UNITED STATES
NUCLEAR REGULATORY COMMISSION
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January 8, 2018

MEMORANDUM TO: Gregory Suber, Chief
Low Level Waste Branch
Division of Decommissioning, Uranium Recovery, and Waste Programs

THRU: Christepher McKenney, Chief
Performance Assessment Branch
Division of Decommissioning, Uranium Recovery, and Waste Programs

FROM: Cynthia Barr, Sr. Systems Performance Analyst ***/RA/***
Performance Assessment Branch
Division of Decommissioning, Uranium Recovery, and Waste Programs

SUBJECT: TECHNICAL REVIEW OF FINAL INVENTORY AND SPECIAL ANALYSIS DOCUMENTATION FOR TANK 12H at SAVANNAH RIVER SITE (DOCKET NO. PROJ0734)

The U.S. Nuclear Regulatory Commission (NRC) staff have performed a technical review of several documents prepared by the U.S. Department of Energy (DOE) that detail development of the final inventory and special analysis (SA) for Tank 12H at Savannah River Site, South Carolina. This technical review supports Monitoring Factor 1.1 “Final Inventory and Risk Estimates”, Monitoring Factor 1.2 “Residual Waste Sampling” and Monitoring Factor 1.3 “Residual Waste Volume,” detailed in the NRC staff’s plan for monitoring the SRS Tank Farm Facilities (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15238B403).

As a result of the review of several DOE documents related to the development of the final Tank 12H inventory and the Tank 12H SA under Monitoring Factor 1.1, the staff concludes that the Tank 12H final estimated inventory is generally adequate for use in performance assessment (PA) calculations such as the Tank 12H SA. NRC staff also concludes that the Tank 12H SA adequately evaluates deviations in the Tank 12H final inventory compared to forecasted inventories used in earlier PA calculations. To reach these conclusions, the staff performed its own independent review and calculations.

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With respect to residual waste sampling (Monitoring Factor 1.2) and based on the staff's review of the programmatic documents listed in the enclosure, the staff finds DOE's methodology to develop final inventory estimates for high-level waste tanks acceptable. Based on the review of SRR-CWDA-2015-00075, SRR-CWDA-2014-00103, and SRNL-STI-2015-00241 related to residual waste sampling and analysis, the staff also finds the implementation of the sampling and analysis plan for Tank 12H adequate for the purpose of developing final estimated radionuclide inventories for use in PA calculations, although several areas of potential improvement are noted in this report, particularly related to collection of representative samples and consideration of uncertainty in determining mass fractions for compositing. To reach conclusions regarding the use of Tank 12H residual waste sampling and analysis results for developing the final estimated inventory, NRC staff independently evaluated the Tank 12H analytical data to calculate the upper 95 percent confidence level (UCL95) for the mean and to perform other statistical analysis. For example, the NRC's independent evaluation showed that other statistical techniques (e.g., bootstrap method) would yield similar results to the DOE's results. Additional technical issues relevant to sampling and analysis are described in the Tank 16H inventory Technical Review Report (TRR) (ADAMS Accession No. ML15301A830) and are not repeated here (e.g., need for future sampling of ancillary equipment). The Tank 16H TRR should be consulted for additional details on those issues.

With respect to volume estimation (Monitoring Factor 1.3) and based on review of SRR-CWDA-2015-00075, and U-ESR-H-00125, the staff finds the implementation of the tank mapping methodology for Tank 12H adequate for the purpose of developing radionuclide inventories for use in PA calculations, although several areas of potential improvement are noted in this report, particularly related to timing of solids mapping and consideration of uncertainty in volume estimates. Additional technical issues relevant to volume estimation are listed in the Tank 16H inventory TRR (ADAMS Accession No. ML15301A830) and are not repeated here. The Tank 16H TRR should be consulted for additional details on those issues.

Concentrations and volume are linearly related to inventory and in many cases, inventory is linearly related to dose. Therefore, the development of waste concentrations and volume, and consideration of uncertainty in waste concentrations and volume estimates is considered risk-significant. With respect to Tank 12H, the uncertainty associated with the final inventory is expected to be less than an order of magnitude, and closer to a factor of 2 or 3 and is therefore considered to be of medium risk-significance. Because not all of the technical issues related to the development of the inventory have been addressed, Monitoring Factors 1.1, 1.2, and 1.3 will remain open at this time.

Enclosure:
Technical Review of Final Inventory Documentation for Tank 12H

SUBJECT: TECHNICAL REVIEW OF FINAL INVENTORY AND SPECIAL ANALYSIS DOCUMENTATION FOR TANK 12H at SAVANNAH RIVER SITE (DOCKET NO. PROJ0734) **DATE January 8, 2018**

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Technical Review of Final Inventory Documentation Supporting Tank 12H Closure

Date: October 2017

Reviewers:

Cynthia Barr, Sr. Systems Performance Analyst,
U.S. Nuclear Regulatory Commission

Programmatic Documents Previously Reviewed (see ADAMS Accession No. ML13085A291):

1. SRR-CWDA-2011-00050, Revision 3, "Liquid Waste Tank Residuals Sampling and Analysis Program Plan," Savannah River Remediation, LLC, Closure and Waste Disposal Authority, Aiken, SC, October 2015.[1]

2. SRR-CWDA-2011-00117, Revision 1, "Liquid Waste Tank Residuals Sampling—Quality Assurance Program Plan," Savannah River Remediation, LLC, Closure and Waste Disposal Authority, Aiken, SC, July 2013.

The Tanks 5 and 6 Inventory Technical Review Report (ADAMS Accession No. ML13085A291) provides a summary of these key programmatic documents. Please consult that technical review report for additional information.

Primary Tank 12H Inventory and Special Analysis Documents Reviewed:

1. SRR-CWDA-2015-00075, "Tank 12 Inventory Determination," Savannah River Remediation, LLC, Savannah River Site, Aiken, SC, Rev. 0, July, 2015.

2. U-ESR-H-00125, Clark, J., "Tank 12 Final Volume Determination and Uncertainty Estimate", Savannah River Remediation, LLC, Savannah River Site, Aiken, SC, Rev. 0, October 2014.

3. SRR-CWDA-2014-00103, "Tank 12H Sample Compositing Determination" Savannah River Remediation, LLC, Savannah River Site, Aiken, SC, Rev. 0, November, 2014.

4. SRNL-STI-2015-00241, "Tank 12H Residuals Sample Analysis Report," L.N. Oji; E.P. Shine; D.P. Diprete; C.J. Coleman; and M.S. Hay, Savannah River National Laboratory, Aiken, SC, June 2015.

5. SRR-CWDA-2015-00073, Revision 0, "Tank 12 Special Analysis for the Performance Assessment for the H-Tank Farm at the Savannah River Site", Savannah River Remediation, LLC, Savannah River Site, Aiken, SC, Rev. 0, August, 2015.

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[1] A previous version of this report (Rev. 1) was reviewed in the Tanks 5 and 6 Inventory Technical Review Report (ML13085A291). A cursory review of the changes in Revision 2 and 3 was conducted for this review.

SRR-CWDA-2015-00075, "Tank 12 Inventory Determination", Rev. 0, July, 2015

SRR-CWDA-2015-00075 summarizes the development of the inventory for Tank 12H in the year 2015 and for the radionuclide inventory decayed to year 2032, the assumed year of H-Tank Farm (HTF) closure. The decayed inventory is used in performance assessment calculations including the Tank 12H Special Analysis. The inventory is also used to support the Tank 12H Closure Module Addendum and calculations to determine if the waste is Class C or greater than Class C waste.

The residuals in Tank 12H are divided into discrete segments for characterization and compositing. These segments are added together to determine the total inventory. The Tank 12H inventory is comprised of the following primary[2] segments:

- Primary waste tank floor residual solids
- Cooling coil surface solids
- Free-liquid in the primary tank at the time of floor sampling

The sampling and analysis plan for Tank 12H is based on estimates of Tank 12H waste volumes, accessibility evaluations, and other programmatic considerations. Preliminary mapping of Tank 12H waste indicated approximately 1000 gallons (4000 liters) of residual solids were present on the tank floor and in a mound behind the tank valve house piping (780 gallons [3000 liters] on the floor and 220 gallons [830 liters] in the mound). Liquid was also present above the tank floor solids but because the liquid volume was slowly decreasing as the tank dried, no initial estimates of the liquid volume were made. Early estimates also indicated that approximately 400 gallons [1500 liters] of scale material were present on the cooling coil surfaces.

A team of contractors considered the Tank 12H residuals distribution, waste volumes, and tank accessibility information to determine sampling locations. Six samples from the waste tank floor, six samples from the mound behind the valve house piping, and three samples from cooling coils were proposed for compositing. However, because sample compositing is mass-based; and preliminary analytical results indicated the cooling coil material had a relatively high density of approximately 4 g/ml, as well as having a very high mercury content, DOE contractors determined that the cooling coil material would not be composited with the floor and mound samples. This decision decreased the number of samples used for Tank 12H compositing from 15 to 12 samples.

Sampling locations are depicted in Figure 1. After sampling locations were determined and DOE contractors initiated sampling, difficulties arose with sample collection. Resampling was necessary for the first three planned sample locations due to low material recovery and accessibility issues (see Figure 1; sample locations labeled with an "R" after the sample number are locations of resamples). Only five of the six floor samples were ultimately collected. Additionally, floor samples were collected while the tank was still "wet" and all samples contained liquid, requiring liquid/solid separation. Final floor and mound residual solids volumes were determined after evaluating additional video footage obtained by the sampling crawler during sampling. An estimated 3,500 gallons ($1.3 \times 10^{+04}$ liters) of free liquid was estimated to be present above the residual floor solids at the time of sampling. Table 1 shows the preliminary and final solids material volume determinations.

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[2] Other segments were assessed but found to be insignificant (e.g., internal tank surfaces, waste internal to equipment, and annulus).

