

**Preliminary Performance Assessment for the Waste Management Area C at the Hanford Site in Southeast Washington – 15331**

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**ABSTRACT**

A performance assessment of Single-Shell Tank Waste Management Area C located at the U.S. Department of Energy's Hanford Site in southeastern Washington is being conducted to satisfy the requirements of the Hanford Federal Facility Agreement and Consent Order, as well as other Federal requirements and State-approved closure plans and permits. The Waste Management Area C performance assessment assesses the fate, transport, and impacts of radionuclides and hazardous chemicals within residual wastes left in tanks and ancillary equipment and facilities in their assumed closed configuration and the subsequent risks to humans into the far future. The part of the performance assessment focused on radiological impacts is being developed to meet the requirements for a closure authorization under U.S. Department of Energy Order 435.1 that include a waste incidental to reprocessing determination for residual wastes remaining in tanks, ancillary equipment, and facilities. An additional part of the performance assessment will evaluate human health and environmental impacts from hazardous chemical inventories in residual wastes remaining in Waste Management Area C tanks, ancillary equipment, and facilities needed to meet the requirements for permitted closure under the *Resource Conservation and Recovery Act of 1976*.

Preliminary results of the performance assessment are evaluating the groundwater and air pathways to determine radiation exposure once radionuclides are released to the environment due to degradation of the engineered barriers. Per DOE Order 435.1, results of the preliminary analyses are being compared to the performance objectives during the 1,000-year post-closure period of compliance. Per the Order, performance assessment results are also being compared to the performance measures related to acute and chronic inadvertent intruder analyses and groundwater protection.

**INTRODUCTION**

Waste Management Area (WMA) C is one of seven WMAs (A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U) containing 149 single-shell tanks (SSTs) built from 1943 to 1964. In general, the WMA C boundary is represented by the fence line surrounding C Farm (Fig. 1). Waste Management Area C contains 12 100-series SSTs and 4 200-series SSTs that were constructed in 1943 to 1944 along with associated ancillary equipment (i.e., diversion boxes, pipes). It was placed in service in 1946, and used to store and transfer waste until mid-1980. Additional ancillary equipment (CR-Vault and CR diversion boxes) were added in the early 1950s. A comprehensive performance assessment (PA) meeting the requirements of U.S. Department of Energy (DOE) Order 435.1 [1] and *Resource Conservation and Recovery Act of 1976* (RCRA) [2] closure analysis for WMA C is in the process of being documented for release in October 2015.



During its operational history, a number of confirmed or suspected waste release events have occurred at WMA C. These included suspected tank leaks and known unplanned releases from waste transfer lines and systems.

Pumping of liquid waste in preparation for removing the tanks from service began in 1976. Currently, the pumpable liquid wastes have been removed from the C Farm tanks and all tanks have been stabilized on an interim basis. Since 2003, there has been a concerted effort to retrieve the waste from the SSTs within WMA C.

As of November 2014, waste retrieval has been completed for 13 of the 16 tanks. Retrieval is underway for SSTs C-102, C-105, and C-111. The retrieval status will continue to evolve concurrent with the development of the PA in fiscal year (FY) 2015.

Fig. 2 illustrates the closure concept for WMA C following tank waste retrieval. Surface facilities will be removed and retrieved SSTs and accessible ancillary equipment with significant void spaces will be filled with grout. Waste transfer pipelines are also expected to be left in place. An engineered surface cover system will be placed over the tank farms and will be monitoring using existing wells.

