steel Liner Corrosion and Waste Release)"

- MF 3.2 "Groundwater Conditioning via Reducing Grout"

- MF 3.3 "Shrinkage and Cracking of Reducing Grout"

- MF 3.4 "Grout Performance"

- MF 3.5 "Vault and Annulus Sorption"

- MF 3.6 "Waste Stabilization (As It Pertains to ALARA)"

MA 3, "Cementitious Material Performance," MF 3.2—"Groundwater Conditioning via Reducing Grout," focuses on the nature of flow or the hydraulic performance of the tank and vault grout, while technical uncertainties related to the geochemical modeling performed to estimate the extent to which groundwater is conditioned by the tank grout and geochemical changes over time is addressed under MA 2, "Waste Release," MF 2.2—"Chemical Transition Times." Both MFs, however, pertain to the rate at which grout degradation proceeds and leads to changes in the chemistry of the infiltrating water over time and are therefore closely related.

Other NRC TER recommendations related to cementitious material or steel liner[1] performance are binned by NRC under PA maintenance activities under MA 6 until NRC obtains a better understanding of overall tank farm facility performance. Should the results of experiments conducted under MA 2, "Waste Release," or MA 3, "Cementitious Material Performance," indicate less than favorable results, NRC staff expects DOE to assess the impact on the results of the PAs. NRC staff also will assess the need for additional experiments, data collection, and modeling to provide support for key barriers in DOE's PAs that might serve to mitigate underperformance of chemical and hydraulic barriers. If the results of waste release experiments show key radionuclides are strongly retained in the residual waste, NRC staff expects other MAs or MA components, including MA 3, "Cementitious Material Performance," will become less important and may be closed as monitoring progresses.

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[1]Steel liner performance is indirectly related to cementitious material performance under MF 3.1— • Hydraulic Performance of Concrete Vault and Annulus (As It Relates to Steel Liner Corrosion and Waste Release).

MF 3.1—Hydraulic Performance of Concrete Vault and Annulus (As It Relates to Steel Liner Corrosion and Waste Release)

DOE relies on steel liners to limit water flow to the residual waste remaining in many of the tanks.[2] DOE's steel liner corrosion modeling relies on concrete vaults, which enclose the HLW tanks, as barriers to fluid flow. DOE assumes the cementitious materials surrounding the steel liners will provide a passive chemical environment that will limit corrosion to a low general corrosion rate (1 μm/yr [0.04 mil/yr] in the base case scenario) prior to carbonation- or chloride-induced steel depassivation that can lead to higher corrosion rates. Because chemical species that induce corrosion (i.e., water, chloride, carbon dioxide, and oxygen) need to be transported through the cementitious materials, NRC staff finds that the uncertainty in steel tank liner longevity is related primarily to the hydraulic properties of the cementitious materials and their effect on the persistence of a chemical and physical environment that will limit corrosion of the steel liner.

DOE's corrosion analyses use diffusion coefficients of carbon dioxide, chloride, and oxygen applicable to intact concrete to model the transport of these species through the concrete vault. Although earlier corrosion initiation times and significantly higher corrosion rates could result if higher diffusion coefficients are assumed, higher diffusion coefficient values are only applied by DOE in limited cases in its probabilistic assessments (i.e., higher diffusion coefficients are not considered in the base case assessments). Also, DOE assumes concrete vault degradation starts once carbonation reaches one-half the concrete thickness, even though steel reinforcements typically have only a few inches of concrete cover (i.e., steel reinforcement is located much closer to the vault surface than one-half the concrete vault thickness). Although rebar corrosion-induced cracking of concrete would be delayed relative to carbonation of the concrete cover, initiation of concrete vault degradation may initiate sooner than assumed in DOE's concrete degradation analysis.

Additionally, although groundwater in-leakage into the concrete vaults is evident at the SRS site,[3] DOE does not consider this phenomenon an important factor that could influence the expected performance of the concrete vaults and steel liner. DOE projects the steel liners for 39 of 51 tanks fail after 10,000 years in the PA reference cases. DOE assumes the steel liners of one Type I and three Type II tanks at HTF are failed initially because of the number of observations of leak sites on their primary liners. While the liners of these tanks do not provide a significant barrier to waste release in the HTF PA, other assumptions (e.g., solubility-controlling phases and associated solubilities) ensure significant releases of key radionuclides are delayed beyond 10,000 years. Should these other assumptions prove incorrect, the risk significance of early liner failure should become evident.