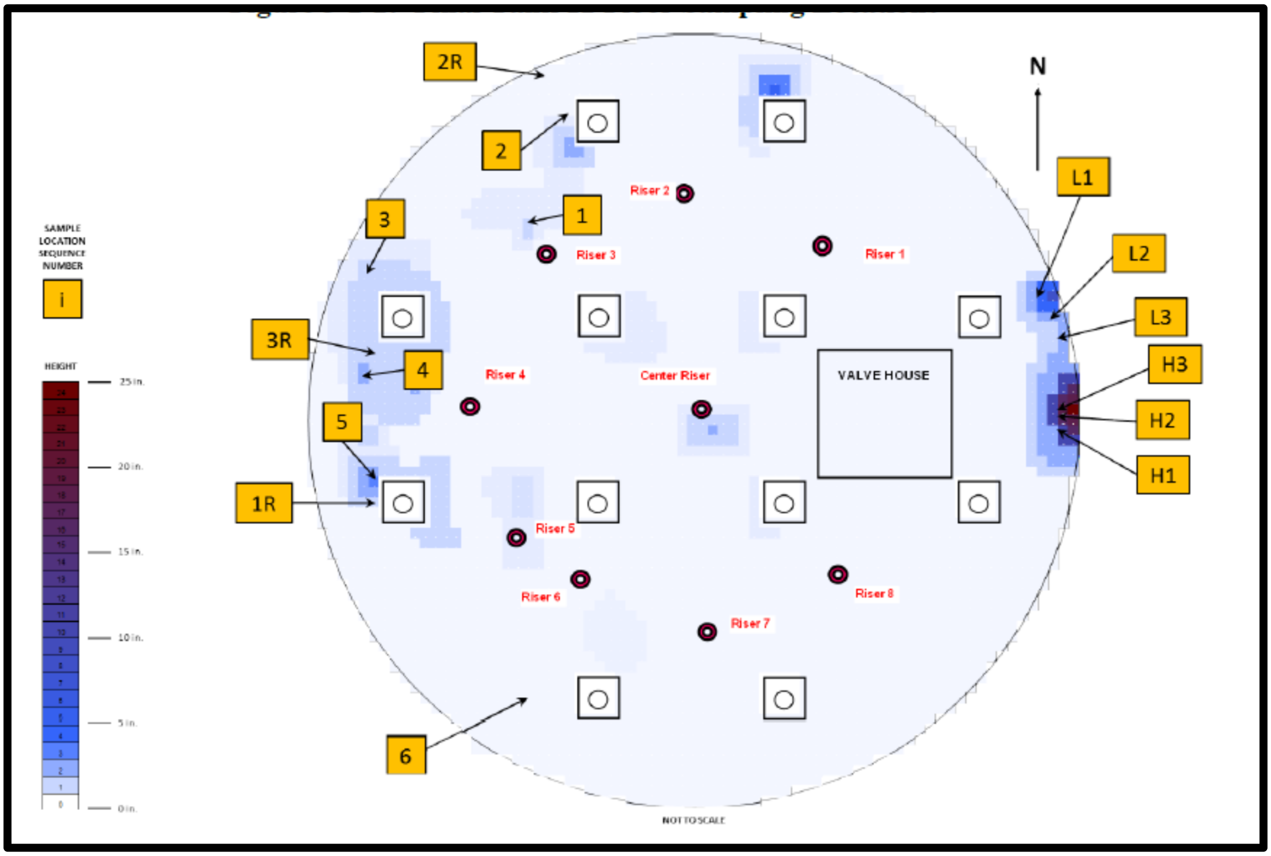

Figure 1 Sample Locations and Sample Numbers (Sample Numbers May Include the Following Letters: "R" for Replacement, "L" for Low Mound Sample, and "H" for High Mound Sample). Image Credit: SRR-CWDA-2015-00075, Figure 3.2-2.

Table 1 Preliminary and Final Volume Estimates. Adapted from Table 3.2--2 in SRR-CWDA-2015-00075.

Residual Material Segment	Preliminary Volume Estimate (gal)	Final Volume Determination (gal)
Cooling Coils	400	400
General Tank Floor	780	800
Mound Behind Valve House	220	700
Total	1400	1900

Note: 1 gallon equals 3.79 liters

After sampling was conducted, the original sample compositing plan was updated to account for the recovery of only five of the six floor samples and the exclusion of the cooling coil samples in the composite samples. Three possible compositing options using the 11 available floor and mound samples were evaluated by Savannah River National Laboratory. The compositing options evaluation considered the sampling variability and the impact on the variance of the sample means for the composite sample creation. A decision was made to use four instead of the typical five samples per composite and to split one sample (T12-F-4) for use in two of the composites. The final compositing scheme is shown in Table 3.3-1 of SRR-CWDA-2015-00075.

The Tank 12H composite samples were analyzed by SRNL to characterize the residual materials. The screening and selection of the radionuclide and chemical analytes for Tank 12H can be found in the "*Recommended Radionuclide and Chemical Analyte List for Tank 12"*, SRR-CWDA-2014-00052.

Composite samples are typically analyzed in triplicate; therefore, a maximum of nine results are reported for analysis of the three composite samples. DOE performed a statistical study of the composite sample analytical results was performed and the mean, standard deviation, and upper 95 percent confidence limit (UCL95) of the mean for the concentration values was calculated. For those constituents where the concentration was non-detectable or less than the target detection limits, the lowest and highest Minimum Detectable Concentrations (MDC) were used to bound the concentration values for the constituent. The statistical study refers to these constituents as having concentrations less than their MDC. For those constituents with a mixture of detected and non-detected concentrations, the constituents were treated as either those with measured values or those with non-detected values. Additional details on how the constituents with a mixture of detected and non-detected concentrations are reported are found in the "*Tank 12H Residual Sample Analysis Report",* SRNL-STI-2015-00241. The mean, standard deviation, and UCL95 of the mean for the composite sample densities and weight percent solids were also provided in the statistical study.

Because the floor samples were collected while the material was covered with liquid, DOE contractors indicate that the actual sample density and weight percent solids of the in-situ material are unknown. The mean of the composite sample air-dried densities of 1.28 g/ml and weight percent solids of 86.5 percent were used to convert residual material mass to volume. These values are also found in SRNL-STI-2015-00241. Because the floor samples contained liquid that was subsequently removed, the in-situ density is lower than the air-dried density. The use of the air-dried density is considered by DOE contractors to be conservative[3].

The method used to determine the final Tank 12H waste volume is presented in the *"Tank 12 Final Volume Determination and Uncertainty Estimate"*, U-ESR-H-00125. As reported in Table 1 above, the final floor residual volume was estimated to be approximately 1,500 gallons (5700 liters) (not including the cooling coil volume). Internal inspections and tank mapping showed small amounts of solids visible on the Tank 12H support columns and primary tank liner wall, which were assumed to be bounded by the estimated cooling coil volume inventory. Likewise, the 13 gallon (50 liter) waste volume estimate for equipment hold-up is insignificant compared to the 1,500 gallon (5700 liter) estimated volume of floor waste (13 gallons [50 liters] is approximately 0.9 percent of the floor residuals volume), and this volume was considered by DOE contractors to be represented by the floor inventory. The Tank 12H cooling coils were flushed as part of waste removal. All chromate cooling water inside the coils was removed during flushing. Therefore, no residual material is expected to be present in the cooling coils and no inventory contribution was assigned to the cooling coil internals. Finally, Tank 12H has a total of 15 leak sites that have historically leaked salt waste into the annulus. The total estimated volume of dried salt waste in the annulus is 25 gallons (95 liters). The 25 gallons (95 liters) of dried annulus waste represents only 2 percent of the 1,500 gallons (5700 liters) estimated for the floor residuals volume and was therefore, also considered represented by the Tank 12H floor residual inventory.

[3] It is unclear what is meant by "conservative" in this context and in certain cases, use of higher densities could be non-conservative. For example, if higher material densities are used in determining mass fractions for compositing and the more dense materials have lower concentrations of key radionuclides, the key radionuclide concentrations could be biased low.

The final radionuclide inventory for 36 radionuclides for the primary tank is presented in the report (SRR-CWDA-2015-00075, Rev. 0). The inventory is calculated by multiplying the solids concentrations by the density of solids and by the residual waste volume; and summing the inventories of the floor, cooling coil surface solids material, and liquid waste inventories.

U-ESR-H-00125, Clark, J., "Tank 12 Final Volume Determination and Uncertainty Estimate"

U-ESR-H-00125 summarizes the final residual solids determination (see Figure 2) and uncertainty estimate of the Tank 12H primary tank volume. In August 2008, Tank 12H contained approximately $2.03 \times 10^{+05}$ gallons ($7.68 \times 10^{+05}$ liters) of sludge (75 inches [190 cm] based on sludge soundings) when Bulk Waste Removal Efforts were initiated. Bulk removal was declared complete in September 2010 after 10 Mechanical Sludge Removal (MSR) campaigns were performed. Two additional MSR campaigns were conducted prior to implementation of the Low Temperature Aluminum Dissolution chemical cleaning technology in June 2011. Between January and June 2012, the sludge heel was washed with low sodium supernate and water during five additional MSR campaigns prior to beginning three Bulk Oxalic Acid (BOA) chemical cleaning campaigns in June 2013. BOA cleaning was completed in July 2013. The preliminary cessation of waste removal activities was declared in January 2014 in preparation for tank residual solids sampling and analysis.

Tank 12H residual solids volume was determined using evidence from video and high resolution photograph campaigns over an approximately 1-year time period. Mixing pumps were not operated and no waste was transferred during this time period. The liquid level never exceeded a height of 4 inches (10 cm) within the tank (above the tank floor). DOE contractors concluded that it is reasonable to assume that the volume of residual solids in the tank and the distribution of the solids remained unchanged across the span of these video and photograph campaigns. A team of trained mappers used the photographic and video evidence and methodologies described in the Tank Mapping Methodology document (SRR-LWE-2010-00240) to determine the height of residual solids. The height of some example landmarks for Type I tanks, such as Tank 12H, are listed in Table 2 and additional specifications are contained in Attachment N of U-ESR-H-00125.

Following BOA in July 2013, Tank 12H was dewatered to a liquid level of approximately 2 inches (5 cm) above the tank floor. Video footage taken during the dewatering transfer was analyzed to produce an initial representation of solids distribution. The tank floor and solids were readily visible beneath the liquid due to lighting conditions. The relative sizes and heights of solids accumulations were estimated using tank landmarks such as horizontal cooling coils, column base plates, and crawler components as reference points. The tank floor was observed to have a generally uniform covering of solids at a height of approximately 0.25 inch (0.64). The height of the solids layer was judged based on welds and attachment points of cooling coil supports.

In August 2013 high resolution photographs were taken from Riser 8 and the Center Riser (see example photograph in Figure 3). These photographs provided a 360 degree view of the tank at three elevations (low, middle, high) from both riser locations. Visibility through the liquid in these pictures was worse in comparison to previous video. Pictures taken from the lower elevation were the most useful as some tank features were observed beneath the liquid. The distribution of solids was stated to be consistent with earlier observations.

