ECF-HANFORD-22-0114
Revision 0

Hanford Site Composite Analysis Special Analysis: P2R Model Predictive Contaminant Transport Simulations - Sensitivity Case

UCAQ-22-01 Inventory Modification for Carbon-14 and Technetium-99 to 218-E-12B, 218-W-3, and 218-W-3A

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract 89303320DEM000030

CPCCo
Central Plateau
Cleanup Company

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Terms

CA	composite analysis
CPCCo	Central Plateau Cleanup Company
CY	calendar year
ECF	environmental calculation file
EMDT	environmental modeling data transmittal
HISI	Hanford Information System Inventory
HSS	hydrocarbon spill source (package)
ICF	integrated computational framework
LLBG	low-level burial ground
P2R	Plateau-to-River (model)
RET	Recharge Evolution Tool

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1 Purpose

This environmental calculation file (ECF) documents the methodologies, assumptions, and results of predictive fate and transport simulations using the Plateau-to-River (P2R) model. This ECF supports the reevaluation of the representativeness of solid-waste radionuclide inventory and release rate from three solid waste sites included in the recently completed Hanford Site Composite Analysis (CA) (DOE-RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020)*). Specifically, this ECF supports the reevaluation of the representativeness of the base case inventory and radionuclide waste release rates from three solid waste sites (i.e., 218-E-12B, 218-W-3A and 218-W-3AE) and two radionuclides (carbon-14 [C-14] and technetium [Tc-99]). These three waste sites and two radionuclides were identified as being the most significant contributors to groundwater contamination and dose in the CA at time periods after the compliance period. The release rates and footprints of the releases from the vadose zone are implemented in the fate and transport modeling utilizing the HSS package.

For details on the inventory and solid waste modeling on which this ECF is based, refer to ECF-HANFORD-22-0109, *Hanford Site Composite Analysis Special Analysis: Inventory and Solid Waste Release Modeling for the LLBG Sensitivity Case.*

2 Background

The technical approach for executing the saturated zone facet of the CA is documented in CP-60406, *Hanford Site Composite Analysis Technical Approach Description: Groundwater*. The description includes discussing the selection of the numerical modeling platform and the details regarding development of input parameters for use in the analysis. The approach calls for using the most current version of the P2R model to simulate groundwater flow and transport for a 10,000-year predictive time period. CP-57037, *Model Package Report: Plateau to River Model Version 8.3*, documents the development and calibration of the P2R model. ECF-HANFORD-19-0119, *Predictive Flow Simulation with the P2R Model for the Composite Analysis Base Case,* describes the changes made to model inputs in order to simulate the predictive flow field for the updated Hanford Site CA. Details regarding the development of the model and the predictive flow simulation are provided in these documents. This includes conceptual model information, comparison of model performance versus observation data, and limitations of the model.

The Hanford Site CA (DOE/RL-2019-52) identified the assumed inventory and release rate of C-14 and Tc-99 from three DOE O 435.1, *Radioactive Waste Management* waste sites as being over conservative and not representative of the expected inventory and release rate from these waste sites. The three waste sites and associated radionuclides that were identified as being nonrepresentative are as follows; Figure 1 shows the locations of these waste sites:

- C-14 inventory in 218-E-12B within the B-63 vadose zone model domain in the 200 East Area Low-Level Burial Ground (LLBG)
- C-14 inventory in 218-W-3A within the LLBG-200W A vadose zone model domain in the 200 West Area LLBG
- Tc-99 release rate in 218-W-3AE within the LLBG-200W A vadose zone model domain in the 200 West Area LLBG

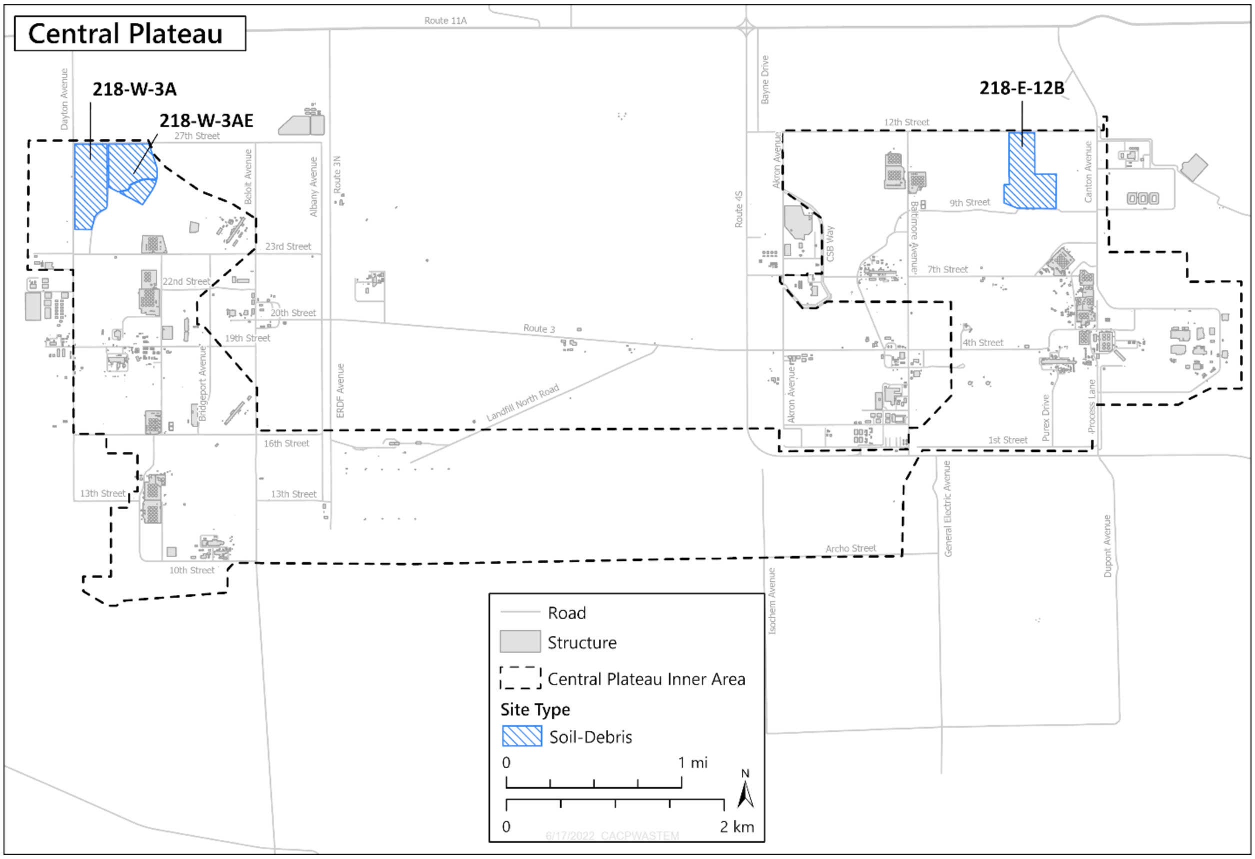

Figure 1. Location of the Solid Waste Disposal Sites Concerned by the CA Maintenance Within Hanford Central Plateau and Corresponding Waste Form Submodel Assignment considered in the CA Update

Although the conservative inventory and waste release assumptions did not affect the predicted groundwater pathway doses for any potential compliance boundary during the compliance period (from calendar years [CYs] 2070 to 3070) and did not affect the predicted pathway doses for the CA compliance boundary during the postcompliance time period (from CYs 3070 to 12070), the conservative assumptions did result in predicted groundwater pathway doses that exceed the administrative limit during the post compliance time period. As a result, the CA recommended that these conservative assumptions be reevaluated during CA maintenance. The purpose of this ECF is to implement the reevaluation of these conservative assumptions, performed in ECF-HANFORD-22-0109 into the fate and transport modeling using the P2R model version 8.3.