The steel liners of eight Type IV tanks are projected by DOE to fail in the DOE PAs after 3,600 years. These tanks provide a rather significant early barrier to waste release should other model assumptions prove incorrect. Because Type IV tank bottoms at FTF are near the water table, NRC staff also is concerned that intermittent flooding of the tank bottoms due to water

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[2]DOE assumes Type I Tank 12H and Type II Tanks 14H, 15H, and 16H are initially failed at HTF because of a significant number of leaksites. Although some tanks at FTF have leaksites (C–ESR–G–00003), DOE does not assume any FTF tanks are initially failed in its PA. In an onsite observation visit in March 2014, DOE clarified that the logic used to determine that tanks were initially failed in the HTF PA was not used for the FTF PA (ML14106A573). If the same logic was applied, DOE may have assumed that some FTF tank liners were initially failed.
[3]See DP-1358 and SRR–ESH–2013–00078, for example.

table fluctuations over the long period of performance could (i) expose the tank liners periodically to corrosive environments and (ii) cause contaminants exiting the basemat to be released directly into the saturated zone. The contaminated zones of Type IV tanks at HTF also appear to be within the zone of water fluctuation (SRNL–STI–2010–00128). DOE also notes in SRNL–STI–2012–00079 that given the close proximity of Type I FTF tanks to the water table, the likelihood that groundwater could come in contact with the grouted tanks is high because the average depth to water ranges from 0.3 to 2 m [1 to 6 ft]. These concerns about periodically exposing the tank liners to corrosive environments and release of contaminants directly to the saturated zone are also applicable to Type II tanks at HTF, which are partially submerged in the water table. Furthermore, Type II tanks at HTF are projected in DOE's PA to have a significant annuluar inventory. DOE should more fully evaluate the potential effect of water in-leakage and drainage on waste release for those tanks that are partially submerged or whose tank bottoms are located in the zone of water table fluctuation.

DOE's lack of consideration of flow through preferential pathways through the concrete vault and annulus in the FTF and HTF reference cases may lead to an underestimate of dose. Consideration of preferential pathways through the system may increase release rates for waste located in both the primary liner and in the annuli of certain tanks. For example, simulated limited flow through preferential pathways in DOE's models may lead to unrealistic estimates of the degree of retention in the cementitious materials compared to what may actually occur in the real system if a greater quantity of flow bypasses the attenuating properties of the concrete vaults. For example, NRC staff indicated in the HTF TER that for HTF Type I and II tanks with residual waste in their annular regions (including the sandpads beneath the liners of Type II tanks), DOE has not adequately evaluated the risk from annular or sand pad releases through preferential pathways through the annuli and concrete vault.

Given the potential risk significance of the steel liner barrier and retention of contaminants in the concrete vault, DOE should provide additional support for the assumptions used in its base case assessment that concrete vaults will remain an effective fluid flow barrier that prevents exposure of the tanks to corrosive conditions for thousands to tens of thousands of years and limits the releases of contaminants initially present in the annuli of certain tanks, most notably certain Type I and II tanks at HTF. A peer review panel that evaluated the DOE PA modeling of waste release and transport noted that fracturing of the cement-based material with preferential flow through cracks would appear to be a more likely scenario that should be evaluated (LA-UR-2012-00079). While referring to the waste release model, this statement by the peer review panel would also apply to cementitious material and steel liner degradation models, and suggests that relatively slow carbonation of cement-based material via matrix diffusion of carbon dioxide may lead to an underestimate of cement and steel liner failure times.

In its HTF TER (ML14094A496), NRC staff also questioned DOE's assumption of low corrosion rates, because oxidation and reduction reactions that control corrosion could be macroscopically separated. Metal locations where oxygen reduction occurs can be physically separated from locations where iron is oxidized and dissolved if the two locations are electrically connected. In other words, limited supply and transport of oxygen to the liner surface may not necessarily limit corrosion rates.

NRC staff will review reports, analog studies, and other information used to support DOE's assumption regarding initial conditions and performance of the concrete vaults. For example, NRC staff will review annual tank inspection reports that provide information regarding trenching, scarifying, and cracking of the concrete vaults, as well as information about groundwater intrusion into the tank vaults. NRC staff will review reports related to previous events that led to potential releases for groundwater in-leakage through joints or cracks in the concrete vaults. Analog studies could include review and evaluation of information obtained from West Valley or other analog sites to better understand the potential for and rates of corrosion of HLW tanks/components, as well as mitigative design measures. As part of this MF, NRC staff also will consider the potential for earlier steel liner failure than assumed in DOE's PA for many of the tanks due to corrosion of steel components (e.g., rebar) in the concrete vaults that are close to the vault surface and due to corrosion resulting from macroscopically separated electrochemical reaction sites. NRC staff will also consider the potential for earlier waste release from the annular regions of Types I and II HTF tanks than assumed in DOE's PA due to flow through preferential pathways.

If DOE performs additional modeling or experiments to study the potential for transport of deleterious species into the tank vaults and subsequent corrosion of the steel liners or tanks, NRC staff will review the documentation or provide input on the design and results of the experiments. Experiments to study steel liner corrosion are expected to be relatively difficult to implement with unknown benefit compared to other experimental investigations recommended in NRC's TERs (ML112371751, ML14094A496) and discussed in this monitoring plan. Therefore, these experiments are not considered a high priority by NRC staff at this time. NRC staff will assume the steel liners will not be effective at mitigating releases for the long periods of time typically relied on for performance in the PAs and will investigate the support for the performance of other barriers to ensure that the POs can be met. Should results of other investigations indicate that tank farm barriers relied on in DOE's reference (or best estimate) PA cases are not expected to perform as well as assumed, then more thought will be given to methods for obtaining additional support for steel liner performance assumptions, including use of a patch model that could simulate such processes as partial failure and slower release rates from the tanks.