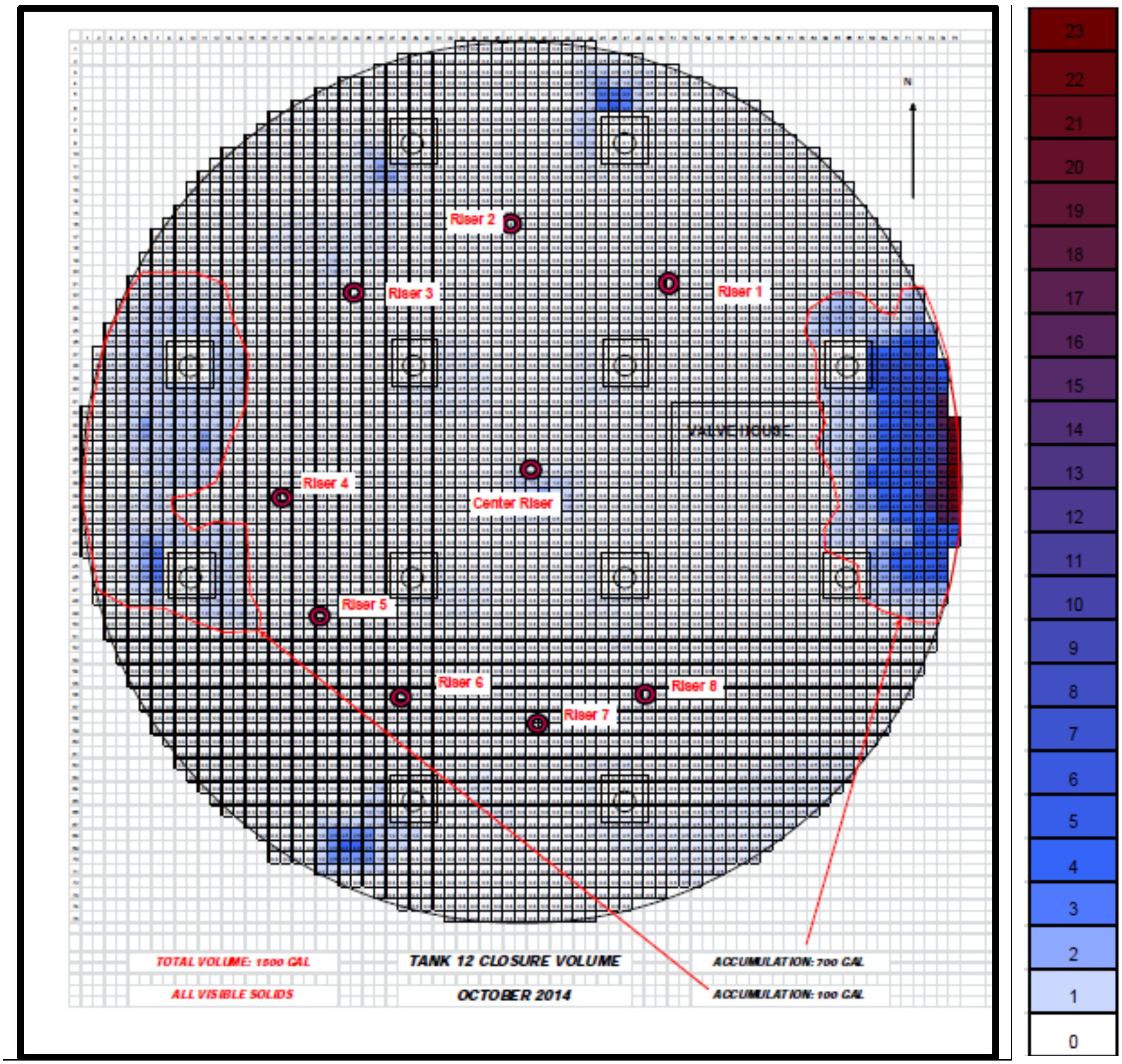

Figure 2 Final Distribution of Solids Used to Determine Residual Waste Volumes for Tank 12H. Legend Provides Thickness of Waste in Inches (1 inch=2.54 cm). Adapted from Attachment A of U-ESR-H-00125.

Table 2 Example Landmarks in Type I tanks. Adapted from Table 3.0--1 in U-ESR-H-00125.

Landmark	Height
Centerline of lower coil	2 inches
Centerline of upper coil	5 inches
Column base plate	4.5 inches
Lower knuckle weld	24 inches
Coil tie-down rod	½ inch diameter
Cooling Coil Pipe	2 inch (2.375 inch outer diameter)

Note: 1 inch=2.54 cm

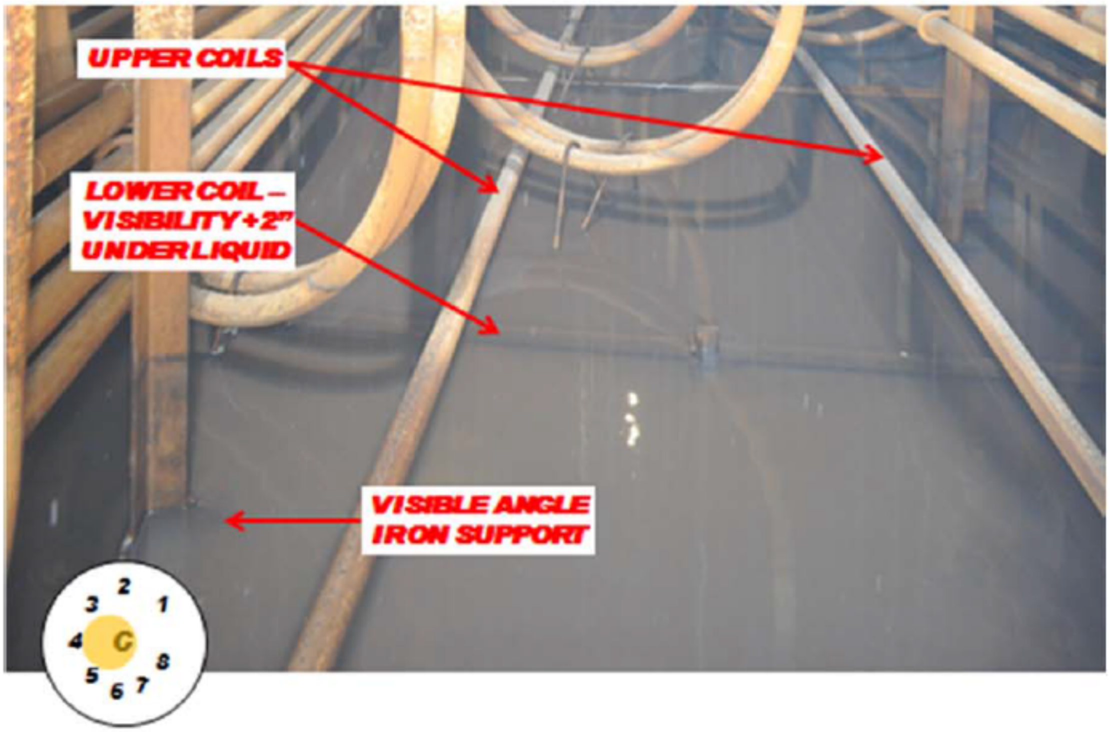

Figure 3 High Resolution Photo from Center Riser Taken In August 2013. Image Credit: U-ESR-H-00125.

In July 2014 robotic sampling crawlers were lowered into the tank to retrieve samples of solids from various locations in Tank 12H (see example image in Figure 4). The crawlers were equipped with an on-board camera that provided a live video feed. Video cameras hung from risers also provided supplemental overhead views of sampling activities. During sampling operations all significant solids accumulations were observed at close proximity. This includes the area where a mound was present on the east side of the tank (see Attachment K in U-ESR-H-125). The sampling video footage was analyzed by the mapping team to confirm the accuracy of the final volume estimate. The crawler was stated by DOE contractors to have provided a critical vantage point that was unattainable with the riser cameras. Sample locations are included in Attachment J of U-ESR-H-125 (and also shown in Figure 1 in this report). The size and shape of the largest accumulation of solids was determined using height landmarks located directly next to the pile.

Continued weekly liquid level observations in the summer of 2014 provided regular visuals of the tank interior. These videos were taken from Risers 3, 5, 8, and Center. This provided visibility in areas of the tank that were previously difficult to view. After reviewing the available photographic and video evidence, a field sketch identifying solids heights was agreed upon by the mapping team (see Attachment H in U-ESR-H-125). The data from the field sketch was then translated to an Excel spreadsheet that models the solids remaining in the tank and calculates an approximate volume (see Figure 2). Each cell in the spreadsheet represents a 1 square foot section of waste tank floor. The approximate material height over each square foot of the tank floor is recorded in the spreadsheet to calculate the volume of residual solids per cell. Summation of all the cells provides the final volume determination. Residual liquid volume was determined by using the Tank Mapping Methodology with horizontal coils as landmarks and

additional observations from the crawler camera. Several data points were taken across the tank that indicated that the tank floor was not level. Information on the tank floor elevations was taken into consideration in estimating the liquid waste volume.

Based on the tank landmarks, it was estimated that the bulk of the residual solids was located under the valve house on the east side of the tank where solids tend to accumulate due to the density of cooling coils in this area. The peak of the residual solids accumulation under the valve house was approximately 35 inches (89 cm). It was estimated that the accumulation under the valve house contains approximately 700 gallons (3000 liters) of residual solids, significantly greater than originally thought, while the total amount of residual solids remaining on the Tank 12H floor was determined to be approximately 1500 gallons (5700 liters) (see Figure 2).

The volume of residual solids coating the internal surfaces of Tank 12H was calculated and documented in M-CLC-H-03256. This calculation considered both the height and the total surface area of the coating. No significant solid coating was observed on the tank wall and columns. Therefore, the tank wall and columns are assumed to have negligible amounts of coating. The total volume of solids associated with the cooling coils was determined to be approximately 400 gallons (1500 liters)[4]. The annulus was previously inspected and was estimated to have less than 30 gallons (100 liters) of salt waste, which is considered negligible by DOE.

a	b

Figure 4 Crawler Photographs Taken in August 2014 While Collecting (a) Sample from a Mound Labeled T12-M-H2 and (b) Sample from the Floor Labeled T12-F-1R. Image Credit: U-ESR-H-00125.

[4] The 400 gallons (1500 liters) is based on what DOE describes as a conservative estimate of the average thickness of the solid coating on the cooling coils of 0.1875 inches (0.48 cm) and assumptions regarding the length of affected coils. Assumptions and estimates are based on visual observation, comparisons of coated versus uncoated coils, known landmarks and component geometries in the tank to estimate affected cooling coil lengths. For additional details see M-CLC-H-03256.

SRR-CWDA-2014-00103, "Tank 12H Sample Compositing Determination" Savannah River Remediation, LLC, Savannah River Site, Aiken, SC, Rev. 0, November, 2014.

SRR-CWDA-2014-00103 provides information on the compositing strategy for the 11 waste samples collected from Tank 12H. The preliminary residuals volume was subdivided into secondary units, referred to as strata or segments, for sampling. The segments were chosen to identify material types important for the characterization study based on material similarities, differences or possible segment heterogeneity.

The initial segments established for sampling and compositing were:

- An undisturbed material mound behind the valve house cooling coil piping,
- Solids on the remainder of the tank floor, and
- The material coating on the cooling coils

Using the methodology in the sampling analysis program plan, the preliminary segment volume estimates, material distributions, and accessibility were used to determine the number of samples for each segment. As sampling progressed, adjustments were required to cope with poor sample recovery, ability to reach the planned sampling areas, and the preliminary scoping analyses results for the coil scrape material and liquid fractions. The cooling coil scrape samples were collected first. Because tank drying efforts were incomplete, the floor residual samples were collected by scooping solids off the floor beneath a layer of free-standing liquid. Due to this collection technique, all floor samples contained a liquid portion, and in some cases, the sample was essentially all liquid. During removal of the first three floor samples, problems with the equipment caused the sample retrieval basket to spin resulting in sample loss. Insufficient recovery and sample loss required resampling for several floor locations. To improve the likelihood of material recovery, some resample locations were moved to areas where more floor solids were thought to be present. To furnish a sample for possible radiological and chemical screening analyses, SRNL was asked to decant and filter the liquid portion present in the floor samples into a common collection bottle. Liquid removal would also speed the sample drying.