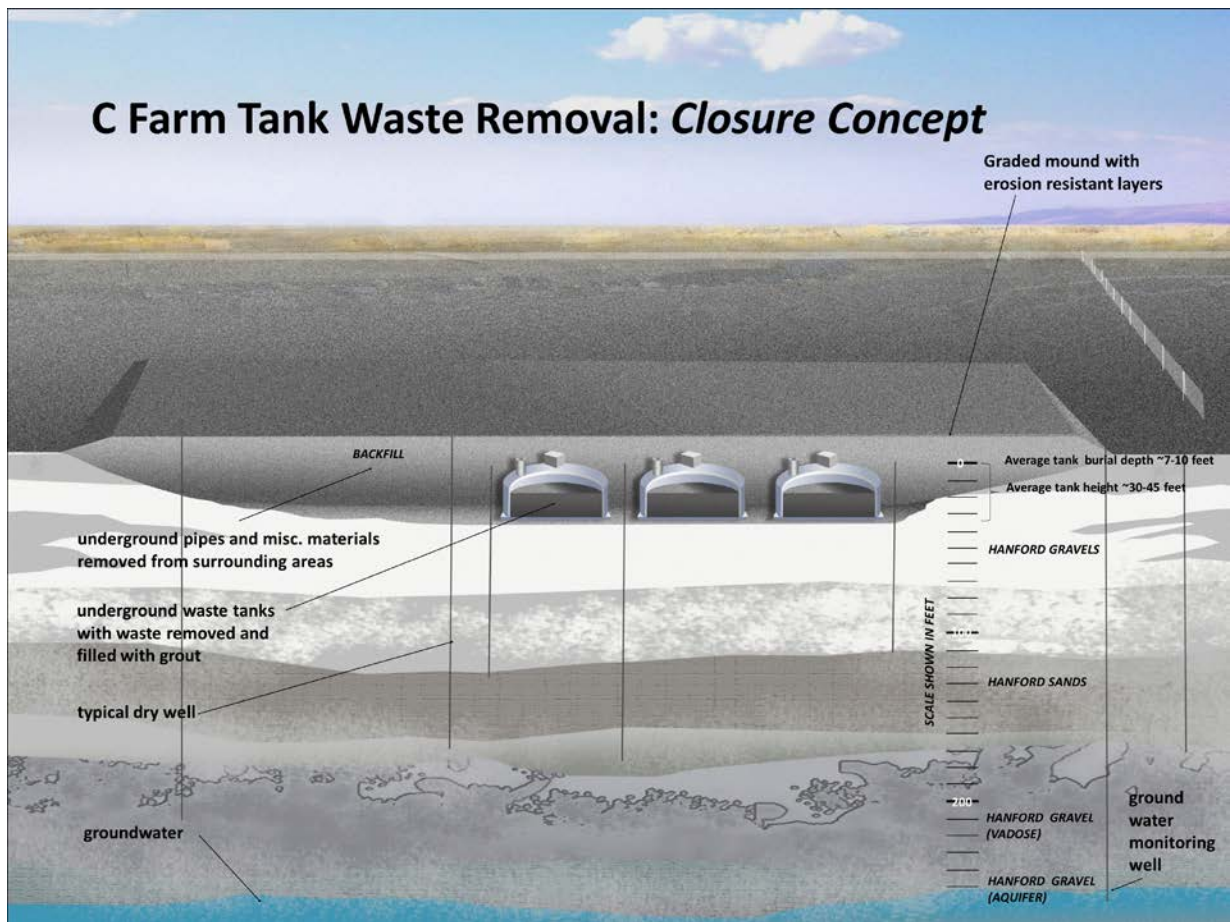


Fig. 2. Conceptual Model of Closure of WMA C.

Fig. 3 shows various pathways of possible exposure evaluated in the PA. The major pathways for contamination entering the environment are the groundwater pathway, the air pathway, and an inadvertent intruder pathway (through drill cuttings brought to the surface). The most important exposure pathway for

hydrologic transport is groundwater use for drinking water, irrigation, livestock watering, and biotic transport. Under the groundwater pathway, it is assumed that moisture from rain and snowfall enters the subsurface, contacts waste, and carries dissolved contaminants through the thick heterogeneous vadose zone to the unconfined aquifer. During the compliance and post-compliance periods, a receptor is assumed to reside 100 m (328 ft) down gradient from the south eastern edge of the WMA fence line.