3 Methodology

Development of the predictive fate and transport simulations using the P2R model is completed using the acquired computer software MT3DMS (Zheng and Wang, 1999, *MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*). The model simulates fate and transport of contaminants using finite differencing to compute concentrations on a cell-by-cell basis within the model domain. Three major aspects of the estimation of these concentrations are as follows:

1. The governing equations for solving fate and transport in the saturated zone
2. The model extent and spatial discretization
3. The management strategy of model inputs and outputs

Each of these is discussed in the following sections.

3.1 Fate and Transport Governing Equations

The governing equation of fate and transport of contaminants in the saturated zone as specified for MT3DMS is shown in Equation 1 (Zheng and Wang, 1999). The equation is solved numerically using finite differencing techniques to estimate concentrations in the subsurface on a cell-by-cell basis. Groundwater fluxes that define the movement of groundwater in the aquifer are solved based on flow simulations completed prior to the execution of the fate and transport calculations. The governing equation can be broken into four key components including advection, hydrodynamic dispersion, sources and sinks, and reactions. Chapter 4 discusses the specific model input parameters that define each portion of the governing equation and are used for this application.

$$\frac{\partial(\theta C)}{\partial t} = \frac{\partial}{\partial x_j}\left(\theta D_{ij}\frac{\partial C}{\partial x_j}\right) - \frac{\partial}{\partial x_i}(\theta v_i C) + q_s C_s + \sum R_n \quad \textbf{(Eq. 1)}$$

where:

$\boldsymbol{\theta}$	=	effective porosity of the subsurface medium, dimensionless
C	=	dissolved concentration of, M/L^3
t	=	time, T
x_i, x_j	=	distance along the respective Cartesian coordinate axes, L
D_{ij}	=	hydrodynamic dispersion, L^2/T
v_i	=	seepage or linear pore water velocity, L/T
q_s	=	volumetric flow rate per unit volume of sources and sinks, 1/T
C_s	=	concentration of the source or sink flux, M/L^3
$\sum R_n$	=	chemical reaction term, M/L^{3}T.

3.2 Model Domain and Discretization

The P2R model domain has the following lateral extent and boundaries: extent north to south is 26.6 km (16.5 mi) and extent east to west is 37.6 km (23.3 mi). The lower-left corner of the model domain is located at easting 557,800 m and northing 116,200 m in the Washington State Coordinate System (NAD_1983_StatePlane_Washington_South_FIPS_4602). The vertical extent of the model comprises the subsurface sediments from the ground surface to the uppermost unit of the Columbia River Basalt Group. The basalt that is assumed to constitute an impermeable lower boundary defines the base of the domain.

The model domain is discretized into a finite difference grid. The grid in the lateral directions is broken up into variably sized cells of 100 by 100 m (328.1 by 328.1 ft), 100 by 200 m (328.1 by 656.2 ft), and 200 by 200 m (656.2 by 656.2 ft). A total of 274 columns and 201 rows constitutes a total of 55,074 laterally distinct cell locations within the model domain. The model is vertically divided into seven model layers between the ground surface elevation and the top of the uppermost basalt surface. The discretization of the vertical layers varies in order to represent the thickness of geologic formations found within the model domain. A maximum of 34,421 of those 55,074 laterally distinct cells are active in the model within each model layer. Figure 2 shows the lateral extent of the P2R model version 8.3 domain along with the groundwater operable units, lateral discretization, and boundary conditions.