The mound samples were collected from material above the liquid layer and the samples were drier than the floor material. All six mound samples were collected. As a contingency against crawler failure or entrapment, three samples were collected in undisturbed material "boulders" that were encountered on the path to the mound behind the valve house piping. Because of their size, angular shape, and location, the boulders are thought to represent the lower portion of material composing the larger mound. The additional three mound samples were collected from the upper portion of the undisturbed mound behind the valve house piping. No liquid separation was performed for the mound samples.

As also discussed in the inventory determination report (SRR-CWDA-2015-00075), after considering cooling coil scoping analysis results, the decision was made not to use the cooling coil material for compositing. Because the coil material would account for approximately 40 percent of each composite sample, the composite sample analyses might be affected by the shift from the typical iron-aluminum matrix to one requiring development of alternate separation and measurement steps. Use of the coil material for compositing would also dilute the radionuclide concentrations by a factor of two and make quantification of low-level radionuclides even more difficult. Low, or no material recovery in the first three samples taken from the floor required resampling, and the resampling locations were shifted to areas containing more material for collection. Due to difficulties with obstructions and lack of material in the southern portion of the tank, no resampling was attempted for floor location 6. Only five of the six primary

tank floor samples contained sufficient material for compositing. Adequate samples were collected for the six mound samples.

Because DOE contractors determined that the cooling coil samples would be analyzed separately, only 11 of the 15 samples typically used were available for compositing. DOE contractors evaluated various options for compositing the 11 samples including the following:

a) Using one floor and two mound samples per composite,
b) Using two floor and two mound samples per composite, and
c) Using three floor samples and two mound samples per composite

The compositing calculation proceeded using option b). Option b) was preferred because option a) made use of fewer samples, and option c) had more shared samples between the three composites. Sample F-4 was chosen for use in two composite samples. The four samples selected for each composite sample are presented in Table 3-4 of the compositing report.

The final volume estimate for the Tank 12H primary tank waste residuals is 1,500 gallons (5700 liters) with an uncertainty of -500 to + 1400 gallons[5] (or range of 1000 to 2900 gallons). The primary tank residual volume is the total of the mound volume and the general floor volume. The mound volume was determined to be 700 gallons (3000 liters) with an uncertainty of -200 to + 100 gallons (-800 to +400 liters). The general floor volume was determined to be 800 gallons (3000 liters) with an uncertainty of -300 to +1,300 gallons (-1000 to +5000 liters). Using a probabilistic Goldsim model and a triangular distribution to represent the uncertain volume, randomly generated volumetric proportions for the floor and the mound segments were determined for each of the three composites. These volume are presented in Table 4-1 of the compositing report. Tables 4-2 through Table 4-4 provide the mass fractions for each of the samples composited for Composite Sample 1, 2, and 3, respectively. Table 4-5 provides the calculation of individual sample mass fractions using the volumes listed in Table 4-1, density information provided in SRNL-STI-2015-00241 Table 2 (after air drying[6]) for floor samples, and Table 3 (24 hour air drying) for mound samples.

SRNL-STI-2015-00241, "Tank 12H Residuals Sample Analysis Report"

The Tank 12H Residual Sample Analysis Report provides information about Tank 12H sampling activities following waste retrieval operations, including statistical analysis of the analytical results. DOE contractors collected and delivered eleven samples from the primary liner (or tank) between May and August 2014: 5 floor samples and 6 mound samples, as well as 3 cooling coil samples. See Figure 5 for an image of "as received" floor samples.

With respect to the five floor samples, after liquid/solids separations[7] with a Nalgene filter membrane, each solid fraction (T12-F-1R, T12-F-2R, T12-F-3R, T12-F-4, and T12-F-5[8]) was

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[5] Note the uncertainty values of -500 to + 1400 gallons (-2000 to +5300 liters) are with respect to the baseline (not absolute values). The absolute range is 1000 to 2900 gallons (3800 to $1.1 \times 10^{+04}$ liters).
[6] Floor samples were air dried for 146 hours prior to the density measurements.
[7] Two of the samples did not have appreciable liquids; therefore, it is assumed that there was no need for liquids/solids separation for these samples (samples T12-F-5 and T12-F-1R).
[8] Locations T12-F-1, -2, and -3 were re-sampled because the SRR believed that insufficient sample had been collected. The re-sampled locations are designated with an "R" after the sample number. The sample locations do not appear to be precisely where the first samples were collected maybe due to the

air-dried for about 146 hours and then the bulk densities and weight percent solids were determined. The bulk densities ranged from 0.93 to 1.97 g/ml for T-12F-2R and T12-F-5, respectively. The weight percent solids was approximately 81 to 85 percent. The five air-dried Tank 12H floor sample solids were then ground, sieved, and homogenized. The samples were ground with a mortar and pestle and passed through an 850 micron sieve (mesh 20), and filtered solids reground until all of the sample solids material passed through the sieve. An image of the (1) homogenized floor and mound samples, and (2) composite samples are found in Figures 6 and 7, respectively. The bulk density for each of the five homogenized, air-dried Tank 12H floor samples was then re-determined. The bulk densities of the homogenized samples ranged from 1.08 to 2.02 g/ml for T-12F-2R and T12-F-5, respectively. The bulk densities of the ground, sieved, and homogenized samples were generally higher than the 146 hour air dried samples.

With respect to the six mound samples, no significant free liquid portion was present[9]; therefore, liquid/solids separation was unnecessary. Each solid fraction (T12-M-H1, T12-M-H2, T12-M-H3, T12-M-L1, T12-M-L2, T12-M-L3) was air-dried for about 24 hours, and then again for 150 hours, before the bulk density was determined. After additional air drying some of the bulk densities went up and some went down. After 150 hours of air drying, the range of bulk density was 0.50 to 0.78 g/ml (low value from sample T12-M-L1 and high value from T12-M-H1). Solids fractions were determined for the as-received samples, and then again after the 150 hours of air drying. Solids fractions changed significantly from a range of 0.46 to 0.59, and then from 0.91 to 0.95 after air drying for 150 hours. Similar to the floor samples, the mound samples were ground, sieved, and homogenized. The bulk density for each of the six homogenized, air-dried Tank 12H mound samples were then re-determined. The bulk densities after homogenization were significantly higher and ranged from 0.55 to 0.97 g/ml. The bulk densities of the mound samples appear to be significantly lower than the floor samples.

Three cooling coil scrape samples were taken and delivered to Savannah River National Laboratory (SRNL) between the dates of May and August of 2014, and analyzed for a limited suite of radionuclides. Two coil samples T12-R8-C-Low and T12-R8-C-Mid were received on July 21, 2014, and weighed 21 and 47 grams respectively. One coil sample T12-R8-C-High was received on July 23, 2014, and weighed 26 grams. The coil samples contain significant quantities of mercuric oxide. See Figure 8 for an image of cooling coil scrape samples.

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low volume of material in those locations. Apparently, insufficient sample was collected from T12-F-6; however, no resample was collected for T12-F-6. Therefore, only 5 floor samples were used in the composite samples.

[9] Although no significant free liquid portion was present, the report indicates that the samples were very wet, sticky and difficult to work with.

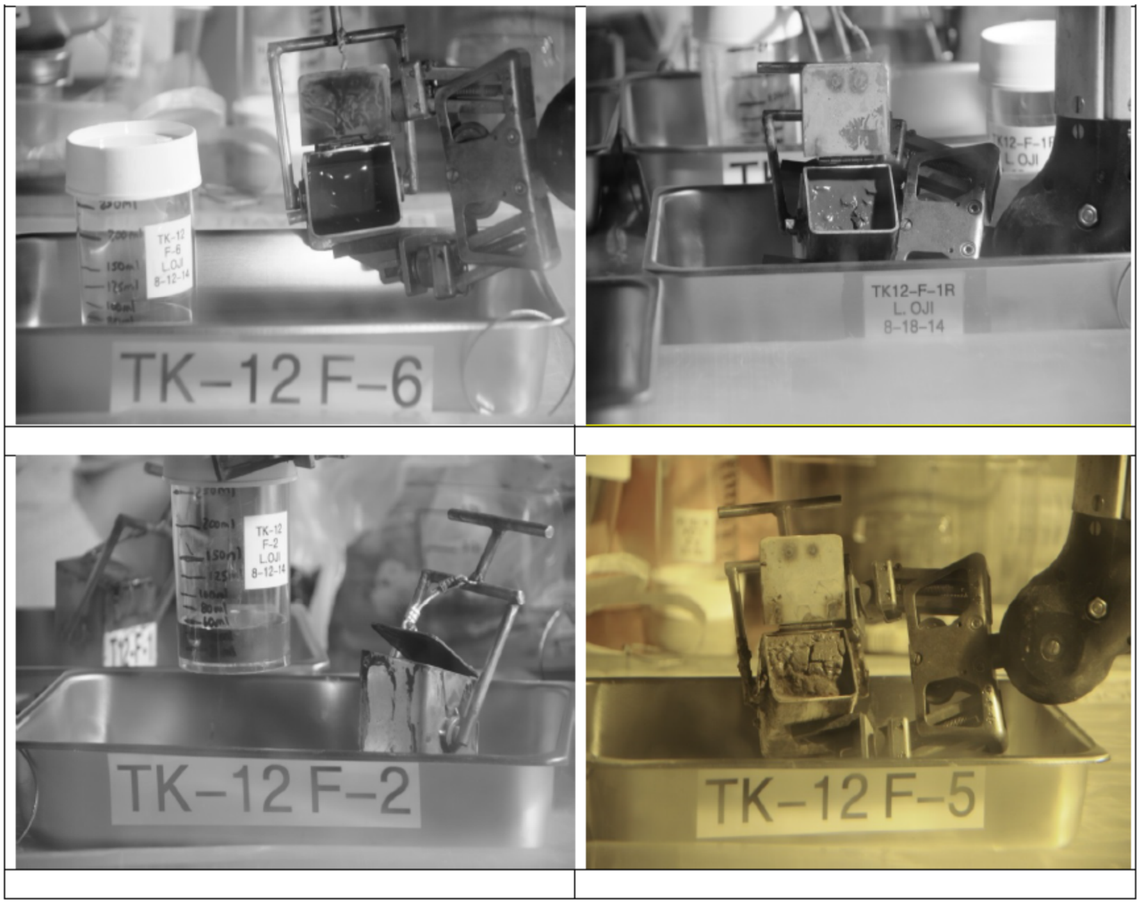
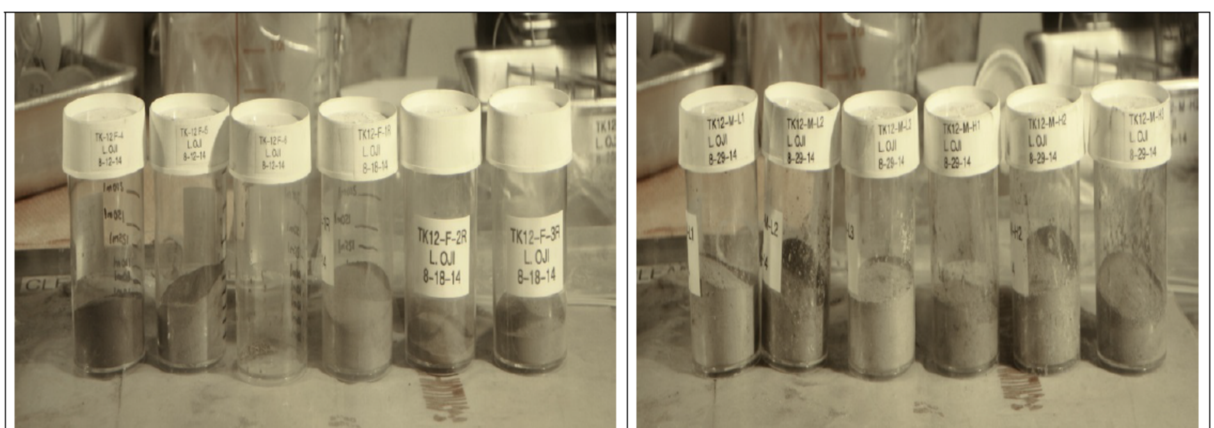


Figure 5 Image of As Received Tank 12H Floor Samples. Image Credit: SRNL-STI-2015-00241.