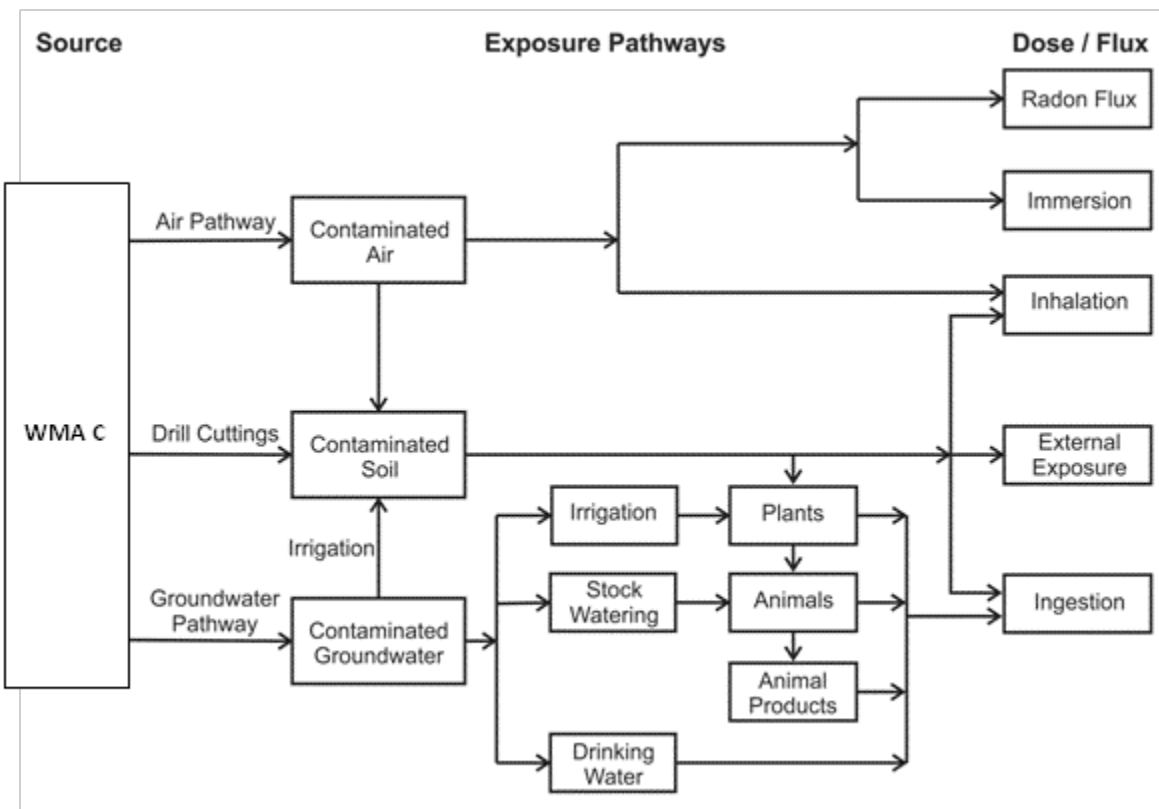


Fig. 3. Overview of the Analysis of Performance for the WMA C PA.

## PERFORMANCE ASSESSMENT APPROACH

The WMA C PA methodology includes deterministic calculations of the estimated impacts from the proposed closure action. Impacts are calculated with the numerical models and a set of inputs and assumptions in an initial PA modeling case developed during the PA scoping sessions between 2009 and 2014. Besides the initial PA modeling case, several other additional sensitivity cases are being conducted to evaluate the effect of changes in key parameter values in the PA analysis. These include selected cases that examine the effect of:

- The timing of potential future tank degradation on contaminant releases and resulting groundwater impacts
- Alternative time-varying recharge rates on the arrival of groundwater breakthrough curves downgradient of WMA C
- Increases in estimated residual inventories on the magnitude of predicted concentrations downgradient of WMA C

- Some alternative hydrogeologic conceptual model sensitivity cases that include
  - An alternative hydrogeologic conceptual model developed by a geologist of one of our stakeholders from Nez Perce Tribe and
  - Some highly heterogeneous representations of the hydrogeologic framework of WMA C.

A best estimate case that provides the expected estimate for how the system may perform given the most current information available is under development. It is assumed that this case will provide a reasonable estimate of the expected performance. Uncertainty and sensitivity analyses using a system level model based on the GoldSim Software [4] will also be performed to understand the importance of key input parameters on transport behavior and dose.

