Draft Waste Incidental to Reprocessing (WIR) Evaluation for Vitrified Low Activity Waste (VLAW) Disposed Onsite at Hanford

Ingrid Milton
U.S. Department of Energy
Environmental Management Program
Office of Regulatory Compliance

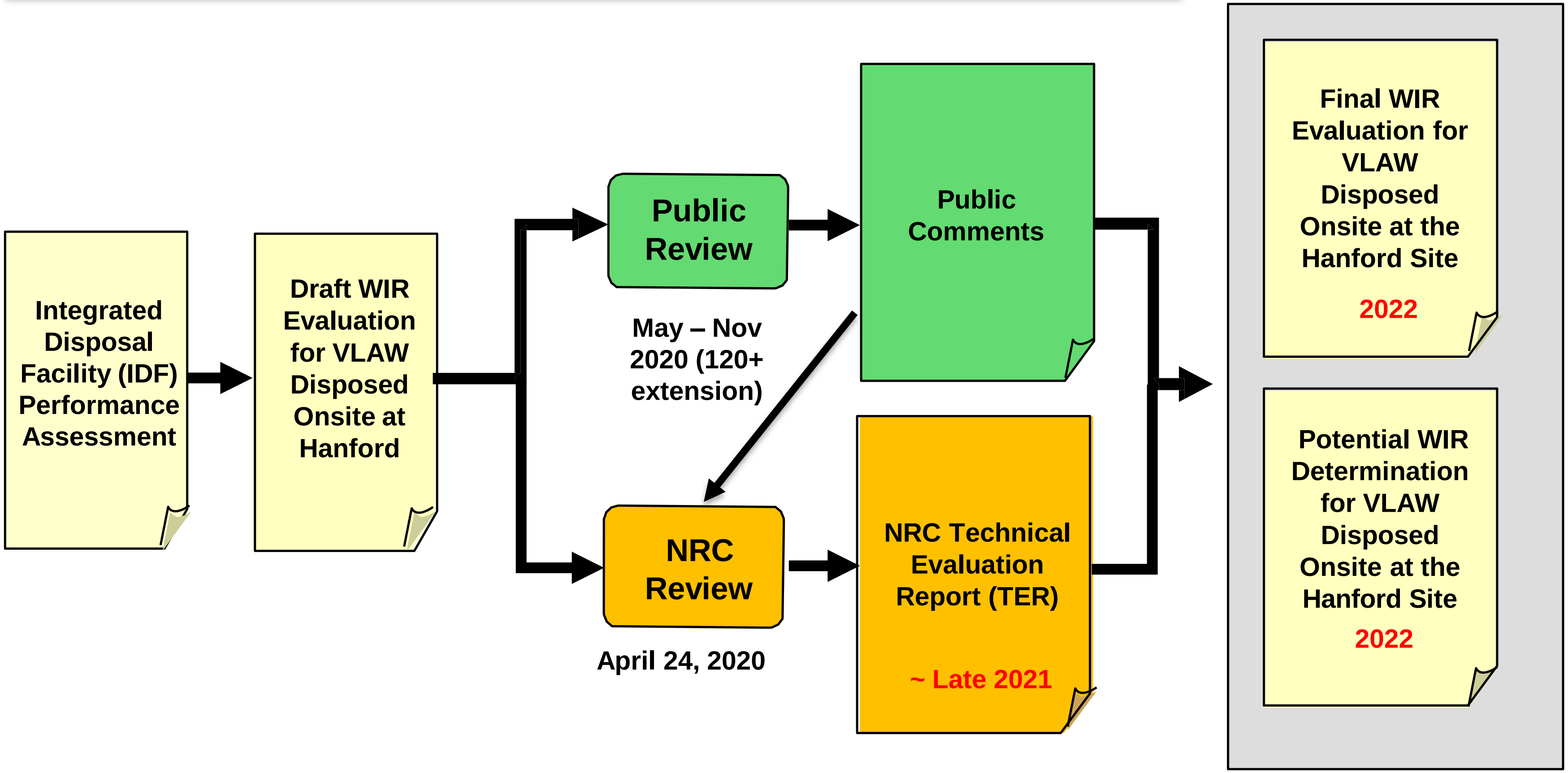
August 26, 2021

Purpose of the Draft Hanford VLAW WIR

- DOE is on track to start vitrifying (immobilizing in glass) certain Hanford low-activity tank waste using the Direct-Feed Low-Activity Waste (DFLAW) approach.
- DOE has prepared a Draft WIR Evaluation to assess whether the vitrified low-activity tank waste can be safely disposed of at Hanford's Integrated Disposal Facility (IDF) as low-level radioactive waste (LLW),
- The Integrated Disposal Facility is a DOE authorized LLW disposal facility and is also permitted by the State of Washington.
- Completing the Draft WIR Evaluation is an important part of the DFLAW mission. It represents a key step toward the safe onsite disposal of Hanford vitrified low-activity tank waste.

WIR Consultation and Public Process

NRC consultation - open public process



DOE Actions　　Nuclear Regulatory Commission　　Public

All dates in red are estimates, subject to change

Open Public Process

NRC reviews DOE documents

DOE and NRC initial public meeting. Overview of document and process. DOE, NRC and WRPS are presenters.

NRC's submit Request for Additional Information (RAI) to DOE

DOE and NRC public meeting # 2 on NRC's RAI. NRC is presenter.

DOE respond to NRC's RAI

Current Stage in Process

DOE and NRC public meeting # 3 on DOE's responses. DOE is presenter.