A: Ground, homogenized and sieved Tank 12H floor solid fraction samples

B: Ground, homogenized and sieved Tank 12H Mound sample solids

Figure 6 Image of Homogenized Samples from Tank12H (A) Floor and (B) Mounds. Image Credit: SRNL-STI-2015-00241.

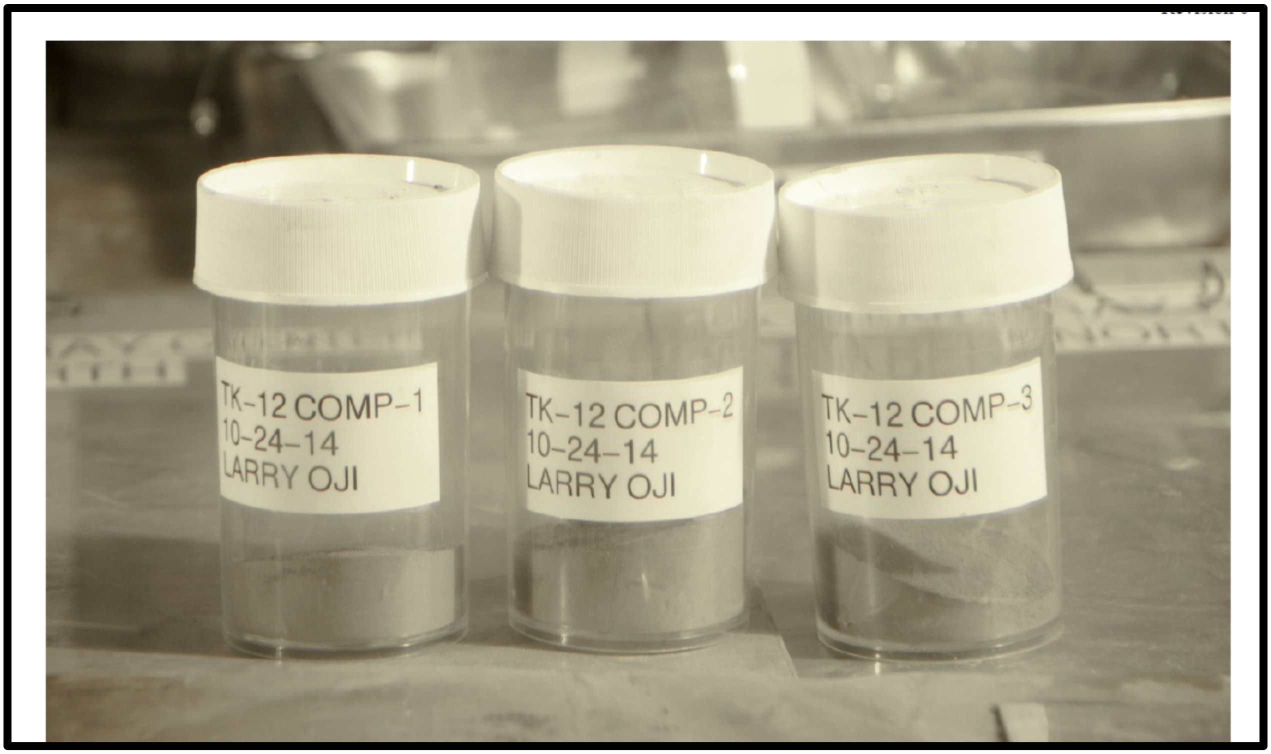
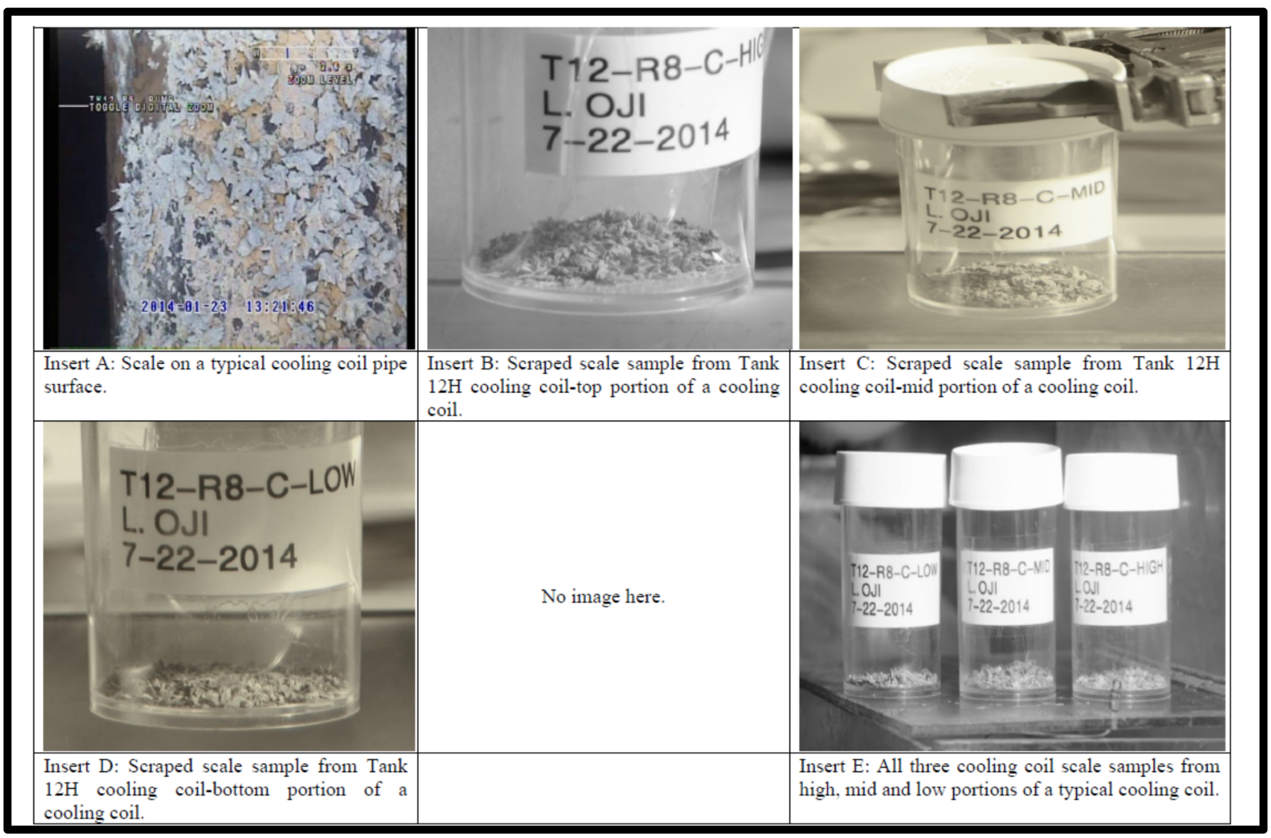


Figure 7 Image of Homogenized Composite Samples. Image Credit: SRNL-STI-2015-00241.



Insert A: Scale on a typical cooling coil pipe surface.

Insert B: Scraped scale sample from Tank 12H cooling coil-top portion of a cooling coil.

Insert C: Scraped scale sample from Tank 12H cooling coil-mid portion of a cooling coil.

Insert D: Scraped scale sample from Tank 12H cooling coil-bottom portion of a cooling coil.

No image here.

Insert E: All three cooling coil scale samples from high, mid and low portions of a typical cooling coil.

Figure 8 Image of Cooling Coil Scrape Samples. Image Credit: SRNL-STI-2015-00241.

After homogenization, a combination of the floor and mound samples (SRR-CWDA-2014-00103 includes the list of samples used in each of the three composites) were composited using a volume proportional compositing scheme. The composite samples were analyzed in triplicate. Thirty-six radionuclides were analyzed. High Th-232 concentrations affected the analytical approaches used in the resin separations and Inductively Coupled Plasma–Mass Spectrometry (ICP-MS) analysis for radionuclides such as U-233, Th-230, and Th-229. As a result, the target minimum detection limit (MDLs) for these radionuclides were not met. For the ICP-MS method, high levels of mercury in the Tank 12H digested samples also affected the lab's ability to meet target detection limits (the detection limits were not met for Th-229, Th-230, Pa-231, U-233, Cm-243, Cm-244, Am-242m). The impact of not meeting the detection limits was evaluated and were found to be acceptable by DOE contractors in SRR-CWDA-2015-00058. Of the list of seven radionuclides for which the target detection limits were not met, two radionuclides, Pa-231 and Am-242m had sufficient numbers of results above the minimum detection limits to support estimates of their mean concentrations and UCL95 values for their means. Am-243 and Cm-245 had some measurements above and below the minimum detection limit. A sufficient number of detectable results were present to support an estimate of the mean and UCL95 value for the mean for Am-243, while Cm-245 had only 2 results above the detection limit. The Cm-245 concentration was summarized by the smallest and largest detection limits.

The mean, standard deviation, and percent standard deviation, and the upper 95 percent confidence limit (UCL95) for the mean concentration were computed for each analyte that had all results above the MDL. The smallest and largest detection limits are used to summarize the concentrations for each analyte that had all results below the minimum detection limits. Most analytes had statistically significant sampling variances (only I-129, Tc-99, and U-232 had no statistically significant sampling variance), but none had heterogeneous measurement variances. Outliers were also evaluated with only Am-243 on composite sample 2 identified as a potential outlier.

The Tank 12H cooling coil scrape samples and the combined liquid fraction were characterized for a limited suite of analytes to provide scoping information. The cooling coil and liquid waste inventories are insignificant compared to the solid floor and mound sample inventory.

SRR-CWDA-2015-00073, Revision 0, Tank 12 Special Analysis for the Performance Assessment for the H-Tank Farm at the Savannah River Site

The Tank 12H Special Analysis (SA) evaluates the impact of the final inventory estimates following sampling and analysis, for Tank 12H on the HTF performance assessment results (SRR-CWDA-2010-00128), and the Tank 16H SA results (SRR-CWDA-2014-00106), which used the final inventory estimate for Tank 16H and a forecasted inventory for Tank 12H. The Tank 12H SA uses the HTF base case (Case A) model to evaluate the risk associated with the remaining residuals that are planned to be grouted in place in Tank 12H. The Tank 12H SA is based on the Tank 12H analyses performed in the Tank 16H SA for each radionuclide that was found to have a final inventory greater than the forecasted Tank 12H inventories used in the Tank 16H SA. The following radionuclides had Tank 12H inventories greater than assumed in the Tank 16H SA: I-129, Pa-231, Th-232, U-232, and Zr-93. The updated inventory is found in Table 3.