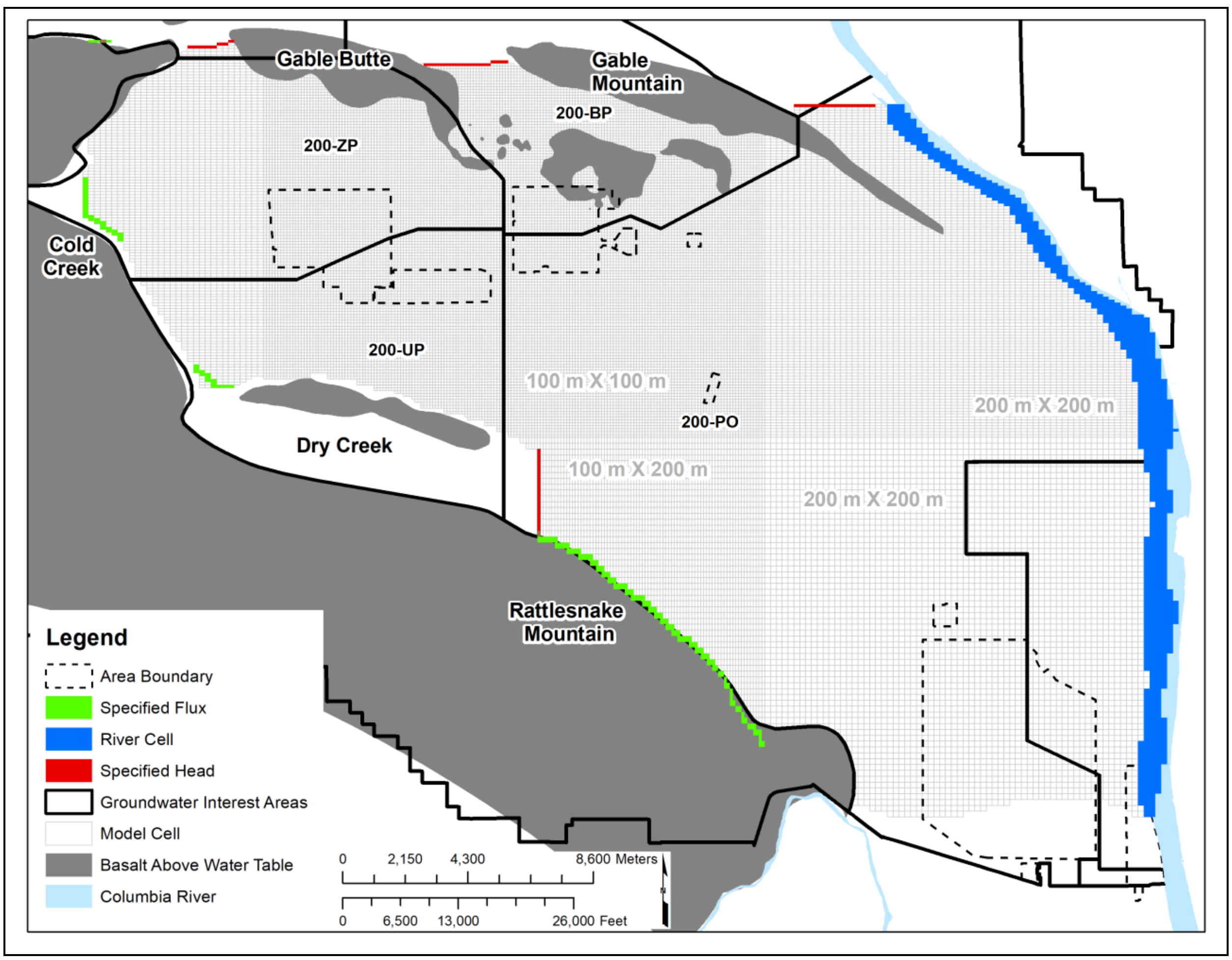

Figure 2. P2R Version 8.3 Model Extent and Groundwater Flow Boundary Conditions

3.3 Configuration Control and Integrated Computational Framework

A configuration control system was developed so that all models generated for the Hanford Site CA (DOE/RL-2019-52) would follow a consistent set of conventions and use only approved input data (e.g., hydraulic and contaminant properties, source releases, etc.). A data configuration and quality-control system, the Integrated Computational Framework (ICF), provides the tools necessary to verify that all model output data are correctly associated with their corresponding input data. The ICF consists of two parts: a file management system, and utility scripts. Each script associated with the ICF is reviewed, tested, and documented to qualify it for use (see CHPRC-04032, *Composite Analysis/Cumulative Impact Evaluation (CACIE) Utility Codes Integrated Software Management Plan*).

The ICF houses all data produced by and in support of the Hanford Site CA modeling effort. The ICF file management system enables model data and inputs to be checked into the ICF, reviewed, and accepted by the ICF administrator. The ICF facilitates the review of model inputs and outputs to provide assurance that outputs can be traced to the work products that were used as model inputs. Separating the data flow from the modeling helps prevent accidental modification and requires a data review prior to acceptance of any data product into the ICF. This pedigree system in the ICF allows users to ascertain all ancestor and derivative products related to any ICF data product, providing confidence that output data are associated with a set of versioned input data.

The utility script pertaining to the ICF used as part of the fate and transport modeling includes a preprocessing utility supporting translation of results from the vadose zone models to the saturated zone model called the HSSMBuilder. The HSSMBuilder utility transcribes Surface Transport Over Multiple Phases[1] output into an MT3D-MST package called the hydrocarbon spill source (HSS) package (Zheng, 2010, *MT3DMS v5.3 Supplemental User's Guide, Technical Report*). Although written specifically for application to hydrocarbon spills, the HSS package can also be used for other contaminants, allowing for arbitrary, time-varying mass or activity sources to be input into the MT3D-MST code for the P2R model.

Normally, mass or activity loading of sources to MT3D-MST must be specified as average loading rates over each time interval simulated in the model, so resolution of time-varying sources is limited by time discretization in the model (i.e., the number and lengths of the time intervals). With the HSS package, mass or activity loading rates can be specified independent of time discretization, allowing for mass or activity loading rates at an appropriate resolution for each source. Before using, the utility underwent testing and review to ensure the codes perform their expected/necessary functions. All use of the software is logged as part of the ICF data management and in Chapter 5 of this ECF. The model inputs created by this method are discussed in Section 4.3.4.

[1] Surface Transport Over Multiple Phases (or STOMP) is a copyright of Battelle Memorial Institute, Columbus, Ohio, and used under the Limited Government License.

4 Assumptions and Inputs

Construction of the numerical fate and transport model for the Hanford Site CA (DOE/RL-2019-52) consisted of developing the required model inputs to the MT3DMS simulation. This included reviewing the various characterization reports and selecting values for input parameters and documenting the assumptions used to execute MT3DMS. The inputs are documented in the following steps:

1. Calculating the predictive flow field
2. Discretizing the temporal domain of the simulations
3. Defining the transport properties for the MT3DMS input files

4.1 Predictive Flow Simulation

Fate and transport simulations in MT3DMS require a flow simulation as a basis for estimated movement of groundwater, directions, and magnitude in the saturated zone. The predictive groundwater flow simulation was developed as a basis for conducting predictions of the movement of groundwater into the future and conducting predictive contaminant fate and transport simulations. The development of the predictive flow simulation is documented in ECF-HANFORD-19-0119. The reader is referred to ECF-HANFORD-19-0119 for details regarding the construction of boundary inputs and boundary conditions for the flow model.

4.2 Temporal Discretization

The temporal discretization is summarized in Table 1. The simulation period for the predictive flow model starts in 2018 and runs for 10,052 years, ending in 12070. A total of 101 stress periods were used with varying stress period length. The length of any stress period through 2570 matched the time periods taken by the Recharge Evolution Tool (RET) documented in ECF-HANFORD-15-0019, *Hanford Site-Wide Natural Recharge Boundary Conditions for Groundwater Models*. The simulation was executed using a Courant Number limitation constraint of 1.0. The maximum transport step allowed during the first 100 stress periods when boundary conditions were changing was set to 1 day. The final stress period allowed for longer transport steps up to 10 days given the length of the stress period and the lack of changes in the groundwater flow field during this time. The Courant Number limiter was applied throughout the simulation temporal domain.

4.3 Transport Simulations

Numerical simulations using MT3DMS were conducted to evaluate the fate and transport of two of the radionuclides as identified in CP-62184, *Hanford Site Composite Analysis: Radionuclide Selection for Groundwater Pathway Evaluation*: C-14 and Tc-99. The implicit finite difference scheme using upstream weighting was used to estimate the fate and transport of these contaminants. This section discusses the initial concentration conditions, transport parameters, and continuing sources of contaminant in the vadose zones used as part of the transport simulations.