NRC issues Technical Evaluation Report to DOE

DOE considers NRC and public comments to prepare Final WIR Evaluation

DOE publishes Final WIR Evaluation and potential Determination

DOE Actions | Nuclear Regulatory Commission | Public

DOE shares all public comments with NRC. DOE and NRC anticipate staff to staff, non-decision conference calls to ask clarification questions which will be open to the public to observe. DOE and NRC will post a summary of all public meetings.

Draft WIR Evaluation Activities

- Advance Notice to stakeholders – April 23, 2020
- Draft VLAW WIR Evaluation to NRC – April 24, 2020
- Federal Register Notice of 120 days comment period – May 26, 2020
- Public meeting – June 10, 2020
- NRC completeness review – June 22, 2020
- Federal Register Notice 60 days comment extension – Sept 22, 2020
- NRC Request for Additional Information to DOE – November 6, 2020
- Public Meeting on NRC's Request – November 19, 2020
- End Public comment period – November 27, 2020
- DOE responses to NRC's Request – June 21 and July 29, 2021

Aug. 26 Public Meeting Purpose: DOE will present responses and provide clarifications to NRC, as requested.

Secondary Generated Waste Section 2 of DOE/ORP-2021-02, Rev 1

"DOE approach was not consistent with the intent of the incidental waste process. DOE's election of vitrification as the primary waste production process results in some key radionuclides that are volatized and effectively separated from the waste (e.g., ^{129}I), or are removed in other processing steps. ***If the majority of that activity that is separated or removed will be disposed in near-surface disposal (i.e. as other than high-level waste), then the resulting waste forms and waste streams are within the scope of the draft waste evaluation****, especially for DOE Manual 435.1-1 Criterion 2 as the key radionuclides drive the long-term risk for the disposal. As a result, NRC has included secondary solids wastes within the scope of the review."*

DOE Response:

- The DFLAW pretreatment process will remove over 99% of the cesium, as well as other key radionuclides.
- The LAW vitrification facility will by design maximize the capture of Tc-99 and ^{129}I in the vitrified glass (VLAW).
- The vast majority of all radionuclides in the pretreated LAW, including Tc-99 and ^{129}I, will be captured in the VLAW and will not be entrained in secondary waste.

DOE Response Continued

- Since the completion of the IDF Performance Assessment (PA), the latest flowsheet modeling shows:
  - ~ 98 % of Tc-99 and ~ 96 % of ^{129}I will be captured in the VLAW.
  - ~ 99% of all radioactivity in the pretreated LAW will be incorporated in the VLAW.
- After pretreatment using the DFLAW approach, the pretreated LAW stream will contain approximately 1% of the radioactivity from the applicable tank waste.
- Otherwise stated, the relevant secondary waste, in combination, will contain ~ 1% of 1% (0.0001) of the radioactivity initially in the applicable tank waste.

DOE Response Continued

- Furthermore, if DOE issues a Final WIR Evaluation and WIR Determination in the future, the pretreated LAW may be managed and disposed of as LLW, subject to the analysis and commitments of the Final WIR Evaluation and WIR Determination.
- Secondary waste generated from processes associated with further treatment, stabilization, solidification, storage, transport or disposal of this pretreated LAW must necessarily continue to be managed and disposed of as LLW and cannot be considered HLW.
- This secondary waste can be disposed of in the IDF, if it is properly characterized and meets the WAC for the IDF, including radionuclide concentration limits to ensure protection of a hypothetical inadvertent intruder.
  - DOE has previously determined that such secondary waste is not HLW under the ORP WIR citation procedure. Alternatively, a citation WIR could be based on the factual situation here which indicates the relevant secondary wastes are akin to “contaminated job wastes” described in DOE M 435.1-1.

DOE Response Continued

- The IDF PA correctly includes secondary waste because it is planned to be disposed at the IDF. This does not mean that secondary waste should be included within the scope of the Draft WIR Evaluation.
- DOE has responded to the NRC RAIs pertaining to secondary waste to provide additional information and clarification. (preliminarily marked with * in this slide presentation)

THE HANFORD SITE

Draft Waste Incidental to Reprocessing Evaluation for Vitrified Low-Activity Waste Disposed Onsite at the Hanford Site, Washington

August 26,2021

Introduction

- Twenty-six Request for Additional Information (RAI) responses were prepared
  - Full response is available to the public on DOE website
- Individual Washington River Protection Solutions subject matter experts will present the DOE responses for the Nuclear Regulatory Commission's (NRC) Request for Additional Information (RAI)
- RAIs are presented as two slides
  - NRC Comment and Path Forward
  - Summary of DOE Response

RAI 1-1 Removal of ^{90}Sr to the Maximum Extent Practicable

- **Comment:** Additional information is needed on the amount of soluble ^{90}Sr expected to be in the waste processed for DFLAW and the technologies that may be used to remove it to the maximum extent practical.
- **Path Forward:** Please provide additional information on what percentage of the ^{90}Sr is estimated to be soluble versus insoluble in the tanks. Please provide additional basis for what percentage of the soluble ^{90}Sr DOE estimates can be extracted using the ion exchange columns, or other technologies planned to be used.