Table 3 Tank 12H Primary Radionuclide Inventory in Curies (Adapted from Table 5.1-1 in SRR-CWDA-2015-00073).

Radionuclide	Tank 12 Forecast in the Tank 16 SA (2032)	Tank 12 Final (2032)	Radionuclide	Tank 12 Forecast in the Tank 16 SA (2032)	Tank 12 Final (2032)
Am-241	7.0E+02	1.3E+02	Pu-239	3.9E+02	4.3E+01
Am-242m	1.0E+00	3.0E-02	Pu-240	3.9E+02	1.6E+01
Am-243	3.0E+00	1.6E-01	Pu-241	2.5E+03	1.0E+02
Ba-137m	2.4E+03	5.8E+01	Ra-226	2.1E-02	2.9E-03
C-14	1.0E+00	3.2E-03	Ra-228	2.1E+00	6.1E-03
Cm-243	1.0E+00	5.1E-02	Sn-126	4.6E+00	1.4E-01
Cm-244	2.0E+01	1.1E+00	Sr-90	1.3E+05	8.1E+04
Cm-245	1.0E+00	3.0E-04	Tc-99	1.2E+01	7.2E-02
Cs-135	5.4E-03	6.3E-05	Th-229	2.1E-03	1.3E-03
Cs-137	2.5E+03	6.1E+01	Th-230	2.1E-02	2.2E-03
I-129	2.6E-02	3.8E-02	Th-232	5.5E-02	6.6E-02
Nb-94	1.1E-01	2.7E-03	U-232	2.1E-02	2.2E-02
Ni-59	8.6E+00	2.0E+00	U-233	3.3E+00	2.0E-01
Ni-63	6.3E+02	1.7E+02	U-234	1.7E+00	5.5E-02
Np-237	7.2E-01	1.6E-01	U-235	2.1E-02	3.4E-04
Pa-231	2.1E-03	1.5E-02	U-238	1.8E-01	5.9E-03
Pu-238	9.8E+03	8.8E+02	Y-90	1.3E+05	8.1E+04
			Zr-93	4.0E-01	4.0E+00

Note: Final Values in Green Are Below and Final Values in Pink are Above the Tank 12H Forecast Inventory Assumed in the Tank 16H Special Analysis, SRR-CWDA-2014-00106.

Figure 9 illustrates the HTF doses using the Tank 12H forecast inventory (from the Tank 16H SA) and using the final Tank 12H inventory (i.e., using higher I-129, Pa-231, Th-232, U-232, and Zr-93 inventory values). Figure 10 illustrates the Tank 12H doses alone using the forecast and final inventory for Tank 12H. The HTF peak dose within 10,000 years is associated with Tank 12H and specifically I-129.

The quantity of I-129 remaining in Tank 12H is 3.8E-02 Ci, which is a 46 percent increase from the Tank 12H forecast inventory (2.6E-02 Ci) used in the Tank 16H SA modeling. The peak I-129 concentration within 10,000 years is driven by Tank 12H at approximately year 2,600. DOE contractors indicated that the I-129 doses are conservative, however, because no solubility controls are assumed in the analysis. DOE estimates of solubility controls on I-129 suggest the possibility that silver or mercury in the residual waste can limit release of I-129 under certain conditions. Under various oxidizing conditions the calculated solubility of silver iodide (AgI) ranges from 2.7E-07 moles/liter (mol/L) to 9.8E-09 mol/L, and the calculated solubility of mercury iodide (Hg_2I_2) ranges from 1.2E-04 to 1.8E-07 mol/L. However, under reducing conditions no solubility limitations from AgI or Hg_2I_2 are applicable. With respect to far-field transport, DOE contractors note that after residual I-129 and mercury are released from the tanks, oxidizing conditions encountered downgradient of the tanks may attenuate I-129

transport through precipitation of mercury iodide (a mechanism which is not currently considered in the PA).

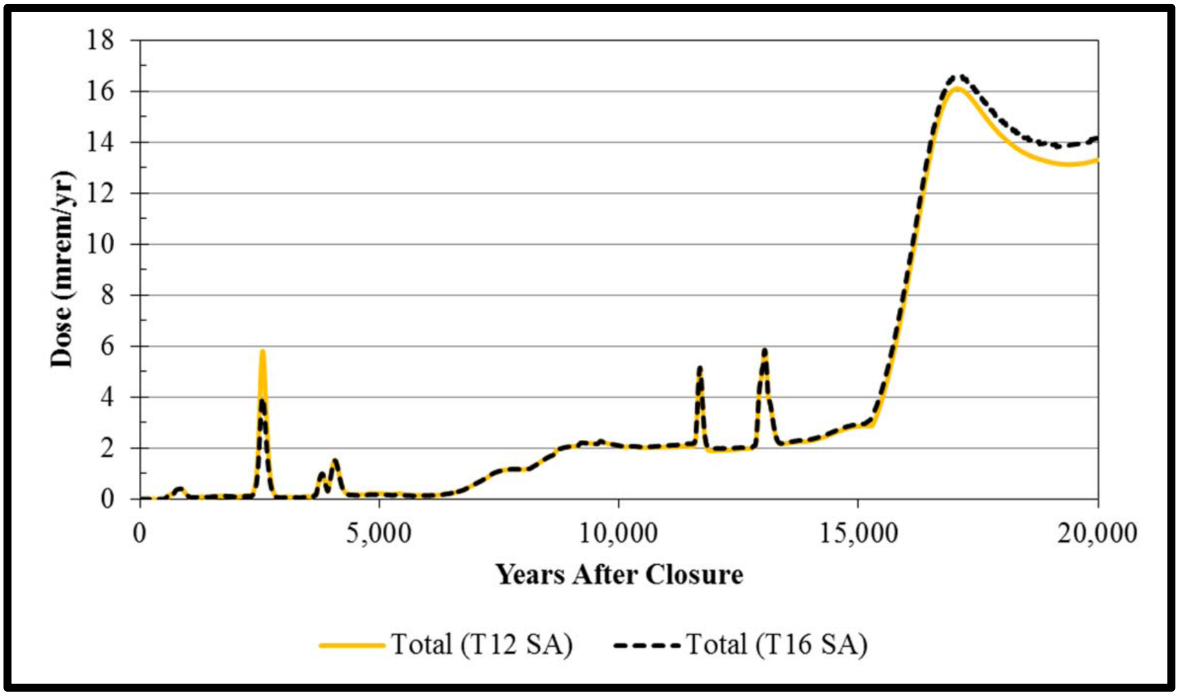


Figure 9 HTF 100-Meter MOP Peak Groundwater Pathway Dose (All Sources). Image Credit: SRR-CWDA-2015-00073, Revision 0.

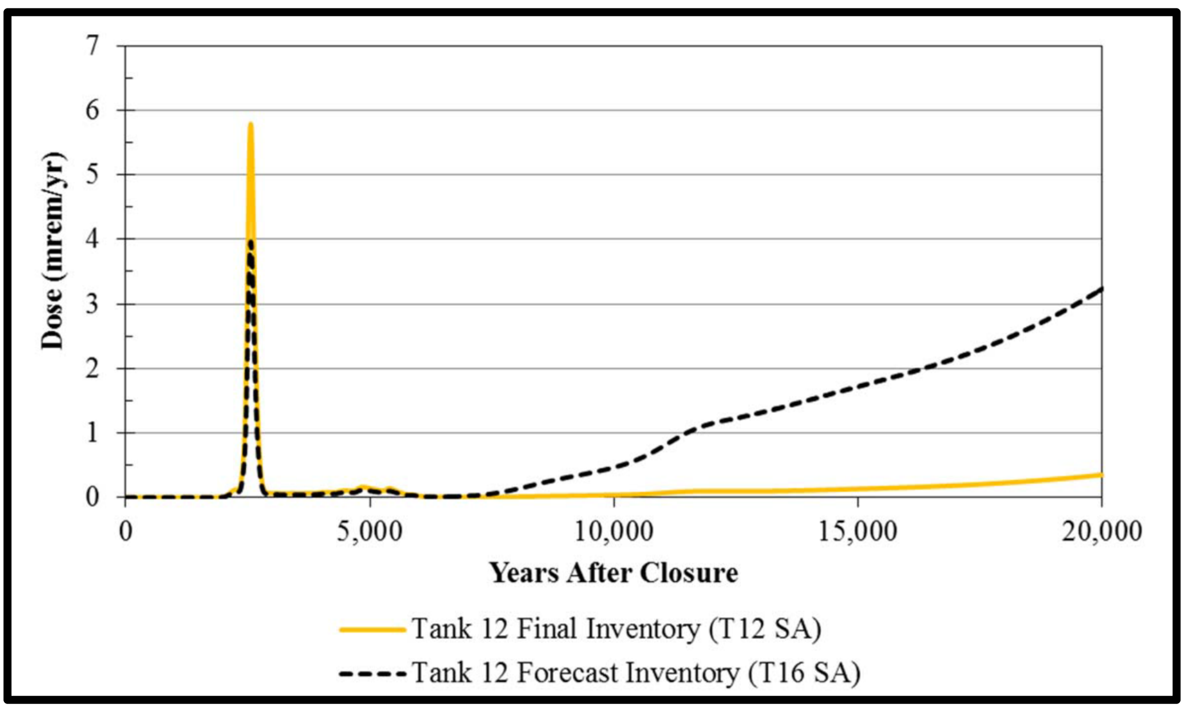


Figure 10 Tank 12H 100-Meter MOP Peak Groundwater Pathway Dose. Image Credit: SRR-CWDA-2015-00073, Revision 0.

The NRC Staff Evaluation:

Sampling and Analysis

The NRC staff finds that the sampling and analysis of Tank 12H residual waste is generally adequate for the purposes of inventory development (and ultimately for use in performance assessment calculations). Nonetheless, the staff comments related to waste sampling and analysis from the Tank 16H inventory TRR (ADAMS Accession No. ML13085A291) generally remain valid and are not repeated in this TRR[10]. Additionally, an evaluation of specific or unique issues associated with the Tank 12H inventory review is provided below.

The staff previously provided comments on DOE contractor's statistical approach used to calculate the 95 UCL of the mean (ADAMS Accession Nos. ML13085A291 and ML15301A830). Specifically, the NRC questioned the basis for a statistical analysis which would allow treatment of the nine analysis results as independent when in fact, there are only three composites analyzed in triplicate. DOE continues to perform the ANOVA F (or Welchs') test to evaluate whether the random effect needs to be considered, which determines whether the nine samples will be treated independently. The random effect represents the sampling error which arises from spatial heterogeneity of the residual material, sampling, sample preparation, and volumetric proportion errors. The model without the random effect (when $F<F_{0.95,2,6} = 5.14325$) treats all nine values as independent and the UCL95 is calculated assuming 8 degrees of freedom[11].