If DOE performs additional modeling or experiments to study the potential for early release of residual waste from the tank vaults through preferential pathways, NRC staff will review the documentation or provide input on the design and results of experiments. Experiments are expected to be difficult to implement because many parts of the concrete vaults and annuli are not presently observable and their present condition is uncertain. However, modeling of waste release from preferential pathways may demonstrate that the performance objectives can be met even with earlier release through preferential pathways. For example, NRC staff recommended in the HTF TER (ML14094A496) that DOE conduct a more comprehensive analysis of the potential release of radionuclides from the annuli and sand pads of Types I and II tanks. To address NRC staff's concerns, DOE considered an alternative scenario that included a preferential pathway (e.g., construction joint) through the Tank 16H vault in a Special Analysis (SRR–CWDA–2014–00106). NRC staff is in the process of evaluating the Special Analysis and will present its review findings in a technical review report to be issued later in FY2015.

NRC staff may conduct technical review activities listed previously in conjunction with onsite observations that could help inform its assessment of the concrete vaults as a hydraulic barrier mitigating steel liner corrosion and waste release. If DOE conducts experiments to provide additional support for concrete vaults as effective hydraulic barriers, NRC staff may observe these experiments at SRS facilities.

MF 3.2—Groundwater Conditioning via Reducing Grout

The hydraulic performance of the tank grout is important to DOE's compliance demonstration because it both limits infiltration and delays chemical transition times to higher solubility, thereby reducing and delaying waste release from the contaminated zone[4] for long periods of time. The transitions in chemical conditions in the grout and residual waste that generally lead to higher solubility are directly dependent on how water flows through the grouted tanks and, potentially, from below the tanks. NRC staff has unresolved technical concerns regarding the potential for the existence or creation of fast flow paths through the grouted tanks. The potential for relatively rapid chemical modifications along these flow paths, and consequent chemical transitions, have not been ruled out. For example, water may flow along cracks relatively rapidly and react with the grout lining the crack walls. This may lead to a chemical environment for percolating water that is quite different from that for water permeating through the bulk grout (e.g., lower pH, higher Eh, and higher aqueous carbonate—as a result of calcification of the crack walls).

In addition to flow through preferential pathways, water table rise could lead to a scenario where residual waste comes into contact with unconditioned groundwater that has not significantly interacted with the reducing grout that lies above the waste residue. As stated previously, water table rise above the bottom of the tanks is primarily a concern for Type IV tanks at FTF and HTF, as well as Type II tanks at HTF that are partially submerged in the water table.

For Type I tanks at HTF, DOE does consider a large fraction of unconditioned water flowing horizontally into the tank system mixing with a small fraction of conditioned groundwater flowing vertically through the reducing tank grout located above the contaminated zone in its base case.[5] However, the level of conditioning afforded by the small quantity of water assumed to flow vertically through the reducing HTF Type I tank grout is nonetheless quite significant. The number of pore water exchanges needed for each chemical transition is actually higher for Type I tanks compared to other HTF tanks (see Table 3-2). This counterintuitive result occurs primarily due to assumptions regarding the chemistry of the saturated groundwater that is assumed to flow into the tank (i.e., low Dissolved Oxygen or DO).[6] With regard to flow assumptions, NRC staff also thinks DOE should provide more support for its assumptions that the engineered system will not interfere with the ability of the reducing grout to sufficiently condition the infiltrating water for fully submerged tanks.

The lack of characterization of the waste, and especially the transuranic elements in it, make the impacts associated with a water table rise scenario uncertain. NRC staff will evaluate the likelihood and assumptions of these scenarios under this monitoring factor through review of historical water table data, groundwater chemistry data, and observations of the conditions and

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[4]DOE assumes that residual waste in the annular regions of HTF Types I and II tanks is soluble, although chemical transition times affect the K_ds or desorption rates for waste located in annuli of Type I tanks (annular waste is loaded in the reducing tank grout that will be used to fill the annuli of Type I tanks).
[5]DOE assumes a ratio of 90- percent unconditioned groundwater and 10-percent conditioned infiltrating water contacting the contaminated zone.
[6]While DOE reports low DO of the unconditioned groundwater as the cause of the longer chemical transition times in SRNL–STI–2012–00404, Table 4.2-8 in the HTF TER indicates that Eh is used in the geochemical modeling to estimate chemical transition times. Because NRC staff analysis of water table well data used in the modeling indicates that Eh and DO may not be well correlated, NRC staff plan to follow up on the effect of Eh and DO on the chemical transition times in DOE's geochemical modeling in a future TRR.

performance of the concrete vaults and other engineered barriers installed during monitoring to affect the flow of water through the tanks.