RAI 1-1 Response

Response:

- It is estimated that 4% of the total ^{90}Sr inventory in the Hanford Tank Farms is soluble.
- Nearly all insoluble strontium is expected to be removed from the tank waste prior to vitrification.
- In process modeling, soluble ^{90}Sr is conservatively assumed to remain in the DFLAW feed and become incorporated into the VLAW. However, laboratory data (PNNL-28945) shows that the overwhelming majority of the soluble ^{90}Sr will be removed by the Crystalline Silicotitanate (CST) in the Tank-Side Cesium Removal process.
- The DOE intends to use sampling and analysis to characterize the amount of ^{90}Sr in every batch received in the LAW Vitrification Facility.

PNNL-28945, 2019, *Characterization of Cs-Loaded CST Used for Treatment of Hanford Tank Waste in Support of Tank-Side Cesium Removal*, Pacific Northwest National Laboratory, Richland, Washington.

RAI 1-2 Percentage of Key Radionuclide Removal*

- **Comment:** Additional information is needed on the percentage of key radionuclides removed from the waste that will be disposed in the Integrated Disposal Facility (IDF).
- **Path Forward:** Please provide the percentages of key radionuclides removed for those key radionuclides (see Table 4-3 of the draft WIR evaluation) that are not already included in PA Table 3-29.

RAI 1-2 Response

Response:

- Table 4-3 in the Draft WIR Evaluation identifies key radionuclides. The second and third columns of Table 4-3 identify as key radionuclides those radionuclides listed in Title 10, Code of Federal Regulations (CFR), Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," Subpart D—Technical Requirements for Land Disposal Facilities, §61.55, "Waste Classification" (10 CFR 61.55), and the last column identifies those radionuclides important to the IDF PA (RPP-RPT-59958).

- Table 1-2-1 in full RAI response provides further information on projected radionuclides removal rates during DFLAW processing. This Table will be added to the final WIR Evaluation.

- For the DFLAW approach, over 99% of the radionuclides in the pretreated LAW will be captured in the VLAW. Note that the pretreated LAW contains less than 1% of the total curies in the DFLAW candidate tanks

- Over 96% of the ^{129}I and over 98% of the ^{99}Tc in the pretreated LAW sent to the LAW Vitrification Facility will be captured in the VLAW.

RAI 1-3 Percentage of ^{99}Tc and ^{129}I Recycled versus Removed *

- **Comment:** Additional information is needed on the percent of the ^{99}Tc and ^{129}I that could potentially be removed from the waste versus remaining in either the VLAW or the Solid Secondary Waste (SSW). (See also RAI 2-10).
- **Path Forward:** Please provide additional information on the percentage of ^{99}Tc and ^{129}I that is expected to be recycled back to the DFLAW feed, percent returned to the tank farm to be disposed of as HLW, and percent purged via the Effluent Management Facility (EMF) evaporator concentrate. Please provide additional information about the accumulator mentioned in Table 3-29 of the PA document. Please specify if the ^{99}Tc is assumed to be accumulating in one component or in multiple parts of the Waste Treatment Plant (WTP). Please provide the hypothetical plan for disposal of the accumulator waste.

RAI 1-3 Response*

Response:

- The DFLAW flowsheet has matured and the EMF design (used during DFLAW only) has been finalized since the PA study was performed. In the current flowsheet configuration:
  - 98.4% of the ^{99}Tc and 96.2% of the ^{129}I is expected to be incorporated into the VLAW by recycling the EMF evaporator concentrate back through the LAW melters.
  - No ^{99}Tc or ^{129}I will be returned to the Tank Farm to be disposed of as HLW.
  - No ^{99}Tc or ^{129}I is currently planned to be purged via the EMF evaporator concentrate.
- The accumulator mentioned in Table 3-29 for Case 8B of the PA document is a modeling tool representing a hypothetical, undefined ^{99}Tc removal operation for mass balance purposes. This case is no longer a potential scenario and will be withdrawn from the analyses performed for the PA for its next revision.

RAI 1-4 Alternative Technology Evaluation Impacting ^{99}Tc and ^{129}I*

- **Comment:** Additional information is needed on the alternative technologies considered for removal of ^{129}I and ^{99}Tc.
- **Path Forward:** As a result of high operating temperatures, the vitrification process appears to selectively partition the ^{99}Tc and ^{129}I to the SSW waste stream during processing of the waste. Given that ^{99}Tc and ^{129}I are key risk drivers, please provide information regarding potential technologies that may have been considered to connect the offgas system to other waste treatments that would result in those key radionuclides being incorporated into HLW compared to the VLAW or SSW.

RAI 1-4 Response*

Response:

- Volatile constituents present in the LAW feed (including radionuclides such as ^{99}Tc and ^{129}I) will non-selectively partition to the melter offgas system, where they are captured by the Submerged Bed Scrubber (SBS) and Wet Electrostatic Precipitator (WESP), reintroduced into the LAW feed at the EMF, and ultimately incorporated into VLAW during DFLAW processing.
- The majority of the ^{99}Tc and ^{129}I in the DFLAW feed (~98% and ~96% respectively) and 99% of all radionuclides from the pretreated LAW are now projected to be incorporated into the VLAW during DFLAW approach.
- The IDF PA will be revised to incorporate these changes as part of PA maintenance. DOE will monitor all waste as it is disposed to ensure that the IDF waste acceptance criteria (WAC) are met and the IDF PA maintained.
- DOE is not pursuing other potential processes that would divert volatized Tc and I to non-VLAW waste streams.