The staff first commented in the Tanks 5 and 6 Inventory TRR (ADAMS Accession No. ML13085A291) that treatment of the nine samples as independent may underestimate the 95th percent upper confidence level for the mean concentration (or UCL95). If, instead, the mean of each triplicate composite is used to represent that composite and those three values are used to calculate the UCL95, the UCL95 would be higher given the fewer degrees of freedom (2 degrees of freedom compared to 8). However, in the Tanks 5F and 6F and Tank 16H TRRs, NRC staff evaluated the impact of treating nine samples as independent and determined the impact was modest[12]. Likewise, the staff evaluated the impact of treating the three composite samples analyzed in triplicate as nine independent samples for Tank 12H and also found the impact to be low. The model which does not consider the random effect (and assumes 8 degrees of freedom) was only used for Tc-99, I-129, and U-232. For all other radionuclides, there was a statistically significant variance between the three composite samples. The staff used bootstrapping methods to determine the 95th UCL of the mean, and found that DOE's calculation of the 95th UCL of the mean was in reasonable agreement with NRC's estimate using resampling methods[13]. Nonetheless, the NRC staff continues to recommend that the

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[10] NRC staff notes that the technical issues discussed in the Tank 16H Inventory TRR were evaluated and the impacts found to be sufficiently low for Tank 16H such that NRC staff were able to make positive conclusions regarding development of the final estimated inventory for Tank 16H. Because the technical issues could lead to more significant errors in future inventory development, or cumulatively contribute more significantly to the estimated doses, NRC staff thinks that DOE should address these concerns in future analyses to support tank closure.

[11] The degrees of freedom is calculated based on the number of samples (nine in this case) minus 1.

[12] Calculation of the UCL95 assuming each composite analyzed in triplicate was a single, independent sample and assuming only three samples (and 2 degrees of freedom) reveals that the distributions would be broader but the impact of treating all of the measurements as independent did not have a large impact on the calculation of the UCL95 for the mean.

[13] The Excel add-in Box Sampler was used to resample the measured values with replacement.

DOE clarify the basis for treating all nine samples as independent in future revisions to the Sampling Analysis Program Plan.

As indicated in previous TRRs, the staff continues to have technical concerns regarding the location and number of samples collected for each of the segments. DOE contractors continue to experience difficulty obtaining samples (e.g., DOE contractors were unable to collect one of six floor samples and did not clearly provide rationale for the number of samples taken from each segment). There may be a benefit from collection of more samples from segments with higher variability or greater volumes, but documentation was unclear on the basis of the sample locations. Initial volume estimates for the mound of residual waste located in close proximity to the valve house was significantly underestimated, as was the case for a similar residual waste mound remaining in previously cleaned tanks (e.g., Tanks 5F, and 6F). Significant errors in preliminary estimates of the relative volumes of segments may negatively impact decisions regarding the number of samples taken from the segments. The staff also noted that material was collected from three boulders on the crawler's path towards the residual waste mound and assumed to be representative of the bottom of the mound. It is unclear whether any samples from the bottom of the mound were attempted or simply assumed to be unnecessary. If the material from the boulders was not representative of the bottom portion of the mound, the composite samples would not well represent the mound concentrations.

Although the best estimate floor volume proportion is around 53 percent (800 gallons [floor] / 700 gallons [mound] + 800 gallons [floor]) (3000 liters [floor] / 2600 liters [mound] + 3000 liters [floor]), the mass fractions of the floor samples used in the composite samples range from 65 to 85 percent (see last column in Table 4) owing primarily to the large differences in densities of the floor and mound samples. However, information on uncertainty in density measurements was not provided, nor was it considered in the volume proportional compositing scheme. Lack of consideration of density uncertainty could be important because of the large variance in density measurements with density of floor samples (range from 0.93 to 1.97 g/ml for the 146 hour air dried bulk density values reported in Table 2 of SRNL-STI-2015-00241, which were used in the compositing protocol [see Tables 4-5 to 4-7 in SRR-CWDA-2014-00103]) being significantly higher than density of mound samples (range from 0.54 to 0.75 g/ml for the 24 hour air dried bulk density values reported in Table 3 of SRNL-STI-2015-00241, which were used in the compositing protocol [see Tables 4-5 to 4-7 in SRR-CWDA-2014-00103]). Composite samples with a disproportionately high mass fraction of floor samples could lead to an underestimate of key radionuclide concentrations because the mound samples may have higher key radionuclide concentrations compared to floor samples particularly for more soluble species (due to limited accessibility and consequently less washing of waste associated with mounds).

The staff also has concerns regarding the consideration of volume uncertainty in the volume proportional compositing approach. Estimates of waste volume are generally based on review of video and photographic evidence and evaluation of position of waste to known landmarks in each of the tanks. Volume estimation is known to be uncertain, but the degree of uncertainty is difficult to quantify and relies heavily on professional judgement. For example, low, best, and high estimates of waste heights (which is directly related to waste volume) are typically based on a limited number of discrete values. These discrete values are typically derived from known heights of landmarks within the tank. The magnitude of uncertainty surrounding the best estimates are heavily influenced by the next highest or lowest landmark height or value rather than a reflection of true measurement uncertainty. In fact, the volume estimation report notes that the values do not reflect analytical uncertainty and warns users of the data of the intended purpose of the uncertainty estimates. The staff also agrees that care should be taken in using the uncertainty ranges provided in the volume estimation report. However, DOE uses the

volume uncertainty range to develop a parameter distribution (triangular distribution using the low, best, and high estimates to parameterize the distribution) for the purpose of assigning sample mass fractions for a very limited number of composite samples (only three composite samples). If volume uncertainty cannot be adequately quantified for the purpose of determining mass fractions for waste segments, as determined by data quality objectives developed specifically for that purpose, alternative approaches to considering volume uncertainty in the compositing scheme should be considered. As discussed above, DOE should also consider uncertainty in all parameters affecting mass fractions, including material density, which may also be an important parameter with respect to inventory calculations. Waste heterogeneity could lead to a situation where average concentrations of key radionuclides are significantly underestimated, if segments with significantly higher mean radionuclide concentrations are underrepresented in sampling and compositing.

Table 4 Mass of Individual Samples in Three Tank 12H Composite Samples

	Sample ID	**Planned Mass (g)**	**Actual Mass (g)**	**Actual weight %**	**Floor weight %**
	M-L-1	4.59	4.583	0.06557143	
	M-H-1	6.03	6.028	0.08614286	
	F-4	26.80	26.815	0.38285714	
	F-5	32.58	32.576	0.46542857	0.848286
Tank 12H Composite 1		**Σ = 70**	**Σ = 70.002**	1	
	M-L-2	9.68	9.688	0.16133333	
	M-H-2	11.35	11.344	0.18916667	
	F-2R	17.76	17.760	0.296	
	F-3R	21.20	21.199	0.35333333	0.649333
Tank 12H Composite 2		**Σ = 60***	**Σ = 59.991**	0.99983333	
	M-L-3	5.81	5.819	0.083	
	M-H-3	7.03	7.040	0.10042857	
Tank 12H Composite 3	F-1R	29.09	29.082	0.41557143	
	F-4	28.06	28.056	0.40085714	0.816429
		Σ = 70.0	**Σ = 69.997**	0.99985714	

*Because only 20 grams of material was collected from location F-2R, the composite sample weight was reduced to a 60 gram sample instead of the targeted 70 gram composite sample mass.

In fact, most of the error associated with determination of average concentrations of key radionuclides in Tank 12H is related to variability between composite samples rather than due to homogenization or measurement errors within a single composite. For most analytes, ANOVA analysis performed by DOE and independently by NRC staff reveals statistically significant differences between composite samples suggesting significant errors with respect to spatial heterogeneity of the residual material, sampling, sample preparation, or volumetric proportion errors. NRC staff further notes that analysis of composite samples in triplicate yields less useful information compared to analysis of additional composites. ANOVA results reveal no significant difference in measurement results within composites. The staff continues to support a

methodology which preserves information on intra-sample variability via compositing within a segment, and the use of volume/mass proportions of segments after average concentrations of key radionuclides are developed for each segment to determine the total inventory. Volume uncertainty could be considered in a probabilistic model to determine statistics on key radionuclide concentration using a larger number of samples (rather than use of the volume parameter distribution for the purpose of selecting just three volumes for each of the two segments to determine segment mass fractions of the composites). DOE contractors have made arguments against such an approach based on cost; however, DOE has not yet provided information on the relative costs of the alternative approaches.

In conclusion, the NRC finds DOE's proposed methodology to develop final inventory estimates for high-level waste tanks acceptable. The staff also finds the implementation of the sampling and analysis approach for Tank 12H adequate for the purpose of developing radionuclide inventories for use in PA calculations, although several areas of potential improvement are noted in this report, particularly related to collection of representative samples, and consideration of uncertainty in determining mass fractions for compositing. In reaching its conclusions, NRC staff considered the risk-significance of the technical issues as well as mitigating factors. For examples, for Tank 12H, the cumulative impact of all of the technical issues discussed in this report are not expected to have a large impact on the results (inventory and dose are not expected to be greater than a factor of 2 or 3 above the best estimates provided in the Tank 12H SA), and DOE considered the impact of inventory uncertainty through sensitivity analysis in the Tank 12H SA, thereby mitigating the impact of uncertainty on the risk estimates. To reach conclusions regarding DOE's use of sampling and analysis results to develop the final Tank 12H inventory estimates, NRC staff reviewed DOE inventory documentation and independently evaluated the Tank 12H analytical data to calculate the UCL95 for the mean and to perform other statistical analysis. For example, the NRC's independent evaluation showed that other statistical techniques (e.g., bootstrap method) would yield similar results to the DOE's results. As indicated above, additional technical issues related to sampling and analysis are listed in the Tank 16H inventory TRR (ADAMS Accession No. ML15301A830) and are not repeated here (e.g., need for future sampling of ancillary equipment). The Tank 16H TRR should be consulted for additional details on those issues.

Volume Estimation

The NRC staff finds that volume estimation of Tank 12H residual waste is generally adequate for the purposes of inventory development (and ultimately for use in performance assessment calculations). Nonetheless, the staff comments related to volume estimation from the Tank 16H inventory TRR (ADAMS Accession No. ML13085A291) generally remain valid and are not repeated in this TRR. Additionally, specific or unique issues associated with the Tank 12H inventory review are discussed below.

In most areas of Tank 12H, the solids level was below the liquid level when tank solids were mapped (see for example, Figure 3). The presence of liquid waste made it more difficult to map residual solids compared to a situation where significant quantities of liquid waste are not present in the tank. It is unclear why mapping occurred during this time period. Documentation should be more transparent regarding decision-making with respect to when tank solids are mapped, and why mapping occurred while there was still a significant quantity of liquid waste remaining in Tank 12H.