NRC staff is concerned with DOE's PA assumptions regarding the transition from reduced to oxidized conditions. For example, it is not clear to NRC staff that infiltrating groundwater will, in fact, be conditioned to low Eh by the tank grout. Under contract with the NRC, CNWRA has collected experimental data relevant to the saltstone disposal facility. These data indicate that even if a significant portion of the system remains in a reduced state, minimal interaction between infiltrating groundwater and the reduced inner pore space of the waste form may occur, such that the Eh of the groundwater is more reflective of the incoming groundwater chemistry, rather than a groundwater conditioned by the waste form grout (Pabalan, et. al., 2012). Because flow rates used in CNWRA experiments are higher than might occur in the real system, it is possible that the experimental conditions might not be representative of the real system. Therefore, DOE should undertake experiments using grout formulations consistent with those used or planned for the tanks to confirm PA assumptions regarding groundwater conditioning and chemical transition times that are important to compliance demonstration. NRC staff will also evaluate data collected from lysimeter studies conducted at SRS, primarily to support the saltstone disposal facility PA, to see whether the data could help corroborate PA assumptions regarding the extent of groundwater conditioning. For example, the extent to which infiltrating water is conditioned by saltstone waste form present in the lysimeters may be used to support assumptions regarding conditioning of infiltrating water by tank grout.

Another DOE PA scenario is characterized by preferential pathways through the grout, along either cracks or shrinkage voids along the tank margins. In reality, carbonation of the grout can be expected to be relatively rapid along the preferential pathways. These calcite/aragonite coatings may inhibit conditioning of ingress water by the grout, such that the pH of the water is more likely conditioned by calcite rather than the grout hydroxide. In addition, the reducing capacity of the grout could decline relatively rapidly along these preferential pathways. DOE evaluated the performance impact of preferential pathways in alternative cases in the PAs.[7] Case G from the FTF PA, developed in response to NRC Requests for Information (RAIs), also addressed other potential issues with DOE's base case analysis. In all FTF PA cases, peak doses were in the range of a few mSv/yr (hundreds of mrem/yr) from Pu-239 (SRS-REG-2007-00002, SRR-CWDA-2009-00054). The primary difference between these cases was the timing of the peak dose. Because Case G also considered an earlier transition to higher solubility-limiting phases, this scenario resulted in peak doses that exceeded the dose standard in 10 CFR 61.41 within 10,000 years. Likewise, Case E from the HTF PA also evaluated the impact of preferential pathways. This scenario also resulted in peak doses that exceeded the dose standard in 10 CFR 61.41 within 10,000 years. Therefore, if Cases G of the FTF PA and E of the HTF PA are found to be more likely than assumed by DOE, the extent to which groundwater is conditioned under this scenario may become important to the compliance demonstration and will be evaluated under this MF.

[7]In the FTF PA or RAI responses, DOE evaluated the impact of preferential pathways in Cases C, D, and G. In the HTF PA, DOE evaluated the impact of preferential pathways in Cases B–E.

MF 3.3—Shrinkage and Cracking of Reducing Grout

As discussed in the preceding section, the hydraulic performance of the tank grout is important to DOE's compliance demonstration because it both limits infiltration and delays chemical transition times to higher solubility chemical conditions, thereby reducing and delaying waste release from the contaminated zone for long periods of time. An important factor in the longevity of the chemical barrier performance within the nonsubmerged tanks is the DOE assumption that the infiltrate reaching the contaminated zone does not bypass the waste tank grout (via fast flow pathways). Instead, downward flow through the grout remains relatively uniform and significant across the plane of the contaminated surface. DOE should provide additional support for this assumption. NRC staff is concerned that in actual field conditions, only a fraction of the grout components may be accessible for reaction with the infiltrate, particularly if flow occurs through preferential fast pathways. Preferential fast flow pathways could include shrinkage gaps that form:

- Between the tank grout and steel liner;
- Between the tank grout and internal fixtures;
- At lift interfaces; or
- In between individual grout flow lobes, including the pseudo-cracks formed at internal fixtures where grout split by an obstacle into two lobes merges back together to form a vertical seam on the trailing edge of the obstacle.

CNWRA observed many of these listed features through an independent, NRC-funded study of large grout monoliths (Walter and Dinwiddie, 2008; Walter, et al., 2009; Walter, et al., 2010; Dinwiddie, et al., 2011; Dinwiddie, et al., 2012). The study is providing information to help assess the robustness of DOE assumptions regarding the nature of flow through the tank grout that affects the calculated chemical transition times. NRC conducts these analyses to independently inform its review rather than make conclusive findings because NRC recognizes these studies cannot fully duplicate conditions in waste tanks at SRS. DOE should consider conducting its own grout studies and inspections of the distribution, consistency, flowability, and topography of the grout, as it is placed in the tanks, as well as measurement of the in-place physical properties of the grout, including vertical distribution and temporal evolution of grout density, porosity, and permeability. These activities could provide the information necessary to support key PA modeling assumptions.