RAI 1-5 Removal and Disposal of Separated ^{129}I*

- **Comment:** In the draft WIR evaluation, DOE indicated that they did not identify a technology that could practically remove ^{129}I from tank wastes. It isn't clear why the ^{129}I that is separated very efficiently by the vitrification process could not be disposed as HLW.
- **Path Forward:** Please provide information as to whether DOE evaluated the disposal of the ^{129}I that would be adsorbed by the two carbon adsorber beds filled with granular activated carbon media as HLW.

  Please also describe what percentage of the ^{129}I can technically and practically be removed using the Carbon Adsorber Beds (CAB).

RAI 1-5 Response*

Response:

- The CABs are used to remove mercury, halides, and acid gases including iodine, for the control of air emissions to meet Environmental Protection Agency air discharge limits and reduce occupational doses. The CABs are not designed or relied upon in the Draft WIR Evaluation as a treatment process for removing ^{129}I to meet the first WIR criterion under DOE M 435.1-1 (concerning removal of key radionuclides to the maximum extent technically and economically practical).
- The CABs will be properly characterized and classified and if characterized as LLW, treated and disposed of in the IDF in accordance with IDF-00002. The CABs are identified as a future newly-generated LLW in the LAW Vitrification Facility Radioactive Waste Management Basis (RWMB).
- The LAW Vitrification Facility off-gas system in combination with the EMF and recycling the EMF bottoms back to the LAW Vitrification Facility will, by design, maximize the capture of the volatized ^{129}I in the VLAW glass. Approximately 96% of the ^{129}I will be captured in the VLAW as explained in the response to RAI 1-2, compared to 57.51% assumed in the IDF PA.
- Revised modeling that has a combination of no returns to the Tank Farms and higher first pass incorporation now projects 96.2% of the iodine will be incorporated into VLAW.

RAI 2-1 Scope of PA Compared to Scope of Draft WIR Evaluation*

- **Comment:** The results from the PA that are directly applicable to the scope of the draft WIR evaluation are not clear. One factor could have been the timing of the completion of the PA and draft WIR evaluation.
- **Path Forward:** Please ensure that the cumulative impact of all radioactive material disposed of at IDF is considered when evaluating the performance objectives of 10 CFR Part 61, including the doses resulting from the DFLAW inventory and the associated secondary wastes generated from processing the DFLAW inventory. If significant portions of key radionuclides end up in processing components, such as the off-gas system and those components are disposed as non-HLW, then they should be included in the results. Please also provide the waste classification results for all relevant waste streams and a demonstration that those streams will be incorporated into a solid physical form.

RAI 2-1 Response*

Response:

- IDF is planned to receive LLW generated from a variety of sources, in addition to VLAW produced during the DFLAW approach.
- To bound the analysis and provide the “cumulative impact” of all waste potentially disposed in the IDF, the IDF PA correctly analyzes all LLW that potentially may be disposed of at the IDF, including secondary waste.
- All waste to be disposed at the IDF must be compliant with IDF Waste Acceptance Criteria, IDF-00002, which requires solid waste forms for disposal.
- Additionally, wastes to be put into IDF must meet the Washington Administrative Code 173-303-140, which only allows wastes that do not contain free liquids.
- Approximately 1% of the total key radionuclides <u>after pretreatment</u> during the DFLAW approach will be in the relevant secondary waste.

RAI 2-2 Model Support for the PA

- **Comment:** Additional information is needed related to demonstrate whether the conceptual and numerical models used in the PA were adequately supported over the range of projected future conditions.
- **Path forward:** Please provide a summary of model confidence-building activities for the VLAW PA model or provide DOE's strategy and plan for future verification activities that are anticipated to be completed. Describe activities that have been included in the PA maintenance plan. Complete modeling with the PA model used for the VLAW PA that shows that transport of 90Sr to the aquifer can be generated in the modeling results under reasonable historical operating conditions.

RAI 2-2 Response

Response: The RAI response includes summaries of:

- Model confidence-building activities
- Intermediate results of numerical modeling including discussions regarding:
  - Secondary minerals formed during glass corrosion
  - Water contacting the waste forms
  - Radionuclide transport time in the vadose zone
  - Transport of ^{90}Sr in the vadose zone
  - Dilution in the saturated zone
- PA maintenance activities planned to verify the representativeness of the models

RAI 2-3 PA Modeling Discretization

- **Comment:** From the information provided, it isn't clear that the numerical model utilized had a discretization sufficient to ensure acceptable accuracy.
- **Path forward:** Please provide additional basis for the discretization of the numerical models used in the PA to simulate near-field flow, release and transport. Demonstrate that the simulated releases were not artificially biased by the stair-stepped grid representation of the slopes of the engineered cover and liner system. Provide a basis for the amount of increase, at the limit, on the fractional release rate from the glass as a function of refined numerical grids for release, and how the model should appropriately account for the uncertainty of a coarser numerical grid.

RAI 2-3 Response

Response: The coarse discretization of the surface barrier in the near-field flow model is expected to have a minimal impact on the fate and transport models used in the PA.

The near-field flow model is used to evaluate:

- Desaturation of cement-based waste forms
- Redistribution of water that can affect the flow regime in the vadose zone
- Initial and boundary conditions for other fate and transport models

The near-field flow model is not used to simulate transport of radionuclides from the waste forms to the IDF bottom.

RAI 2-4 Near-field and UZ Modeling Approach

- **Comment:** Use of uniform properties and discrete layers may not yield accurate contaminant flux rates primarily for near-field flow.
- **Path forward:** Please provide information that demonstrates that the numerical grids used for near-field flow were sufficient to evaluate performance. This could include performing numerical modeling of near-field flow and transport using refined spatial and temporal representations with natural heterogeneity. Please provide additional support for the numerical model results.