Table 1. Temporal Discretization of Predictive Transport Model

Stress Periods	Duration (yr)	Description	Maximum Transport Step Size
1 to 82	82	82 annual stress periods from 2018 through 2099	1 day
83	35	1 stress period from 2100 through 2134	
84	16	1 stress period from 2135 through 2150	
85	343	1 stress period from 2151 through 2493	
86	23	1 stress period from 2494 through 2516	
87	3	1 stress period from 2517 through 2519	
88	1	1 annual stress period for the year 2520	
89	4	1 stress period from 2521 through 2524	
90 to 91	2	2 annual stress periods from 2515 through 2526	
92	2	1 stress period from 2527 through 2528	
93	1	1 annual stress period for the year 2529	
94	3	1 stress period from 2530 through 2532	
95	2	1 stress period from 2533 through 2534	
96	8	1 stress period from 2535 through 2542	
97	7	1 stress period from 2543 through 2549	
98 to 99	2	2 annual stress periods from 2550 through 2551	
100	18	1 stress period from 2552 through 2569	
101	9,500	1 stress period from 2570 through 12070	10 days

4.3.1 Initial Concentration Plumes

One of the contaminants, Tc-99, requires an initial state variable representing the concentration of contaminants distributed within the saturated zone of the aquifer. The process for developing these estimates is documented in ECF-HANFORD-20-0062, *Mapping the Concentration Distribution of Contaminant Plumes to the Computational Grid of the Plateau to River Model Version 8.3*. In summary, observed concentration data at wells and two- and three-dimensional interpolations of plume concentration distribution were used to map plume concentration to the model grid. Two estimates for Tc-99 contaminant were created: a best-estimate condition and a worst-case condition. Generally, the best-estimate condition calculated the average concentration within the boundary of each numerical grid cell and the worst-case condition to the highest magnitude concentration value. Initial concentration distributions were estimated for the radionuclide Tc-99. The best-estimate condition produces the simulation results that will be used for calculating dose. The worst-case scenario initial condition is included as a sensitivity simulation.

No estimate of plume extents and distribution in the subsurface was developed for C-14. In this case, the simulation assumes a pristine aquifer initial concentration of 0 pCi/L for the start of simulations. Concentrations in the subsurface are not observed at levels necessitating the creation of plume estimates in as part of annual reporting for the saturated zone on the Central Plateau (see DOE/RL-2018-66, *Hanford Site Groundwater Monitoring Report for 2018*).

4.3.2 Transport Parameters

This section discusses the selection of transport parameters used as part of the base case simulations supporting the CA. The parameters are selected from characterization data compiled in reports specific to the Hanford Site or based on literature values, where necessary, that are documented in the tables presented in the following sections. The parameter values reflect information that are typically used to support fate and transport modeling in support of remedial decisions at the Hanford Site. These parameters include soil properties, geochemical properties, and dispersion selected for the two simulated radionuclides.

4.3.2.1 Soil Properties

Soil properties for the fate and transport simulation are shown in Table 2. The effective porosity and bulk density values are provided with their respective geologic units. The basis for each selected parameter value is also included in the table.

Table 2. Composite Analysis Saturated Zone Facet Transport Model Soil Properties

Property	Geologic Unit	Value	Basis
Effective Porosity	Hanford formation, CCU	0.2	Approximate central value (arithmetic average) of the mean value for all Hanford sediments representative of the saturated zone – either estimated, interpreted from aquifer tests or tracer tests, or calculated from lab tests on samples taken from within 5 m above the water table to the bottom of a specified borehole (Table D-17 in DOE/RL-2007-28). Textural description is assumed to approximate the gravelly sand or sandy gravel CCU described in PNNL-18564 and the basis for its assigned bulk density of 1.93 g/cm^3.
	Rtf, Rwie, Rwia	0.15	Approximate central value (arithmetic average) of geometric mean values for Hanford sediments representative of the saturated zone – either estimated, interpreted from aquifer tests or tracer tests, or calculated from lab tests on samples taken from within 5 m above the water table to the bottom of a specified borehole (Tables D-3 and D-17 in DOE/RL-2007-28).
	Rlm	0.3	Value used for 200-BP-5 and 200-PO-1 modeling (Table 4-6 in ECF-HANFORD-13-0031). Estimated from Table 6.3 in PNNL-15239 where θ (total porosity) = 0.316 for sediment (Rlm) from borehole 299-W15-46, depth of 131 to 131.7 m with a total silt/clay content of 82.2% (36.7% clay).

Table 2. Composite Analysis Saturated Zone Facet Transport Model Soil Properties

Property	Geologic Unit	Value	Basis
Bulk Density	Hanford formation, CCU	1.93 g/cm^3	Table 6.2 in PNNL-18564. Value is selected as representative of the Hanford formation gravel-dominated CCU immediately overlying the upper Ringold Formation unit 4 (see Figure 3-1 in CP-57037). According to the authors of PNNL-18564, the value represents the best professional judgement of technical experts/authors of reports cited in PNNL-18564, with the sediment class nomenclature qualitatively described in Table 6.2 as Hanford formation gravelly sand or sandy gravel.
	Rtf, Rwie, Rlm, Rwia	1.90 g/cm^3	Table 5.2 in PNNL-18564. Value is representative of the saturated Ringold Formation members typically comprising fluvial gravel, moderately to strongly cemented, and interstratified with finer-grained deposits. The values represent the reports cited in PNNL-18564, with the sediment class nomenclature qualitatively described in Table 6.2 as Rg-Ringold Formation sandy gravel. (Note: the well bedded fine-to-coarse sand to silt sediments of the Taylor Flat member are explicitly excluded from the ascribed qualitative description.)

Note: Complete references citations are provided in Chapter 8.

CCU = Cold Creek unit

Rlm = Ringold Formation member of Wooded Island – lower mud unit

Rtf = Ringold Formation member of Taylor Flat

Rwia = Ringold Formation member of Wooded Island – unit A

Rwie = Ringold Formation member of Wooded Island – unit E

4.3.2.2 *Geochemical Properties*

As contaminants flow through the groundwater, they interact with the soil particles depending on the nature of the contamination. The geochemical processes simulated as part of the fate and transport of contaminants include adsorption to the soil matrix and radioactive decay. Linear partitioning coefficients were assigned for each radionuclide based on field specific data and literature values (Table 3). Half-lives and the respective decay rates are also provided in Table 3.

Table 3. Composite Analysis Saturated Zone Facet Transport Model Adsorption Properties

Radionuclide	K_d (mL/g)	Half-Life (year)[a]	Half-Life (day)	Degradation Rate (day^{-1})
C-14	0	5.70E+03	2.08E+06	3.33E-07
Tc-99	0[b]	2.11E+05	7.71E+07	8.99E-09

a. EMDT-DE-0006, *Half-lives for Typical Hanford Site Radioactive Contaminants* (Appendix A in this document).

b. Applied 50% gravel correction to values in Table 10 of ECF-HANFORD-19-0121, *Selection of Vadose Zone Flow and Transport Properties with Gravel Fraction Corrections for the Hanford Site Composite Analysis and Cumulative Impact Evaluation.*

Note: Degradation rate calculated from half-life (rate=ln(2)/half-life).

4.3.3 Hydrodynamic Dispersion

As contaminants move through the subsurface plumes of contaminants tend to spread. This is caused by molecular diffusion based on concentration gradients and the interaction with soil particles through tortuous and variable paths called dispersivity. The total effect of these phenomena on the contaminant plume is referred to as hydrodynamic dispersion. Where flow of groundwater is relatively high, as within the saturated zone of the suprabasalt aquifer at the Hanford Site, the dispersivity component outweighs diffusion on impacts to the concentration. This renders the effect of the diffusion term on concentration negligible in the saturated zone. The input parameters and discussion related to selection of these values for the Hanford Site CA base case are shown in Table 4.