DOE also should consider design measures to minimize the occurrence of negative features, events, or processes related to grout placement. For example, DOE should consider removal of in-tank equipment that could lead to development of shrinkage-induced annuli around equipment or corrosion of steel components and associated cracking due to corrosion product expansion. DOE also should ensure the ability of the tank grout to fill all void spaces (i.e., grout should be self-leveling) to minimize imperfectly bonded grout seams and voids that may form in between grout pours. DOE should research and evaluate shrinkage-compensating agents for use in its grout formulations to minimize shrinkage, shrinkage gap formation, and creation of annuli and void space within the tank grout, as recommended in SRNL-STI-2011-00551.

Preferential fast flow pathways also include cracks that form due to thermal or mechanical stresses (e.g., those due to settlement or corrosion product expansion from steel component corrosion). NRC will request information regarding thermal gradients generated during tank grout curing and evaluate potential for thermal cracking in a future technical review activity or onsite observation. In its technical reviews of the final configurations for Tanks 18F/19F; and Tanks 5F/6F at FTF, NRC staff noted that a more detailed thermal analysis that considers the specific grout pour sequence and geometry to determine the impact on grout porosity, hydration products, and the potential for thermal cracking of the tank ground would improve model support (ML13269A365; ML14342A784). Cracking due to settlement is discussed in Section 6.2.

NRC staff also is concerned with potential formation of cracks in the tank grout due to alkali-silica reaction (ASR). ASR is a process whereby reactive aggregates break down under exposure to the highly alkaline pore solution in concrete, which can result in significant expansion and, in some cases, cracking of concrete. This concern arose because the grout being used to fill Tanks 18F and 19F included 3/8-inch granite "pea gravel" as an aggregate, instead of using only sand aggregate, as described in the DOE's FTF PA document (SRS-REG-2007-00002), and because of recent observations of concrete cracking at the Seabrook Nuclear Power Plant in Seabrook, New Hampshire. In that facility, granite aggregates also were used in the concrete mix. ASR is a slow process, and its occurrence at Seabrook became evident only decades after the plant was constructed. Grout fill mix in Tanks 18F and 19F contained less Portland cement than the concrete mix used at Seabrook and likely would be less susceptible to ASR. Nevertheless, NRC staff is concerned that DOE's criterion for acceptance of vendor-supplied granite aggregate relies on short-term alkali reactivity tests (ASTM C–1260), which is unlikely to predict the occurrence of ASR over the very long period of performance for compliance with PO 61.41. NRC staff first raised the ASR technical issue with DOE in an onsite observation (ML12191A210). NRC staff also discussed this issue in its technical review reports for Tanks 18F/19F grouting, and Tank 5F/6F grouting (ML13269A365 and ML14342A784). NRC staff will continue to discuss this issue with DOE and evaluate the potential for ASR to negatively impact tank farm performance in future technical review activities or onsite observations.

NRC staff will review grout formulations, calculations, research, test methods, and results to ensure the disposal facility is designed to minimize fast flow path development. NRC staff may conduct technical reviews in conjunction with onsite observations that could include such activities as video inspections of grout pours, observations of grout tests, and inspections of test specimens.

MF 3.4—Grout Performance

During onsite observations, NRC staff will verify the actual grout formulation DOE uses is consistent with performance assumptions in the PAs (SRS–REG–2007–00002, SRR–CWDA–2010–00128) and design specifications assumed in the final waste determinations (DOE/SRS–WD–2012–001, DOE/SRS–WD–2014–001). DOE should evaluate significant deviations from the design specifications to ensure expected grout performance will not be negatively affected. In addition, NRC staff will evaluate DOE's program for sampling, testing, and accepting grout materials to ensure materials conform to DOE specifications and national standards, such as ASTM C–989. The verification program should incorporate a comprehensive record-keeping system to include, for example, (i) plant operation records; (ii) vendor-provided test reports on the grout components; (iii) as-received acceptance test reports on bleed, slump, and/or flow of each grout batch (e.g., ASTM C–232, ASTM C–143, ASTM C–1611) and records of any additional water or other components added onsite to meet the acceptance criterion prior to emplacement; (iv) DOE laboratory test results of composite or grab samples; and (v) certification of shipping records. As part of its evaluation, NRC staff expressed concern about the use of commercially available Portland cements in Tanks 18F/19F and 5F/6F because up to 5-wt% substitution with limestone can occur that could lower the pH buffering capacity of the grout and the observations of bleedwater segregation that could

potentially impact hydraulic properties and grout quality and affect the timing of release of key radionuclides (ML13269A365; ML14342A784).