RAI 2-4 Response

Response: The discretization and use of the near-field flow model is discussed in RAI 2-3. This RAI response includes additional discussion on how uncertainty in near-field flow is addressed in the PA.

The RAI response also discusses the sensitivity cases that were performed to address the effects of:

- uncertainty in hydrologic conditions on glass corrosion rates
- new glass corrosion analyses with alternate hydraulic characteristics of the fractured glass
- new glass corrosion analyses with refined numerical grids

NOTE: The results of new simulations are provided with the response for RAI 2-12.

RAI 2-5 Disposition of Nitrate*

- **Comment:** Previous evaluations by DOE had a large amount of nitrate (9×10^6 kg) that would be disposed of in IDF. The current inventory cases have values ranging from 1.6×10^5 kg to 2.2×10^6 kg. It is not clear how the nitrate is being removed or where it will be disposed.
- **Path Forward:** Please describe the removal and disposition of nitrate from the waste feed for VLAW.

THE HANFORD SITE

RAI 2-5 Response*

- A summary material balance across the LAW Vitrification system for the IDF PA showed that approximately 50% of the nitrate/nitrite in the LAW feed is converted to non-hazardous N_2 gas in the melter.
- A portion of the NO_2 and NO gases remaining in the melter offgas stream are converted to aqueous NO_3^- in the primary offgas system and recycled to the LAW feed.
- A Selective Catalytic Reduction (SCR) unit in the secondary offgas system will then reduce about 98% of the remaining NO_2 and NO gas to non-hazardous N_2 gas.
- The SCR is followed by a caustic scrubber that captures about 20% of any residual NO_2/NO gas exiting the SCR, converting it to aqueous NO_3^-.
- The caustic scrubber effluent is routed to the LERF/ETF and represents the main contributor to the IDF NO_3^- inventory in grouted ETF liquid secondary waste during the DFLAW approach.
- Following DFLAW, the main contribution will be liquid effluents from continued LAW and potential supplemental LAW vitrification (for which DOE has made no decisions).
- The estimated nitrate inventory in ETF grout for the Tank Closure and Waste Management Environmental Impact Statement ($9X10^6$ kg) was based on a 2005 HTWOS model run, which predated the IDF PA model runs. Since that time the flowsheet has matured, and only a small fraction of nitrate ($1.6X10^5$ kg) will survive the LAW vitrification and offgas treatment processes and be incorporated in the grouted ETF Liquid Secondary Waste (LSW) assumed to be disposed of in the IDF.

RAI 2-6 Glass Wasteform and Volatile Species Distribution

- **Comment:** Additional information is necessary to demonstrate that volatile species would be uniformly distributed in the glass inside a canister after cooling.
- **Path Forward:** Please provide additional basis that ^{99}Tc will be uniformly distributed in the glass of production-scale canisters and that deposition on the canister surfaces will not occur. If information is not available, provide plans that describe how the assumed distribution of ^{99}Tc will be verified prior to full-scale production, or show that the results of the performance assessment, including uncertainties, are not sensitive to the distribution of ^{99}Tc within the glass wasteform.

RAI 2-6 Response

- Analysis of samples taken from small-scale, continuously-fed melters (VSL-11R2260-1) showed that the concentration of ^{99m}Tc reached steady-state in the majority of the tests. Comparison between poured glass and melt pool dip samples showed agreement within 6% in DM10 melter tests and within 2.5% in DM100 tests, indicating uniformity of ^{99m}Tc concentration throughout the glass.
- Sulfate salt phases that could contribute to non-uniform ^{99}Tc distribution can and will be mitigated with process controls to prevent their formation, as they can also significantly impact melter component life.
- Deposition on canister surfaces is not expected to occur due to:
  - Purposeful formation of a cold cap in the melter which increases ^{99}Tc incorporation in the glass and decreases volatilization from the melt pool
  - Reductants will be added to reduce Tc_2O_7 to less volatile TcO_2
  - Volatile ^{99}Tc will be captured the offgas system and recycled to the melter feed, which increases the amount of ^{99}Tc immobilized in the LAW glass
  - Glass containers will be actively ventilated as the glass is poured, which will remove gases from the container head space, thereby minimizing the potential for volatiles to condense on the container walls
  - Poured glass cools rapidly while the container walls remain hot, so any volatiles driven off before the glass cools would be re-evaporated when they contact the container walls early in the cooling process.

RAI 2-7 Glass Waste Form Fractional Release Rate

- **Comment:** The development of the fractional release rate expressions to represent glass degradation may not adequately reflect all significant sources of uncertainty.
- **Path Forward:** Please address the treatment of the uncertainties with the development of glass fractional release rate expressions for the PA. If necessary, revise the expressions and generate new PA results that reflect the full range of uncertainty in the glass degradation rates. If appropriate, the expressions used in the system model uncertainty analyses should be revised. The uncertainty associated with the performance of production-scale glass may be addressed by providing DOE's performance verification plan to assure the quality and performance of production-scale glass.