Table 4. Composite Analysis Saturated Zone Facet Transport Model Dispersivity Properties

Property	Value	Basis
Longitudinal dispersivity	3.5 – 6.2 m	Values are within the range (approximately 0.2 to 15 m) of high-to-intermediate reliability values reported from tracer tests conducted in unconsolidated sediments at measurement scales of 100 to 200 m. High reliability values were considered by Gelhar et al. (1992) and adopted by Schulze-Makuch (2005) as accurate within a factor of two. Accuracy estimates were not provided for intermediate reliability values. Based on the P2R model grid cell sizes and the finite difference solution used in the P2R model, the longitudinal dispersivity may introduce some numerical dispersion, however the model adequately represents the contaminant concentrations at the P2R scale based on calibration to field data.
Transverse dispersivity	0.7 – 1.24 m	20% of longitudinal. Transverse dispersivity is generally considered to be approximately an order of magnitude smaller than longitudinal Dispersivity (Gelhar et al., 1992). A review of transverse Dispersivity in S-N/99205-103-REV1 indicates that, in general, transverse horizontal dispersivity is a factor of 3 to 30 less than longitudinal dispersivity.
Vertical dispersivity	0.0 m	Assumed that due to the longitudinal and lateral scales of transport and the dominance of horizontal flow in the P2R model domain (DOE/RL-2007-28), vertical dispersion is minimal (DOE/RL-2008-56). Simulation of no vertical dispersion will result in conservatively high concentrations in the upper portion of the aquifer when considering continuing sources arriving at the water table at future dates.
Molecular diffusion constant	0.0 m^2/d	Negligible term due to the comparatively large longitudinal and lateral scales of transport and predominance of advective flow.

Note: Complete reference citations are provided in Chapter 8.

PTR = Plateau-to-River (model)

4.3.4 Continuing Sources

The MT3DMS code simulates fate and transport in the saturated zone. A key feature of the simulation is the estimated contaminant activity reaching the saturated zone over time from the vadose zone. As part of the Hanford Site CA (DOE/RL-2019-52), vadose zone simulations were carried out that provide estimates of activity that reaches the saturated zone from the vadose zone. The vadose zone simulations provide estimates of activity starting at 2018. Contaminant activity that arrived at the groundwater prior to the Hanford Site CA simulation start date is represented in the initial condition contaminant plume distribution (discussed in Section 4.3.1).

The HSSM Builder utility from the CA ICF, discussed in Section 3.3, was used to transcribe vadose zone results into the HSS packages for use with MT3DMS. The HSS inputs are documented as part of the ICF. Appendix B includes the ICF check-in form for MT3DMS input HSS packages under the title "HSSMCAM22 version 1.0." The data include estimates of continuing sources derived from previous performance assessments at the Hanford Site documented as environmental modeling data transmittals (EMDTs) listed in Appendix C. Figure 3 shows map of the spatial distribution of total estimated activity of Tc-99 that enters the saturated zone over the entirety of the 10,052-year simulation. Similar plots for each of the 2 radionuclides documented in this ECF that are estimated to pass activity from the vadose zone to the saturated zone are included in Appendix D.

After the HSS packages were created using the native tool, mass balance checks were developed to ensure that the total activity predicted to reach the vadose zone was represented in the saturated zone simulations. Table 5 shows the results of the mass balance. The difference between the activity predicted by the vadose zone models and the activity input into the saturated zone models is minimal.

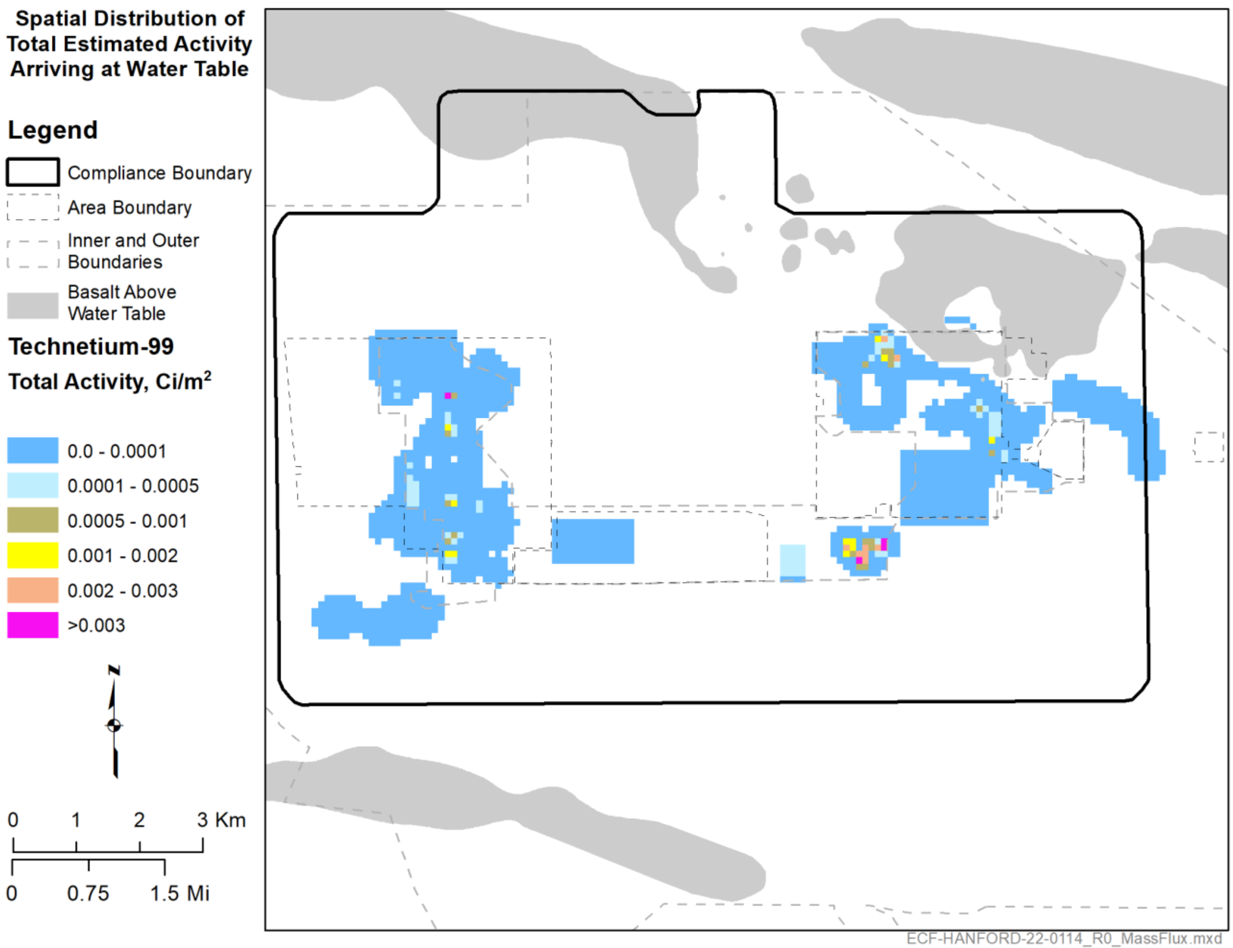

Figure 3. Spatial Distribution of Simulated Activity Entering the Saturated Zone from the Vadose Zone for Tc-99 over the Entire Length of Simulation Temporal Discretization