The source term for the initial PA modeling case analysis considers key radionuclides and hazardous chemicals present in residual waste left in tanks and ancillary equipment within WMA C at closure. The inventory used in the source term model includes the current disposed inventory (as of November 2014) for nine of the 100-series tanks and four 200-series tanks where retrieval has been completed. A forecasted inventory for the three remaining 100-series tanks and ancillary equipment that have yet to be retrieved has been developed. A total of 46 radionuclides and 18 hazardous chemicals are evaluated in the WMA C PA. A summary of inventories for three key constituents (Tc-99, chromium, and total uranium) adapted from inventory estimates made for the tanks and ancillary equipment [5] are provided in Table I.

TABLE I. Summary of estimated inventories for selected key constituents for single-shell tanks and ancillary equipment, and pipelines in the closed WMA C used in an initial PA modeling case

	<sup>99</sup> Tc (Ci)	Chromium (kg)	Total Uranium (kg)
Single-Shell Tanks	1.81E+00	6.58E+03	1.15E+02
Ancillary Equipment	5.45E-02	1.08E+03	2.94E+01
Pipelines	4.61E-02	9.12E+02	2.49E+01
Total	1.91E+00	8.58E+03	1.69E+02

The closed WMA C conceptual model is composed of man-made as well as natural components (Fig. 4). The manmade components of the system that influence contaminant migration include a closure surface barrier, the tank farm and ancillary equipment infrastructure, and the distribution of waste in the subsurface. The natural components of the system that influence contaminant migration are the several underlying, nearly horizontal stratigraphic layers within the vadose zone and the unconfined aquifer.

The PA modeling considered reduction of net infiltration from the presence of an engineered cover (surface barrier) over WMA C. The surface barrier is assumed to remain intact and allow only negligible amounts of net infiltration for the first 500 years (i.e., 2020 to 2520), coinciding with an estimated 500-year barrier design life, which includes a 100-year institutional control time period.

For the purpose of assessing the long-term performance, a closure date of 2020 is assumed for WMA C. In the post-closure assessment, four time periods are considered as presented in Table II, as follows.

- A 100-year institutional control period when the engineered surface cover (overlying WMA C) is working to its full barrier capability resulting in 0.5 mm/yr recharge rate under the base of WMA C.
- An additional time period of 400 years after the institutional control period during which the full barrier capability results in 0.5 mm/yr recharge rate under the base of WMA C.
- A time period after 500 years after closure during which the surface cover barrier function is assumed to be fully degraded at the start of the time period (assuming a design life of 500 years).