RAI 2-07 Response

- The glass dissolution model is based on transition state theory coupled with alkali ion-exchange and secondary mineral reaction feedback mechanisms.
  - It is widely accepted and extensively studied within the international nuclear waste glass corrosion scientific community
- The IDF PA uncertainty analysis evaluated fractional release rates that spanned more than three orders of magnitude to account for uncertainties in both the dissolution model and the parameter values.
  - None of the realizations in the uncertainty analysis exceeded the 25 mrem/yr dose limit in 1,000 or in 10,000 years
- Corrosion rate testing using a set of statistically-designed glass formulations representative of the enhanced VLAW glass compositional region is on-going.
  - Data to date indicate dissolution rates are within the range analyzed in the PA
  - Results are being incorporated into the IDF PA model through the annual update process and will be used for additional uncertainty analysis
- Properties of glass made from both simulated and actual waste have been found to be in excellent agreement over a range of scales, from crucibles to 5MT/day melters; therefore, it is not necessary to verify performance at production scale.

RAI 2-8 Glass Cracking

- **Comment:** Additional information is needed on the basis for the assumed factor of 10 increase in specific surface area of the glass to account for cracking.
- **Path Forward:** Please provide additional technical basis for the assumed effect of cracking on glass specific surface area, utilize a bounding value or provide plans to verify the assumed value in production-scale glass canisters. Please describe the cooling cycles anticipated to be used during glass production.

RAI 2-08 Response

- The increase in surface area available for glass corrosion due to cracking depends on the degree of cracking and the susceptibility of the cracks to corrosion.
    - The degree of cracking is driven by the cooling rate and profile and the properties of the container material in contact with the glass. For air cooled, stainless steel containers the geometric surface area has been shown to increase by an average factor of 27.
    - The susceptibility of the cracks to corrosion is governed by the location of the cracks in the monolith, the geometry of the cracks, and the rate of corrosion. Published results show 13% to 40% of crack surface area is available for corrosion.
    - The product of these two parameters is the multiplier to account for corrosion in cracks. The multiplier ranges from 3.5 to 10.8. The value of 10 used in the IDF PA is at the upper end of this range.
- A plot of the VLAW container centerline and surface temperatures vs. time during cooling to near ambient temperature is provided.

RAI 2-9 Glass Stage III

- **Comment:** Additional information is needed to support the basis that Stage III glass corrosion will not occur for disposal of vitrified waste at IDF.
- **Path Forward:** Please demonstrate Stage III behavior is unlikely taking into consideration the potential temperature ranges and degrees of openness of the disposal system. This may be done by performing geochemical modeling or generating experimental data using relevant fluid compositions and appropriate minerals. PA calculations could be used to address the significance of the formation of Stage III behavior.

RAI 2-09 Response

- The impacts of Stage III on contaminant release from VLAW glass buried in the IDF is being assessed in four ways.
  - Long-term laboratory tests with VLAW glasses in closed, aqueous systems at 90°C and 40°C. These have been on-going for more than a decade. Stage III has been observed at 90°C, but not 40°C.
  - Stage III rates at temperatures down to 22°C are being measured using zeolite seeding tests. The rates will be used in sensitivity analyses using the IDF PA computer model.
  - Chalcedony is being replaced by a secondary mineral reaction network that reflects new laboratory data.
  - *In-situ* testing of VLAW glass dissolution is being conducted at the Hanford 200-Area Field Lysimeter Test Facility.
    - Tests include VLAW glass buried in IDF backfill soil with controlled water infiltration rates.
    - Contaminant release data will be collected for several decades.
- Preliminary data from Stage III zeolite seeding tests show dissolution rates in the majority of the glasses tested would not result in contaminant releases exceeding DOE Performance Objectives and groundwater protection standards over 10,000 years.
- As a defense-in-depth measure, glass composition constraints could be implemented to ensure potential Stage III dissolution rates at IDF conditions would be well below a rate that would exceed IDF performance objectives.

THE HANFORD SITE

RAI 2-10 Volatile Species and Glass*

- **Comment:** One of the most important aspects of uncertainty associated with the VLAW PA appears to be the assumed partitioning of various species, especially volatile species between different waste types. Additional information is needed to support the amount of volatile species that will be retained in glass (Case 7 – the base case).
- **Path Forward:** Please provide additional basis for the base case inventory or revise the base case inventory to be consistent with the observed testing data. For the base case inventory, DOE should observe mass balance, glass concentrations of volatile species, concentration of species in salt phases and reliability of the off-gas system. For the base case inventory DOE should also account for the disposal of volatile species that build up in the system components and in what form they will be disposed.

RAI 2-10 Response*

- Certain volatile species (Tc, I, Cs) have a low retention rate in glass which can be overcome by capturing them in the offgas system and recycling to the vitrification feed.
- The base case IDF PA technetium inventory indicates that, with recycle, approximately 99.9% of the Tc will be incorporated in the glass.
- The NRC reviewers noted that small scale melter tests with Tc-99m (RPP-54130) showed 99.8% capture of Tc in the offgas but lower amounts of Tc measured in the glass. Two tests showed formation of a Tc-rich sulfate salt layer on the melt pool surface.
- Subsequent analyses of the data from the melter tests (VSL-13R2800-1) confirmed the effectiveness of Tc capture in the offgas system and subsequent melter tests (VSL-16R3840-1) accounted for all of the Tc in the system and confirmed the effectiveness of offgas recycle to achieve nearly 100% incorporation of Tc in the glass product.
- Formation of a Tc-rich sulfate salt layer is not expected to occur during DFLAW operations because sulfate solubility limits are accounted for in the glass formulation algorithms. Sulfate layers formed in some of the melter tests when sulfate levels in the melter feed met or exceeded solubility limits.
- Accumulations of Tc in offgas system components can be effectively controlled by periodic flushing, as demonstrated by the high mass balance closure in the DM-10 melter runs where this technique was employed.