Table 5. Comparison of Total Simulated Activity Passing from the Vadose Zone to the Saturated Zone for Each Contaminant

Contaminant	Total Simulated Activity from Vadose Zone Models (Ci)	HSS Packages		MT3D Activity	
		Total Activity (Ci)	Percent Difference	Total Activity (Ci)	Percent Difference
C-14	6.48596E+02	6.48596E+02	-0.00001	6.48596E+02	-0.00007
Tc-99	9.82394E+02	9.82394E+02	-0.00001	9.82394E+02	0.00001

HSS = hydrocarbon spill source (package)

One of the assumptions made when passing activity flux of radionuclides from the vadose zone to the saturated zone using the HSS package is vertical placement of activity within the model grid. Figure 4 shows a hypothetical vertical configuration of MT3D grid cells for a row and column within the model grid. The diagram shows that the uppermost layer is unsaturated, the second layer is partially saturated, and all layers below are fully saturated. For this discussion both partially and fully saturated cells are termed active cells. The HSS package, used to define the input of activity into the MT3D model, allows the user to select any layer within the vertical column as the injection point of the radionuclide activity. The assumption used for the Hanford Site CA (DOE/RL-2019-52) is to use the uppermost active model cell.

The top of the water table was selected as the injection point into the aquifer because it mimics the assumption used in the flow model where recharge to the aquifer from the vadose zone occurs at the water table. The Hanford Site has a dynamic water table based on the historic discharge of liquid waste to the groundwater. Mounding of the water table was observed historically and the water table at present day is declining closer to the pre-Hanford conditions. From a numerical modeling perspective this means the uppermost model layer changes throughout the simulation as the water table rises and falls. The HSS package requires the selection of the cell for injection of mass be made before the simulation starts and remains static throughout the temporal domain of the simulation.

Given that the uppermost cell can change throughout the simulation, the selection of the radionuclide injection location is determined based on the results of hydraulic head levels from the numerical groundwater flow model completed prior to the fate and transport simulations. Simulated heads are evaluated and the uppermost vertical layer that remains active for each row and column pair over the entire simulation is selected as the vertical location of radionuclide activity injection. This assumption is made to approximate the activity reaching the saturated zone at the water table after migrating through the vadose zone.

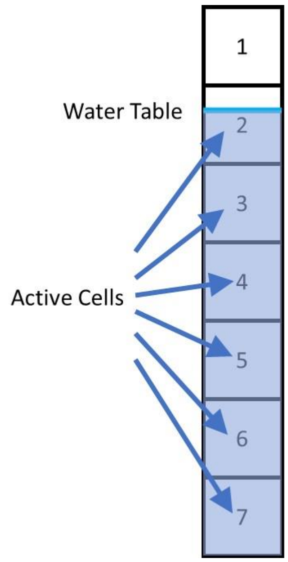

Figure 4. Example Column of Vertical Cells from the MT3D Model Showing Active Cells Based on Water Table Height

5 Software Applications

MT3D-MST, Excel®, ArcGIS®, and R software programs were used for this calculation. MT3D-MST is Central Plateau Cleanup Company (CPCCo) approved software, managed, and used in compliance with the policy regarding software. Excel, ArcGIS, and R are approved support software as established in CP-66776, *MODFLOW and Related Codes: Software Management Plan*.

MT3D-MST was executed on the GAIA cluster. The details regarding the cluster are presented below. A copy of the *Software Installation and Checkout Form* for the MT3D-MST installation used for this calculation is provided in Appendix E to this ECF.

The GAIA Fate and Transport Modeling Platform, owned by CPCCo and operated by Mission Support Alliance, consists of ten Dell® PowerEdge® R740 Servers. Each with dual 28-core Intel® Xeon® Platinum 8180M@2.5GHz, 768GB of RAM. The head node (U.S. Department of Energy Property number WF32991) is running CentOS v.7.4.1708.

The results of CPCCo acceptance testing (CP-66778, *MODFLOW and Related Codes Build 9 Software Acceptance Test Report*) demonstrate that the MODFLOW-2000/MT3D-MST software is acceptable for its intended use by the CPCCo. Installations of the software are operating correctly, as demonstrated by the GAIA Fate and Transport Modeling Platform.

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® Dell and PowerEdge are registered trademarks of the Dell Corporation, Round Rock, Texas.

® Intel and Xeon are registered trademarks of the Intel Corporation, Santa Clara, California.

5.1 Approved Software

For approved calculation software used in this calculation, the required descriptions are provided below.

5.1.1 Description

MT3D-MST

- **Software Title:** MT3D-MST
- **Software Version:** CHPRC[2] Build 0008 (executable name "mt3d-mst-chprc08dpl.x"), double precision compilation
- **Hanford Information System Inventory (HISI) Identification Number:** 2518 (Safety Software Level C)
- **Authorized Workstation type and property number:** Linux® Cluster, Linux Cluster, Hanford Local Area Network Property Tag (Front End Node) WD56054
- **Authorized User:** S. Tomusiak
- **CPCCo Software Control Documents:**
  - CP-66810, *MODFLOW and Related Codes: Software Requirements Specification Report*
  - CP-66776, *MODFLOW and Related Codes: Software Management Plan*
  - CP-66777, *MODFLOW and Related Codes Software Test Plan*
  - CP-66811, *MODFLOW and Related Codes Requirements Traceability Matrix: CHPRC Build 9*
  - CP-66778, *MODFLOW and Related Codes Software Acceptance Test Report: CHPRC Build 9*

5.1.2 Software Installation and Checkout

Copies of the *Software Installation and Checkout Forms* for the authorized users and authorized workstations for software used that requires this documentation are provided in Appendix E to this ECF.

5.1.3 Statement of Valid Software Application

The preparers of this calculation attest that the software identified above, and used for the calculations described in this calculation, is appropriate for the application and used within the range of intended uses for which it was tested and accepted by CPCCo. Because MT3D-MST are graded is Level C software, use of this software is required to be logged in the HISI. Accordingly, this ECF has been logged by the software owner in the HISI under Identification Number 2518.