Also, NRC staff will evaluate the adequacy of the verification program pertaining to DOE's supply of grout components, such as blast furnace slag. NRC staff's evaluation will be based, to the extent practicable, on direct observation of ongoing activities and interviews with key DOE personnel. The review will evaluate certain aspects of the program:

- Representativeness of the samples collected
- Adequacy of the analytical equipment
- Calibration of the analytical equipment
- Adequacy of verification records

To minimize degradation in the quality and chemical reactivity of the slag and Portland cement, DOE must store the material in weather-tight silos or bins to prevent contact with moisture. During onsite observations, NRC staff will examine silos or bins for storage of the slag and cementitious materials. In addition to the grout formulation, curing conditions are expected to have a significant effect on the short- and long-term performance of the emplaced grout. Numerous studies have shown that improper curing results in a variety of undesirable effects, such as lower strength, high permeability, and several types of cracking. For example, early age cracking could occur due to thermal and self-dessication stresses and uneven lift topography. DOE streamed live video (over the internet) of the initial grout pours into Tank 18F, which provided important information regarding grout flowability and non-self-leveling grout behavior. The technology needed to observe most stages of grout emplacement has thus been proven, and DOE should continue to use this technology during grout emplacement. NRC will review video footage of grout emplacement activities to (i) provide confidence that grout behavior during emplacement is understood and (ii) incorporate this information into NRC reviews of PA updates. NRC staff performing onsite observations will verify grout placement is conducted under proper temperature and humidity conditions or that steps are taken to ensure proper curing of the grout. NRC staff will also evaluate DOE's efforts to ensure that grout is able to flow into voids within the tanks and remaining equipment so that no risk-significant void space remains in the grouted tanks and vaults.

MF 3.5—Vault and Annulus Sorption

An additional NRC concern pertains to the hydraulic and chemical performance of the concrete vault walls and floor, which NRC considers an important barrier to radionuclide release. Despite the relatively short transport pathway, sorption onto the concrete attenuates release of HRRs, such as isotopes of Np and Pu, by orders of magnitude in DOE's PAs. DOE barrier analyses indicate the presence of a fast flow path through the basemat causes a more rapid release of contaminants. This effect is more evident for Pu because of its high sorption coefficient in oxidized concrete. Notwithstanding results of the barrier analyses, a fast flow path through the basemat is not considered a likely scenario in the DOE PA base cases. DOE needs to provide support for its base case assumption that the basemat will remain intact. In particular, the basemat underneath Type IV tanks is only 10 cm [4 in] thick and could be susceptible to cracking due to stress imposed by the mass of emplaced grout.

Additionally, the concrete vaults and reducing annular grout were shown in the HTF PA to be a potentially significant barrier to waste release. NRC staff will review studies and information regarding the sorptive capacity of these cementitious materials in attenuating releases from the vaults, as well as the chemical transition times of these cementitious materials as they affect sorption that may be important to the compliance demonstration.

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APPENDIX E
MA 4, “NATURAL SYSTEM PERFORMANCE”

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MF 4.1—Natural Attenuation of Key Radionuclides

The choice of appropriate distribution coefficient (K_d) values for radionuclides in the natural system is very important to PA analyses and has been the subject of considerable effort at SRS. As radionuclides are leached from the waste and released to the soil, sorption in the natural system will be a critical barrier that will depend on a number of factors, including pH, ionic strength of the solution, speciation of the radionuclides, and their oxidation state(s).

In the FTF PA (SRS–REG–2007–00002), Pu is one of the most important radionuclides contributing to peak dose. For oxidized forms of Pu (V/VI), the "best" value for K_ds is 16 mL/g. For reduced forms of Pu (III/IV), the best value for K_ds is 300. Because Pu can exist in several redox states at the same time, a combination best value was suggested as 290 mL/g. These values were taken from SRNL–STI–2009–00473 as the best estimates for sandy sediment. As explained in the report, the combination value is a hybrid that is taken to describe fractions of Pu in two different oxidation states: 95 percent of reduced Pu (III/IV) and 10 percent oxidized (V/VI) [sic].

Subsequent to preparation of the DOE's FTF PA (SRS–REG–2007–00002), Section 6.3.5.3.4 of the Tanks 18F and 19F Special Analyses (SRR–CWDA–2010–00124) explains that Pu K_ds values were reevaluated. Section 6.3.6.1 of the special analyses (SRR–CWDA–2010–00124) considers the impact of the new K_ds values on the deterministic model results. A statistical analysis of 65 K_ds values (SRNL–STI–2011–00672) taken from many areas and materials around the SRS was conducted in an attempt to reexamine K_ds from a site-wide perspective. SRNL–STI–2011–00672 only grossly considers chemistry in evaluating K_ds for FTF (e.g., pH is binned into two categories—greater or less than 7—and Pu redox state is not considered). SRNL–STI–2011–00672 recommends a K_d value of 650 L/kg for FTF based on the following: (i) information from a modeling analysis (Demirkanli, et al., 2007) of long-term lysimeter studies (Kaplan, et al, 2006) indicates that a K_d of 1,800 L/kg should be used and (ii) the statistical analysis shows that the 290 L/kg value used in the FTF PA is in the lower quantile. The sediment in the lysimeter appears to have had more clay in it than typically found at FTF, and so the 1,800 L/kg value was lowered to 650 L/kg. This value, in turn, was increased for the near field of the tanks, using a factor of two recommended in SRNL–STI–2009–00473 to account for greater adsorption due to elevated pH resulting from grout component leaching. Technical issues associated with DOE's development of the Pu K_ds are discussed in an NRC staff technical review report (ML12272A124).