THE HANFORD SITE

RAI 2-11 Comparison of STOMP and GWB

- **Comment:** Additional information is needed to support why some comparison cases for glass release rates generated with STOMP and Geochemist's Workbench (GWB) have non applicable entries.
- **Path forward:** Please provide the results to complete Tables 5-4 and 5-9 of the PA or describe why the use of one model was appropriate for certain entries. Confirm that the missing entries were not a result of a lack of numerical convergence or similar issues.

RAI 2-11 Response

Response: The decision to simulate a prescribed alternative condition using just one software application or both software applications considered:

- Model capability
- Availability of computational resources
- Excessively long run times with very limited additional value

None of the instances when only a single model was used for a sensitivity case were attributable to a lack of numerical convergence or similar modeling issues.

RAI 2-12 Sensitivity and Uncertainty Analyses

- **Comment:** The sensitivity and uncertainty analyses presented by DOE did not include some aspects that may be important to risk-inform the review process and to determine if the relevant criteria are likely to be met.
- **Path forward:** Please expand the sensitivity and uncertainty analyses to include the items discussed above in the basis part of this comment (e.g., additional glass release uncertainties, inventory splits, inventory uncertainties).

RAI 2-12 Response

Response: DOE believes the suite of sensitivity and uncertainty analyses discussed in the PA are sufficient to evaluate compliance with the performance objectives and to identity the activities for PA maintenance.

The RAI response also provides additional discussion or new sensitivity analyses on topics that the NRC raises in the "Basis" part of the RAI. These topics include:

- the surface barrier degrading faster than the liner system
- hydraulic properties on VLAW glass release
- secondary mineral reaction network on VLAW glass release
- other sources of uncertainty on VLAW glass release
- inventory splits on groundwater pathway concentration and dose
- total inventory on groundwater pathway concentration and dose

RAI 2-13 Quality Assurance

- **Comment:** Some aspects of the quality assurance program were not clear from the documentation provided.
- **Path Forward:** Please provide the qualification status of software and databases that supply information to the performance assessment calculations or the plans to determine the qualification status of the referenced software and databases. Please provide the verification results or plans for verification of the release rate and unsaturated flow phenomena simulated by STOMP for glass degradation as applicable to the performance assessment.

RAI 2-13 Response

Response:

- Version 5.0 of the Hanford Defined Waste Model spreadsheet was completely verified through the spreadsheet verification process at the time of the revision. With regard to the VLAW Draft WIR Evaluation, estimates from the HDW are being used for planning and screening purposes only.
- The thermodynamic database, thermos.com.V8.R6+.tdat, is a copy of a publically available, standard database for geochemical modeling. The data included in the database are treated by the DOE as accepted data that do not require qualification.
- Field lysimeter tests are currently underway to corroborate VLAW corrosion simulations in conditions similar to the conditions expected in the Hanford Site IDF. (ref RAI 2-9)

RAI 2-14 Geologic Uncertainty

- **Comment:** The basis for the interpretation of the geology underlying the footprint of the IDF that removed the Ringold E formation is not clear.
- **Path forward:** Please provide additional basis for the reinterpretation of the location of the Ringold E and indicate whether groundwater protection standards apply to this unit.

RAI 2-14 Response

Response: DOE acknowledges that there is uncertainty in the Geologic Framework Model (GFM) describing the sediments underneath the IDF.

The RAI response provides additional discussion on:

- reasons for the uncertainty and changes in the interpretations in the GFM over time evolution of and current location of the Ringold Unit E in GFMs near the IDF
- current interpretation of the hydraulic conductivity of hydrostratigraphic units near the IDF (see response to RAI 2-16)

RAI 2-15 Vadose Zone Parameters

- **Comment:** The log-normal fit of the van Genuchten alpha parameter for the H2 unit does not appear to represent the data well at the tails of the distribution.
- **Path forward:** Please discuss the implications of the deviation in the fitted distributions from the underlying data.

RAI 2-15 Response

Response: DOE acknowledges that there is uncertainty in the vadose zone hydraulic parameter values used to evaluate the fate and transport of radionuclides released from the base of the IDF to the water table. This uncertainty was evaluated in the PA.

The RAI response provides additional discussion on:

- development of the distributions used in the model
- impact the sampled hydraulic parameter distributions have on the predicted moisture content in the Hanford formation
- updated comparisons of predicted and observed moisture contents in the Hanford formation near the IDF
- impact of using alternative vadose zone hydraulic property sets that are representative of the observed moisture content near the IDF

RAI 2-16 Saturated Zone Hydraulic Conductivity

- **Comment:** The changes to the estimated hydraulic conductivity values for the saturated zone over time suggest the base case value best estimate may not be reliable.
- **Path forward:** Please discuss confidence building activities to support the base case saturated zone hydraulic conductivity values assigned. Please discuss plans to verify the base case saturated zone hydraulic conductivity.

RAI 2-16 Response

Response: DOE acknowledges that there is uncertainty in the hydraulic conductivity of the aquifer sediments underneath the IDF and included an evaluation of this uncertainty in the IDF PA uncertainty analysis.