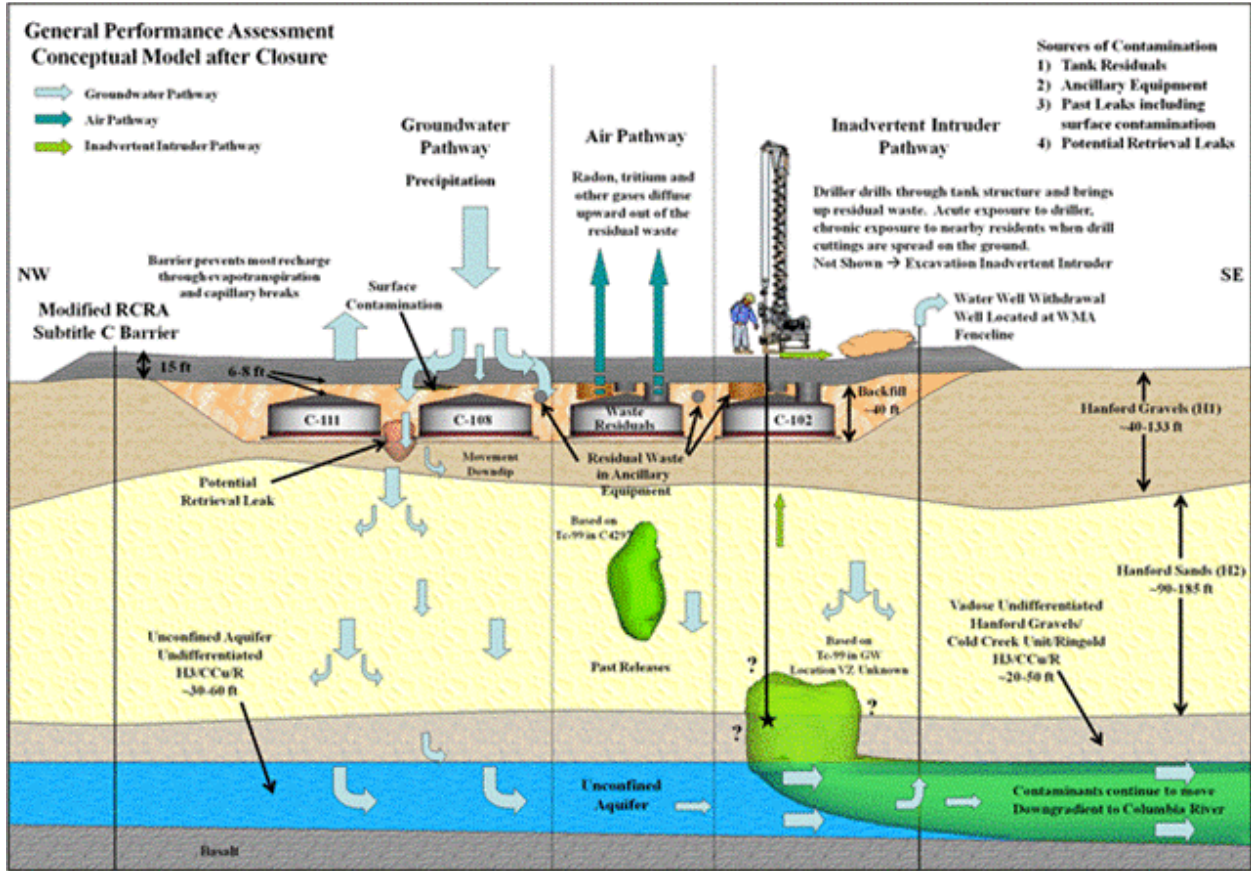


Fig. 4. Schematic Conceptual Representation of the WMA C Site and Various Pathways.

The post-compliance period (beyond 1,000 years) up to 10,000 years for the purpose of evaluating uncertainty and sensitivity on dose estimates. Maximum impacts from long-lived mobile radionuclide and hazardous chemicals occur within this time period.

Net infiltration (recharge) estimates for each of the time periods [6] is presented in Table II. The recharge rates can vary spatially within each time period depending upon the type of vegetation or state of engineered barrier.

Based on the conceptual models for different pathways, numerical models were developed to estimate the contaminant concentrations within water, air, or soil as a function of time. A three-dimensional flow and transport model was developed using the Subsurface Transport Over Multiple Phases code developed by Pacific Northwest National Laboratory [7] to evaluate the impact to the environment from the groundwater pathway. The model assumed that infiltration of moisture from precipitation eventually enters the facility. However, most of the moisture is diverted around WMA C during operations and for the first 500 years after closure. Contaminants, based on their relative inventories associated with different tanks and ancillary equipment, are released into the vadose zone by contact with recharge water. The infiltrating moisture, along with contaminants, travels through the vadose zone with the contaminant transport times influenced by the equilibrium sorption characteristics (determined by the distribution coefficient  $[K_d]$ ).