The work to analyze and model results of the SRS Pu lysimeters has led to a model in which a reduction rate and an oxidation rate drive concentrations of different Pu redox states at any given time (SRNL–STI–2009–00473; Kaplan, et al., 2006; Demirkanli, et al., 2007). This leads to a small fraction of mobile Pu and a large fraction of relatively recalcitrant Pu. To reproduce the profiles in the lysimeters, the two rates and the retardation factor needed to be adjusted. In lysimeters containing reduced Pu sources, a retardation factor of 15 was used for Pu in the small, mobile fraction, while a retardation factor of 10,000 was used for the larger fraction. Even with the high retardation of the large fraction, modeling was not able to capture the overall Pu distribution in the lysimeter by using a single species retardation factor (Demirkanli, et al., 2007). A small, mobile fraction was needed to mimic the soil profile of Pu below the source.

The long-term lysimeter experiments conducted at SRS and other work referenced in Kaplan et al. (2006) show that although most Pu is in the (IV) state, there is a small component that at times is in a much more mobile form. In fact, most Pu that is in solution (albeit a very small concentration) is in the Pu (V) form. Even PuO_2(s), which had been considered a stable form of Pu (IV), has been shown to oxidize in the presence of water, forming a substantial fraction (27 percent) of Pu (VI) (Haschke, et al., 2000). In SRS sediment, it is thought that Pu cycles repeatedly through the Pu (IV) and Pu (V) oxidation states in response to wet/dry cycles (WSRC–MS–2003–00889).

From SRNL–STI–2009–00473 the best K_d value for sandy soil for Pu (V/VI) is 16 mL/g, while for Pu (III/IV) the best value is 300 L/kg. Recognizing that Pu chemistry is especially complex and disproportionation presents a difficult problem, NRC staff suggests that averaging K_d values for different oxidation states is not appropriate, even if values are weighted for proportions of different redox states.

A potential additional complication is the possibility that Pu (III) can be produced by certain common Fe (II) species, and that the Pu (III) form can be more soluble or mobile than Pu (IV). The finding by Felmy, et al. (2011) that Pu (IV) can be reduced to Pu (III) by Fe (II) and that the presence of certain Fe (III) minerals increases the reaction rate suggests that for long times a single K_ds, steady-state adsorption model may not be appropriate. For the SRS lysimeters containing sources of reduced Pu, XANES showed that in the soil, Pu was distributed as follows: approximately 37 percent Pu (III), 67 percent Pu (IV), 0 percent Pu (V), and 0 percent Pu (VI) (Kaplan, et al., 2007). This distribution was essentially the same for both the Pu (III) and Pu (IV) lysimeters. In both cases, most Pu remained very close to the source over 11 years; however, a small but measurable quantity of Pu in the sediment had migrated to a maximum of 15 cm [5.9 in] from the source, giving a concentration of about 1 pCi/g. XANES is not sensitive to species that are less than about 5 percent abundance, so even if some Pu (V) were present, it would almost certainly not be observed. From the evidence based on research at SRS, it is apparent that in the presence of reduced Pu, some small fraction can be oxidized, enter solution, and become relatively mobile. This is probably an ephemeral process, with Pu (IV) and Pu (V) switching back and forth, but always heavily dominated by Pu (IV). Factors such as complexation of the aqueous phase and possibly microbiological activity will potentially influence this distribution in a currently unknown way.

SRNL–STI–2012–00106 provides a discussion of the possible solid phases and aqueous species in which Pu may reside in residual tank wastes. Recent SEM analysis (of a single waste sample) is reported (Hay, et al., 2012) to show Pu present as discrete, small (<1 um) particles that are currently not characterized. The mass of these particles seems to be smaller than total Pu in the sample, suggesting that some Pu also is coprecipitated. Further, the formation of $PuO(CO_3)xH_2O_{(solid)}$ or $Pu(OH)_2(CO_3)_{(solid)}$ in the presence of aqueous Pu carbonate species in the tank heels is viewed as a likely possibility. In fact, carbonate concentrations of about 0.04 M were measured in the aqueous phase of Tank 18F heels. Recently, XRD analysis of Tank 18F heels shows the presence of $Na_4UO_2(CO_3)_3$ and calcite at about 10 percent of the crystalline solid phase material (SRNL–L3100–2012–00017). The presence of these solids and the measured aqueous carbonate concentrations strongly suggests that some Pu in the heels is in a carbonate form. If Pu is present as a carbonate solid, then at pH 9.8, relatively high Pu solubilities of around 1×10^{-6} mol/L can be expected. Hobbs suggests that the OH^- from the grout, in contact with the heels, should convert the carbonate to less soluble $Pu(OH)_{4(am)}$ or $PuO_{2(am,\ hyd)}$. However, it is not clear whether this process does in fact take place; Hobbs recommends experiments to verify the transformation. These observations suggest that at least some of the Pu in the aqueous phase in the heels will be negatively charged carbonate complexes of higher solubility. SRNL–STI–2012–00106 reported that $Pu(OH)_2(CO_3)_2^{-2}$ was the dominant solution Pu species between pH 9.4 and 10.1, while $Pu(OH_4)(CO_3)_2^{-4}$ was the dominant Pu solution species when pH was between 12 and 13. If these species are present in leachate from the grouted tanks, then very low K_ds values can be expected. The stability of these species under high pH and varying redox conditions is not clear.