The RAI response provides additional discussion on:

- uncertainty estimates for this parameter simulated in the PA model
- base case values being consistent with calibrated groundwater models
- base case values being consistent with pumping tests conducted in the Central Plateau
- planned PA maintenance activities to further evaluate the hydraulic conductivity of the aquifer in the southeast corner of the IDF

RAI 2-17 Intruder*

- **Comment:** DOE provided the dose result to an inadvertent intruder resulting from the average waste but did not provide the range of potential intruder doses that could be anticipated.
- **Path forward:** Please provide the range of dose impacts to an inadvertent intruder from each waste stream disposed in the IDF that is within the scope of the draft waste evaluation as discussed previously in this document.

RAI 2-17 Response*

Response: DOE acknowledges that there will be variability and uncertainty in the various wastes disposed of in the IDF.

This RAI response provides additional and new discussion on:

- development of the IDF Waste Acceptance Criteria disposal limits based on intruder analyses
- use of administrative controls for package placement to protect hypothetical human intruders
- new analysis evaluating the monthly variability in VLAW composition during and after DFLAW demonstrating that the dose to the hypothetical human intruder does not exceed performance objectives and performance measures
- DOE believes that the site-wide institutional control plan, WAC concentration limits and evaluations comparing the contents of waste packages to the concentration limits will provide reasonable expectation that the performance objectives and performance measures will be met for protection of the hypothetical human intruder at the IDF.

RAI 2-18 ^{90}Sr Inventory Uncertainty

- **Comment:** Additional information is needed regarding the uncertainty in the ^{90}Sr inventory estimate and how the inventory uncertainties are propagated into the GoldSim model.
- **Path forward:** Please provide a description of how 90Sr inventory uncertainty impacts the dose to the inadvertent intruder. Please provide the reference RPP-CALC-61254, Rev 3.

RAI 2-18 Response

Response: The uncertainty estimate for ^{90}Sr inventory described in the PA is not an uncertainty estimate in the VLAW product, but is an uncertainty estimate in the total tank waste inventory.

The RAI response provides additional discussion on:

- development of the uncertainty for ^{90}Sr inventory in tank waste discussed in the PA
- expectation that waste with the highest ^{90}Sr inventory uncertainty will be fed to high-level waste vitrification
- uncertainty for ^{90}Sr inventory in tank waste similar to DFLAW feed is about 3.5%.
- RPP-CALC-61254 Rev 3 uploaded to NRC Box site

RAI 2-19 Releases from the ETF-LSW Waste*

- **Comment:** Additional information is needed on the modeled release of ^{129}I and ^{99}Tc from the ETF-LSW.
- **Path forward:** (abridged) Please provide additional information on the expected fractional release rate for ^{129}I and ^{99}Tc for the ETF-LSW waste form. Consider providing an evaluation of the potential fractional release and the dose from the ETF waste using an effective diffusion coefficient value that does not include sorption. Consider providing an evaluation of the potential dose if the inventory in this waste stream is higher than assumed using a revised effective diffusion coefficient value. Please provide additional information on the basis for the diffusive length assumed for the ETF-LSW waste.

RAI 2-19 Response*

Response: The grout used to solidify LSW is different from the grout used to encapsulate debris and solidify other non-debris waste. Because the grout used in the PA calculations was developed in the laboratory specifically for the ETF-LSW, it is appropriate to use different characteristics for this waste stream.

The RAI response provides additional discussion on:

- development of the ETF-LSW grout formula
- development of radionuclide-specific diffusion coefficients for this grouted waste stream
- sensitivity cases evaluating uncertainty in the waste stream properties including sorption and diffusion coefficients
- the derivation of the diffusive length used in the model

RAI 2-20 I Sorption on the SSW-GAC and SSW-AGM Waste Forms*

- **Comment:** Additional information is needed for the assumed sorption of ^{129}I on the SSW-GAC (Granular Activated Carbon) and SSW-AgM (Silver Mordenite) waste forms.
- **Path forward:** Please provide additional information to support the assumed K_d values for ^{129}I on the SSW-GAC and the SSW-AgM waste forms and if any research and development activities have taken place on this topic to date and provide the results of those activities. Alternatively, provide a sensitivity analysis showing the effect on the release rates and potential dose from ^{129}I from these two waste forms if the sorption on these waste forms is lower than assumed in the model.

RAI 2-20 Response *

Response: DOE identified that the performance of the SSW-GAC and SSW-AgM waste streams to retain ^{129}I is a key assumption in the PA and commenced research to develop properties for this waste stream.

The RAI response provides additional discussion on:

- results of the research investigating the properties of these waste streams
- results of updated release modeling for ^{129}I from this waste stream using the PA system model

NOTE: Additional simulations using STOMP are underway.

RAI 2-21 Releases from Cementitious Waste Forms*

- **Comment:** More information is needed on the process for determining and evaluating the final cementitious grout specifications for waste streams stabilized with cementitious grout.
- **Path forward:** Please provide additional information, if any, that has been developed on the planned specifications for the cementitious grout mixes to be used to stabilize waste generated as part of WTP operations. Provide the WAC for the current PA, if available. Provide a description of the process that will be used to design and the cementitious grout mixes to ensure that the performance of the grout mixtures will be consistent with the performance assumed in the PA for all of the expected compositions of the waste streams.

RAI 2-21 Response*

Response: The grout evaluated in the PA to solidify or encapsulate SSW is a commercially available product from a local concrete supplier and has been/is used on-site to encapsulate and solidify waste prior to disposal.

The RAI response provides additional discussion on:

- anticipated use of the grout evaluated in the IDF PA process used to evaluate other grout formulas for selected waste streams if adopted in the future

Questions?


The Hanford Reach
White Bluffs Overlooking the Columbia River