The staff also notes the (right) skewed parameter distribution used to describe the uncertainty in the floor segment volume. The uncertainty range was used to determine the percentage of

individual floor samples represented in each composite. While an overestimate of the *total* volume would clearly lead to higher key radionuclide inventory and consequently dose results, the impact of overestimation of the volume of a particular segment (i.e., floor or mound segment) depends on whether the key radionuclide concentration is higher or lower in the segment with the overestimated volume. For example, if the concentration of a key radionuclide was lower in one segment (e.g., floor segment) compared to the other segment (e.g., mound segment), and the relative volume of the segment with the lower radionuclide concentration was overestimated, then that segment would be overrepresented in the composite sample, leading to a lower key radionuclide concentration and associated dose. Because key radionuclide concentrations are not reported for individual segments, it is difficult to assess the impact of potential overrepresentation of floor segment mass in the composite samples. However, it is expected that the key radionuclide concentrations in the less accessible and less washed mound samples would generally be higher than the more accessible and well washed floor samples, particularly for more soluble constituents in the waste.

Attachment I of U-ESR-H-00125 (copied in Table 5 below) shows a systematic approach whereby mappers assign low and high end waste heights based on the best estimate waste height and in some limited cases the expected uncertainty of the waste height (based on quality of data in certain areas of the tank). It is unclear why the upper estimates of volumes in Tank 16H and Tanks 12H are significantly higher than they were for Tanks 5F and 6F (see Table 6) unless the methodology for assignment of uncertainty in volume estimates changed (e.g., procedures and training were developed or updated to standardize the tank mapping methodology) as tank farm closure progressed.

Table 5 Assignment of High and Low End Waste Heights Based on Best Estimate Waste Heights (Inches)

Best Estimate	High Estimate	Low Estimate
0.125	0.25	0.125
0.25	0.5*, 0.75	0.125
0.5	1.0*, 1.5	0.25
0.75	1.25	0.25
1.0	1.5	0.5
1.25 to 6.0	+1.0	-1.0
6.25 and over	+2.0	-2.0

*Notes:
[1]1 inch=2.54 cm
[2]The uncertainty value for the column labeled "high" is lower for areas of the tank accessed by the crawler compared to areas of the tank where less information is available to assess true solids heights. Sample cups, as well as the crawler itself, were used as landmarks to better assess waste heights. Adapted from the Attachment I table in U-ESR-H-00125.

Table 6 Evolution of Uncertainty Estimates in Tank Volume Estimates

	Tank 5F Gal (factor)	Tank 6F Gal (factor)	Tank 16H Gal (factor)	Tank 12H Gal (factor)
Low Estimate	1300 (0.68)	2200 (0.73)	220 (0.67)	1000 (0.67)
Best Estimate	1900	3000	330	1500
High Estimate	2700 (1.42)	4000 (1.33)	660 (2)	2900 (1.9)

Note: 1 gallon-3.79 liters

DOE contractors should consider improvements in methods used to determine volume uncertainty if waste volume uncertainty estimates will continue to be used to determine the mass fractions of samples used in compositing. Larger volumes of particular segments do not necessarily translate to higher inventory of key radionuclides because imprecise volume uncertainty estimates could lead to biases in the segments represented in composite samples. Depending on whether the segment has higher or lower concentrations of key radionuclides, the bias may lead to higher or lower radionuclide inventories. Therefore, it would be difficult to manage uncertainty in volume estimates in the compositing scheme with conservative assumptions, as it is not always clear what volume estimates are conservative with respect to key radionuclide inventory and associated dose. DOE should attempt to refine its methods for considering uncertainties that impact the mass fractions of segments used in compositing. With respect to use of volume uncertainty ranges for use in PA calculations, DOE's approach seems reasonable although efforts to refine the uncertainty estimates through some form of validation would be beneficial to decision-making. Data quality objectives for volume estimation should be developed, if they have not yet been developed, considering the different uses of volume estimates with respect to inventory development and use in PA calculations.

In conclusion, the staff finds the implementation of the volume estimation approach for Tank 12H generally adequate for the purpose of calculating radionuclide inventories for use in PA calculations. Nonetheless, the NRC continues to recommend that DOE attempt to better understand uncertainty in volume estimates through some form of validation (e.g., comparison of volume estimates using visual information against measured values). In reaching its conclusions, NRC staff considered the risk-significance of the technical issues as well as mitigating factors. For examples, for Tank 12H, the cumulative impact of all of the technical issues discussed in this report are not expected to have a large impact on the results (inventory and dose are not expected to be greater than a factor of 2 or 3 above the best estimates provided in the Tank 12H SA), and DOE considered the impact of inventory uncertainty through sensitivity analysis in the Tank 12H SA, thereby mitigating the impact of uncertainty on the risk estimates. To reach conclusions regarding the adequacy of DOE's Tank 12H waste volume estimates, the staff reviewed DOE inventory documentation related to waste volume determinations. As indicated above, additional technical issues related to volume estimation are listed in the Tank 16H inventory TRR (ADAMS Accession No. ML15301A830) and are not repeated here.

Tank 12H Final Inventory and Risk Estimates

DOE evaluated the impact of changes in the final estimated Tank 12H inventory from preliminary estimates in the Tank 12H SA. The NRC staff finds DOE's Tank 12H SA technically acceptable. NRC notes, however, that approaches to account for inventory uncertainty in the SA could be improved. For example, in previous SAs, inventory uncertainty was considered using probabilistic methods to more fully propagate parameter uncertainty in the analysis. In the Tank 12H SA, inventory uncertainty was considered through a limited number of sensitivity analysis (e.g., assuming one-half and twice the inventory of Tank 12H, or removal of the cooling coil inventory). Technical issues discussed in the Tank 18F (ADAMS Accession No. ML13100A230), Tanks 5/6F (ADAMS Accession No. ML13273A299), and Tank 16H (ADAMS Accession No. ML15301A710) SA TRRs generally remain valid and are not repeated in this TRR (e.g., lack of support for the reference case and limited consideration of multivariate uncertainty analysis in special analyses). Those TRRs should be consulted for additional details on those issues. Although DOE presented qualitative arguments regarding the conservatism of the I-129 dose estimates, DOE did not perform additional PA calculations to study sensitivity of PA calculation results to I-129 transport parameters (e.g., solubility and K_d) and relied on the calculations presented in the Tank 12H SA; therefore, the staff did not

evaluate supporting information for I-129 transport parameters. Should DOE update its I-129 risk estimates in the future, the staff will review those calculations at that time.

Teleconference or Meeting:

There were no teleconferences regarding the Tank 12H inventory.

Follow-up Actions:

The NRC staff will continue to monitor the DOE's tank sampling and analysis program under Monitoring Factor 1.2 "Residual Waste Sampling" listed in the NRC staff's plan for monitoring the Tank Farms (ADAMS Accession No. ML15238B403) focusing on the technical issues listed in this TRR. In particular, NRC will monitor DOE's efforts to improve methods to ensure collection of representative samples and more appropriately consider uncertainty in parameters affecting calculations to determine mass fractions for compositing.

The NRC staff will also continue to monitor DOE's tank volume estimation program under Monitoring Factor 1.3 "Residual Waste Volume" listed in the NRC staff's plan for monitoring the Tank Farms (ADAMS Accession No. ML15238B403) focusing on technical issues listed in this review report. In particular, NRC will monitor DOE's efforts to develop lessons learned with respect to use of preliminary estimates of waste volumes as it impacts sample collection (e.g., recurring underestimates of mound volumes), its consideration of the best timing for mapping of residual solids (i.e., after liquid waste has largely been pumped or evaporated from the tank), and its efforts to better understand volume uncertainty, if relied on for use in determining mass fractions for composites.

The NRC staff will also continue to monitor DOE's development of a final inventory estimate for use in Special Analyses under Monitoring Factor 1.1, "Final Inventory and Risk Estimates" listed in the NRC staff's plan for monitoring the Tank Farms (ADAMS Accession No. ML15238B403) In particular, NRC staff will monitor DOE's efforts to address the technical concerns listed in this TRR when developing inventories for the Tank Farm tanks in the future. In general, inventory is considered by the NRC staff to be of medium risk-significance. The technical concerns identified by the NRC staff in this report for Tank 12H are also collectively considered to be of medium risk-significance based on their importance to NRC staff's assessment of DOE (tank farm) disposal action compliance with the performance objectives in 10 CFR Part 61, Subpart C.

Open Issues:

There are no open issues associated with the DOE's program for estimating final tank inventories or performing final risk estimates under Monitoring Factors 1.1, 1.2, and 1.3.

Conclusions:

For reasons discussed above, and as a result of the review of several DOE documents related to the development of the final Tank 12H inventory and the Tank 12H SA under Monitoring Factor 1.1, the staff concludes that the Tank 12H final estimated inventory is generally adequate for use in performance assessment (PA) calculations such as the Tank 12H SA. The staff also concludes that the Tank 12H SA adequately evaluates deviations in the Tank 12H final inventory compared to forecasted inventories used in earlier PA calculations. To reach these conclusions, the staff performed its own independent review and calculations.

With respect to residual waste sampling (Monitoring Factor 1.2) and based on the staff's review of the programmatic documents listed in the enclosure, the staff finds DOE's methodology to develop final inventory estimates for high-level waste tanks acceptable. Based on the review of SRR-CWDA-2015-00075, SRR-CWDA-2014-00103, and SRNL-STI-2015-00241 related to residual waste sampling and analysis, the staff also finds the implementation of the sampling and analysis plan for Tank 12H adequate for the purpose of developing final estimated radionuclide inventories for use in PA calculations, although several areas of potential improvement are noted in this report, particularly related to collection of representative samples and consideration of uncertainty in determining mass fractions for compositing. To reach conclusions regarding the use of Tank 12H residual waste sampling and analysis results for developing the final estimated inventory, NRC staff independently evaluated the Tank 12H analytical data to calculate the upper 95 percent confidence level (UCL95) for the mean and to perform other statistical analysis. For example, the NRC's independent evaluation showed that other statistical techniques (e.g., bootstrap method) would yield similar results to the DOE's results. Additional technical issues relevant to sampling and analysis are described in the Tank 16H inventory Technical Review Report (TRR) (ADAMS Accession No. ML15301A830) and are not repeated here (e.g., need for future sampling of ancillary equipment). The Tank 16H TRR should be consulted for additional details on those issues.

With respect to volume estimation (Monitoring Factor 1.3) and based on review of SRR-CWDA-2015-00075, and U-ESR-H-00125, the staff finds the implementation of the tank mapping methodology for Tank 12H adequate for the purpose of developing radionuclide inventories for use in PA calculations, although several areas of potential improvement are noted in this report, particularly related to timing of solids mapping and consideration of uncertainty in volume estimates. Additional technical issues relevant to volume estimation are listed in the Tank 16H inventory TRR (ADAMS Accession No. ML15301A830) and are not repeated here. The Tank 16H TRR should be consulted for additional details on those issues.

Concentrations and volume are linearly related to inventory and in many cases, inventory is linearly related to dose. Therefore, the development of waste concentrations and volume, and consideration of uncertainty in waste concentrations and volume estimates is considered risk-significant. With respect to Tank 12H, the uncertainty associated with the final inventory is expected to be less than an order of magnitude, and closer to a factor of 2 or 3 and is therefore, considered to be of medium risk-significance. Because not all of the technical issues related to the development of the inventory have been addressed, Monitoring Factors 1.1, 1.2, and 1.3 will remain open at this time.

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