5.2 Support Software

The production of the HSS package used an approved utility calculation software in compliance with CHPRC-04032. The utility code, "HSSM Builder" (a.k.a. build_hssm.py), was tested and qualified for use in compliance with the requirements specified in CHPRC-04032 and as documented in the consolidated tool package attachment for the tool. Other support software including Excel, ArcGIS, and R were used in figure making, adjusting file formats, and other support functions in creating this report. These support software were used in accordance with CP-66776**.**

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[2] CH2M HILL Plateau Remediation Company (CHPRC) was the contractor at the time the software build was qualified for use.

® Linux is a registered trademark of Linus Torvalds (individual), Boston, Massachusetts.

6 Calculation

The set of simulations created to support the Hanford Site CA (DOE/RL-2019-52) include simulations for each of the two contaminants. This chapter describes the organization of the simulation sets, and includes figures, charts, and tables that are available for each of these simulation sets.

6.1 Simulation Organization

Simulations developed in support of the Hanford Site CA were grouped based on contaminant and the simulated initial plume concentrations at time zero in the model. For simulations with nonzero initial concentrations, two initial concentration fields represent the aquifer based on the worst-case scenario and the best estimate of the concentrations. This includes Tc-99. The other contaminant, C-14, was simulated assuming a pristine aquifer thus only one simulation was run. The total number of simulations for the base case was three (one worst-case scenario initial condition and two best-estimate initial conditions). The development of these two initial concentration conditions is discussed in Section 4.3.1. Simulation results in each contaminant and both conditions are presented.

6.2 Assessing Plume Migration for Existing Plumes

The simulation outputs from each of the simulations mentioned previously were processed to create a set of figures to illustrate the fate and transport of the simulated contaminants. The figures created include plan view contour maps and summary charts for the maximum concentration for various regions of the model. An example of the figures showing results for the Tc-99 simulation for best estimate concentration initial conditions is shown in Figure 5. The following sections describe the features of the figure layout to aid in figure interpretation. A full set of figures for all of the simulations including best estimate and worst-case initial concentrations, as applicable) conducted for this ECF are included in Appendix D.

6.2.1 Plan View Contours

Figure 5 shows a plan view contour plot for the Tc-99 plume after 50 years of simulation. Several aspects of the figure help identify the simulation scenarios. There is a title in the upper right-hand corner that describes the total number of years that have been simulated. The simulation time 0, 52, 152, 552, 1,052, 2,052, 4,052, 10,052 years are provided for each contaminant and simulation in Appendix D.
The simulation provides an estimate of concentration at each of the seven layers in the model domain. The plan view contour plots only display the maximum concentration from any layer in the model. Thus, the plan view contours provide a conservatively high estimate of the concentration within the aquifer by illustrating the maximum value of all seven layers.

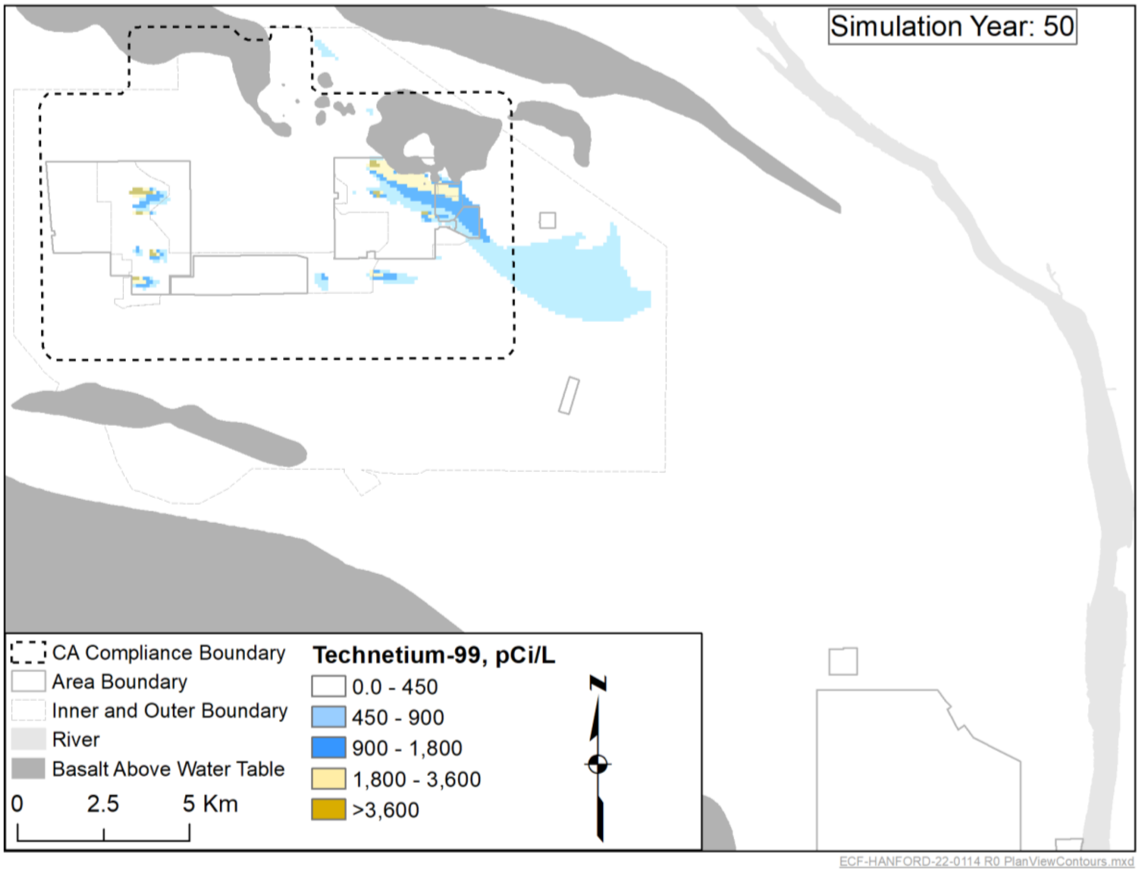

Figure 5. Plan View Contours of the Tc-99 Plume at Simulation Time 50 Years Based on Best Estimate Concentration Initial Conditions

6.2.2 Peak Concentration Summary

The extent of the P2R model version 8.3 domain was subdivided into multiple zones as a means of presenting plume behavior with respect to the CA Compliance Area of the Hanford Central Plateau (Figure 6). A total of three zones are designated signifying the areas within the CA Compliance Boundary (Within_Compliance_Boundary), at the CA Compliance Boundary (At_Compliance_Boundary), and the remaining modeled extent of the Hanford Site (Beyond_Compliance_Boundary). Peak concentration (pCi/L) time series plots (both 1,000- and 10,000-year time series) were generated for each simulation conducted as part of this calculation (total of three) for each of the three zonation extents. Peak concentration is defined as the maximum concentration within a zone for a given point in time. Figure 7 and Figure 8 provides examples of the 10,000- and 1,000-year (respectively) time series plot for Tc-99 peak concentration values. The remaining two sets of radionuclide figures, including both best estimate initial concentrations and worst-case initial concentrations, are presented in Appendix D of this ECF.