Therefore, based on the information presented previously, NRC staff will monitor DOE's efforts to conduct transport modeling that explicitly accounts for the multiple oxidation states of Pu that may be present or may form during transport through the FTF far field. K_ds for Pu should be developed based on sorption studies relevant to FTF (i.e., based on sorption to sediments encountered during transport from the FTF tanks to various points of compliance and considering important changes to geochemical conditions that may occur over space and time).

As expressed in the HTF TER (ML14094A496), NRC staff has technical issues associated with the cement leachate factors applied in the HTF Performance Assessment (SRR–CWDA–2010–00128, Table 4.2-25). The cement leachate factors are used to account for the effect of high pH leachate on the ability of natural soils to sorb key radionuclides also present in the leachate. The cement leachate factors used in the HTF PA are based on information provided in SRNL–STI–2009–00473 and Hanford site data. As stated in the HTF TER, because the Hanford site geological and geochemical environment contrasts sharply with SRS, using Hanford site data to calculate the factors for SRS is not justified without an element-by-element analysis of the chemical processes affecting sorption. Element-specific considerations were applied to some but not all key radionuclides when deriving cement leachate factors. With respect to uranium and neptunium, DOE uses cement leachate factors for sand greater than 1, and DOE selected a value of 0.9 for Pu, which is higher than the value of 0.25 used in the Hanford study. Selection of the Pu and U cement leachate factors is based on solubility arguments. However, sorption describes a different natural attenuation mechanism, which is different than solubility constraints, and solubility limits may not be appropriate for application in the natural environment. Furthermore, the sorption behavior of actinides at high pH in the unsaturated zone may be strongly dependent on the presence of carbonate species. Sorption may decrease in the presence of elevated pH if high carbonate concentrations exist in the natural environment.

NRC staff recently issued a technical review report (ML12272A124) related to MF 4.1, "Natural Attenuation of Pu," and MF 4.3, "Environmental Monitoring," listed in NRC staff's FTF Monitoring Plan (ML12212A192). The NRC staff listed a few follow-up actions that were not included in the original FTF monitoring plan, including the following:

- The NRC staff will continue to monitor support for cement leachate factors developed for Pu (and other constituents). DOE could provide support for cement leachate factors by performing site-specific analyses (this issue will be addressed under MF 4.1, "Natural Attenuation of Key Radionuclides").

- The NRC staff will continue to monitor the basis for selection of the Nb distribution coefficient or K_d value of 160 L/kg used in the Tanks 5F and 6F Special Analysis. DOE could address the technical issues by verifying that the batch experiments did not exceed solubility limits and are representative of conditions at FTF (e.g., plot solid phase versus aqueous phase concentration or K_d versus concentration; evaluate K_d for FTF aquifer soils) or performing additional experiments to verify the Nb K_d (this issue will be addressed under MF 4.1, "Natural Attenuation of Key Radionuclides").

- The NRC staff will continue to monitor the ability of the tank farm monitoring well network to detect releases from the tank farm facilities following closure. DOE could evaluate the monitoring well network by performing an analysis of the centerline of plumes emanating from tank sources should releases occur in the future and providing input on optimal well locations to ensure that future releases from the tank farm facility would be detected (this issue will be addressed under MF 4.3, “Environmental Monitoring”).

- The NRC staff will continue to evaluate the source of elevated Tc-99 levels in well FTF 28. It is not clear that releases from the F-Area Inactive Process Sewer Line could migrate vertically to the lower zone of the UTRA in such a short distance from the source. This evaluation is important to ensure that the hydrogeological system at FTF is well understood and that releases from the tanks could be detected by the monitoring well network. DOE could provide additional support for the source of contamination detected at well FTF 28 by performing particle tracking to better understand contaminant plume trajectories. DOE could also perform a more formal statistical analysis of FTF and Western Groundwater Operable Unit well data to correlate contaminant concentrations associated with various sources (this issue will be addressed under MF 4.3, “Environmental Monitoring,” and MF 6.2, “Model and Parameter Support”).

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