TABLE II. Timeline and recharge rates considered for representing the evolution of WMA C in the initial PA modeling case

Phase	Conditions	Time frame (yrs)	Recharge on Surface (mm/yr [in./yr])			
			Natural Vegetation	Tank Farm Disturbed Surface	Non-Tank Farm Disturbed Surface	Surface Barrier
Pre-Operations	Before Construction of WMA C	Prior 1944	3.5 [0.14]	Not present	Not present	Not present
Operations	Current Conditions During Operations at WMA C	1944-2020	3.5 [0.14]	100 [3.9]	22 [0.87]/ 63 [2.5]	Not present
First 100-years Post-Closure	Post-Closure During Institutional Control Period	2020-2120	3.5 [0.14]	Not present	3.5 [0.14]	0.5 [0.02]
Early Post-Closure (100 to 500 years)	Post-Institutional Control Period to End of 500-yr Barrier Design Life	2120-2420	3.5 [0.14]	Not present	3.5 [0.14]	0.5 [0.02]
Late Post-Closure (after 500 years)	Post-Barrier Design Life	2420-12020	3.5 [0.14]	Not present	3.5 [0.14]	3.5 [0.14]

In the initial PA modeling case, a diffusion-controlled release from the grouted tanks and advection-controlled release from the pipelines along with equilibrium sorption-desorption processes (i.e.,  $K_d$  control) were implemented. In this case, the residual waste layer is conceptualized to be located at the top of the grout at the bottom of each tank. The combined minimum thickness of concrete and grout layer under the residual waste is 20.3 cm (~8 inches). This is considered to be a physical barrier to release of contaminants to the underlying vadose zone. While the grout/concrete layer is intact, only diffusive transport of contaminants across this layer is considered. When this layer is degraded, both advective and diffusive transport to the vadose zone can occur.

The diffusion coefficients of contaminant through the grout/concrete layer are derived from laboratory leaching experiments [6,8] that range from  $10^{-9}$  to  $10^{-14}$   $\text{cm}^2/\text{s}$ . These values are implemented for the various cases being evaluated for the PA, with the initial PA modeling case using the highest value of  $10^{-9}$   $\text{cm}^2/\text{s}$ . The diffusive area considered is taken to be the base area of the structure being modeled (tank or CR-vault). For the pipelines, the area is based on the assessed area of the tank farm where pipelines are generally present. It is currently defined by a square of length of 164 m and covers the majority of the WMA C area.

## PERFORMANCE OBJECTIVES AND MEASURES

Per DOE Order 435.1, PA results from radionuclide impacts from the residuals will be compared to the performance objectives outlined in Table III that include for:

- A 25 mrem/yr dose limit for an all pathways exposure

- A 10 mrem/yr dose limit for an air pathway exposure and
- A 20 pCi/m<sup>2</sup>/s flux limit for radon at the surface of the facility.

TABLE III. Performance objectives and measures for radionuclide impacts under DOE Order 435.1

Analysis Type	Dose/Concentration	Timeframe
<b>Performance Objectives</b>		
All Pathways	25 mrem/yr (EDE) (excluding dose from radon and progeny in air)	1,000 years post-closure
Air Pathway	10 mrem/yr (EDE) (excluding dose from radon and progeny in air)	
Radon Release	20 pCi m <sup>-2</sup> s <sup>-1</sup> radon flux (at surface of disposal facility) or 0.5 pCi/L (0.0185 Bq/L) of air may be applied at the boundary of the facility	
<b>Performance Measures</b>		
Inadvertent Intrusion – Acute	500 mrem (EDE) (excluding the dose from radon and its progeny in air)	
Inadvertent Intrusion – Chronic	100 mrem/yr (EDE) (excluding radon in air)	
Groundwater Protection	Beta-gamma dose equivalent ≤ 4 mrem/yr (based on Federal MCL)	
	Gross alpha activity concentration ≤ 15 pCi/L (including Ra-226 but excluding radon and uranium)	
	Ra-226/Ra-228 ≤ 5 pCi/L (based on Federal MCL)	
	Federal MCL Sr-90 = 8 pCi/L Tritium = 20,000 pCi/L Uranium = 30 µg/L	
EDE = effective dose equivalent MCL = maximum contaminant level		

Per DOE Order 435.1, PA results will also be compared to the performance measures outlined in Table III that include for:

- A 500 mrem limit for acute exposure to an inadvertent intruder
- A 100 mrem/yr limit for chronic exposure to an inadvertent intruder and
- A variety of measures related to Groundwater Protection
  - Beta-gamma dose equivalent limit of ≤ 4 mrem/yr
  - Gross alpha activity concentration limit of ≤ 15 pCi/l and
  - Federal maximum contaminant levels (MCLs).

To meet the requirements related to site closure under RCRA, PA results for hazardous chemical impacts will also be compared against a variety of groundwater protection-related concentration limits and risk thresholds as summarized in Table IV that include:

- Federal MCLs and
- Washington State Model Toxic Control Act risk-based concentrations and cumulative risk levels.

TABLE IV. Performance measures for groundwater protection for hazardous chemicals



<b>Recommended Concentration and Risk Thresholds</b>
Federal MCL (hazardous chemicals)
2007 MTCA risk-based concentrations Target risk level = $1 \times 10^{-6}$ or hazard quotient = 1
2007 MTCA Cumulative Risk Level = $1 \times 10^{-5}$ or hazard index = 1 Radionuclides – Target Risk Range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$
MCL = maximum contaminant level MTCA = Washington State Model Toxics Control Act

## **PLANNED MODEL UPDATES AND ANTICIPATED PA SCHEDULE**

Based on evaluation of results of initial PA modeling case, the PA effort is in the process of updating the initial PA case with the following changes:

- Updated residual inventory estimates for the three remaining unretrieved tanks
- Use of waste form release of Tc-99, uranium, and chromium based on recent experimental work conducted on residual waste samples from the retrieved tanks
- Updated effective diffusion coefficients through grout based on sediment-concrete half-cell experiments at Pacific Northwest National Laboratory
- Updated hydraulic properties for various hydrostratigraphic units based on evaluation of measured moisture contents in and around WMA C
- Updated aquifer hydraulic properties based on recent hydraulic measurements and numerical groundwater modeling results in the Central Plateau area.

Current goals for the PA effort are to complete and submit PA Revision 0 documentation for tank residual impacts in the fall of 2015. Documents that will be produced include a DOE Order 435.1 PA for radiological impacts and RCRA Closure Analysis for hazardous chemicals impacts. Once these documents are released, they will undergo a DOE internal review by the Low-level Waste Federal Review Group.

## **SUMMARY AND CONCLUSIONS**

A long-term analysis of human health and environmental impacts of residual wastes left in tanks and ancillary equipment within a closed WMA C is in the process of being prepared. Documents that will be produced as part of this analysis will include the following.

- DOE Order 435.1 analysis of radiological impacts evaluating related performance objectives:
  - All Pathways Dose Impacts
  - Air Pathway Dose Impacts and Radon Fluxes
  - Inadvertent Intruder Dose Impacts
  - Acute Exposure Scenario
  - Chronic Exposure Scenarios
  - Groundwater Protection.
- RCRA Closure Analysis of hazardous chemical impacts evaluating related groundwater protection recommended concentration and risk thresholds.

This preliminary evaluation of performance of a closed WMA C has been developed using projected estimates of volumes and inventories for selected tanks based on either Hanford Tank Waste Operations Simulator or best-basis inventory estimates. Preliminary analysis have not been able to account for:

- Final inventories for wastes left in three retrieved SSTs (C-101, C-107 and C-112) that will be developed from waste residual sampling and analyses
- Final volumes and inventories for waste left in three SSTs (C-102, C-105 and C-111) that are in the process of being retrieved
- Final volumes and inventories for waste left in the CR-vault tanks, the C-301 catch tank, and other ancillary equipment where retrieval has not been initiated.

Based on progress to date with unretrieved tanks, it is anticipated that final volumes for the unretrieved tanks may be above final volumes assumed in the initial PA. The PA effort anticipates evaluating an additional sensitivity case that will examine, as bounding inventory case, the volume and concentration for waste remaining in these unretrieved tanks based on the best-basis inventory at the time that this information is finalized for the initial version of the PA.

Eventually, once retrieval of these SSTs and other ancillary equipment has been completed and final inventories have been estimated based on waste residual sampling and analysis, the impacts from these final volumes and inventories will need to be evaluated. Analysis of final closure volumes and inventories will not be included in the initial version of the PA that will be released in the fall of FY 2015 but will be considered in the next iteration of the PA.

## REFERENCES

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