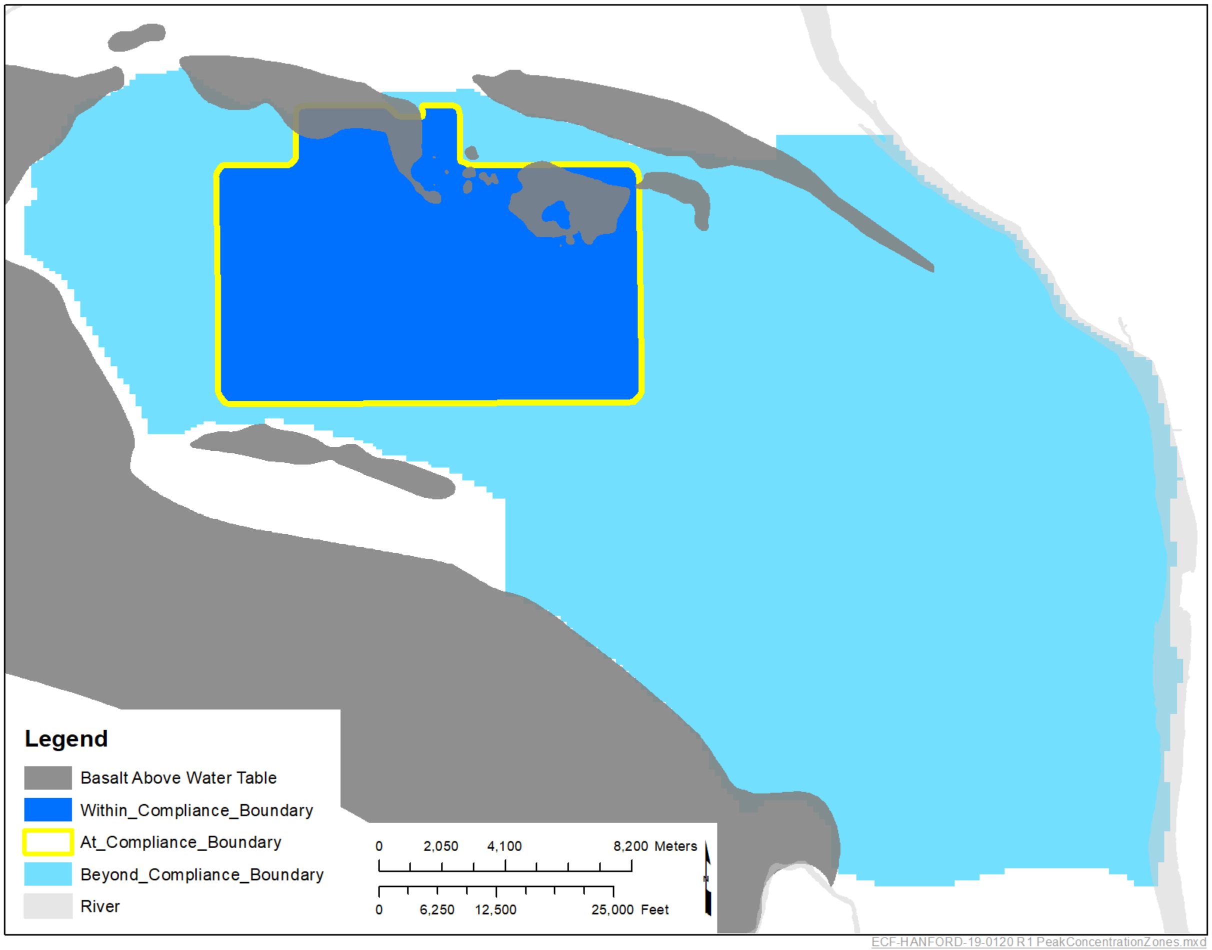

Figure 6. P2R Model Version 8.3 Peak Concentration Summary Zonation Extents

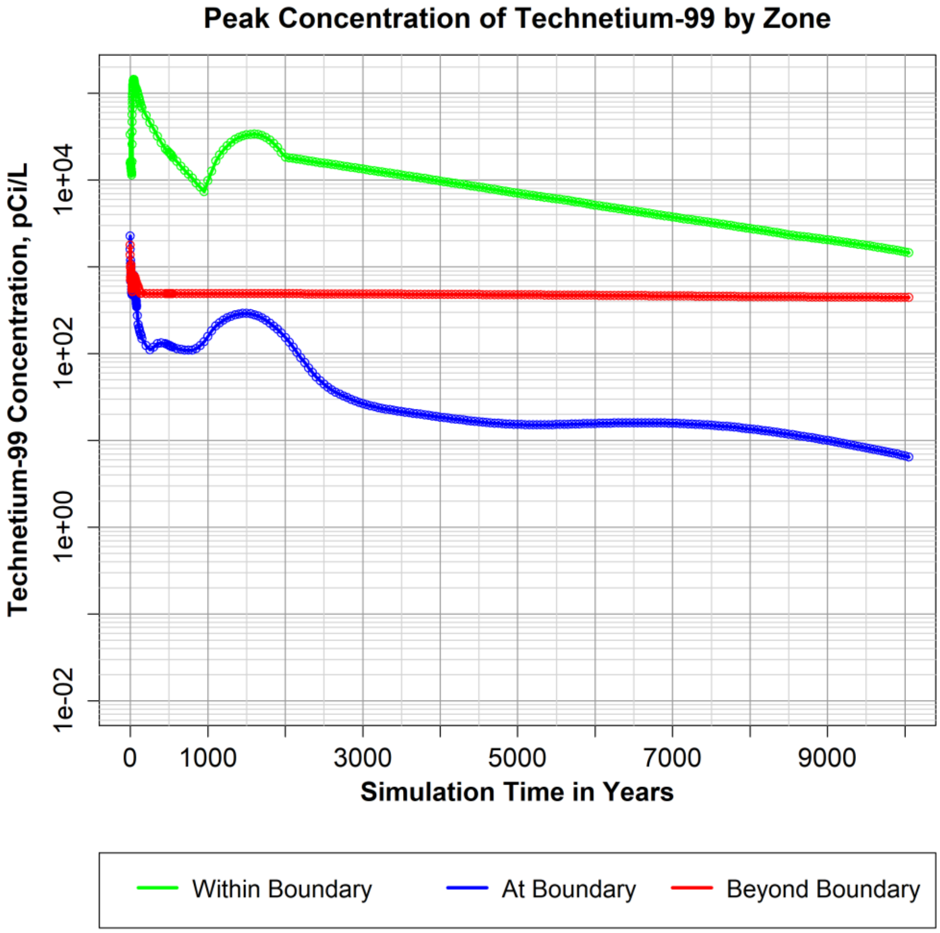

Figure 7. Peak Concentration of Technetium-99 from the Start of Simulation to the End of the Simulation Within, At, and Beyond the Compliance Boundary Assuming the Best Estimate Initial Concentration

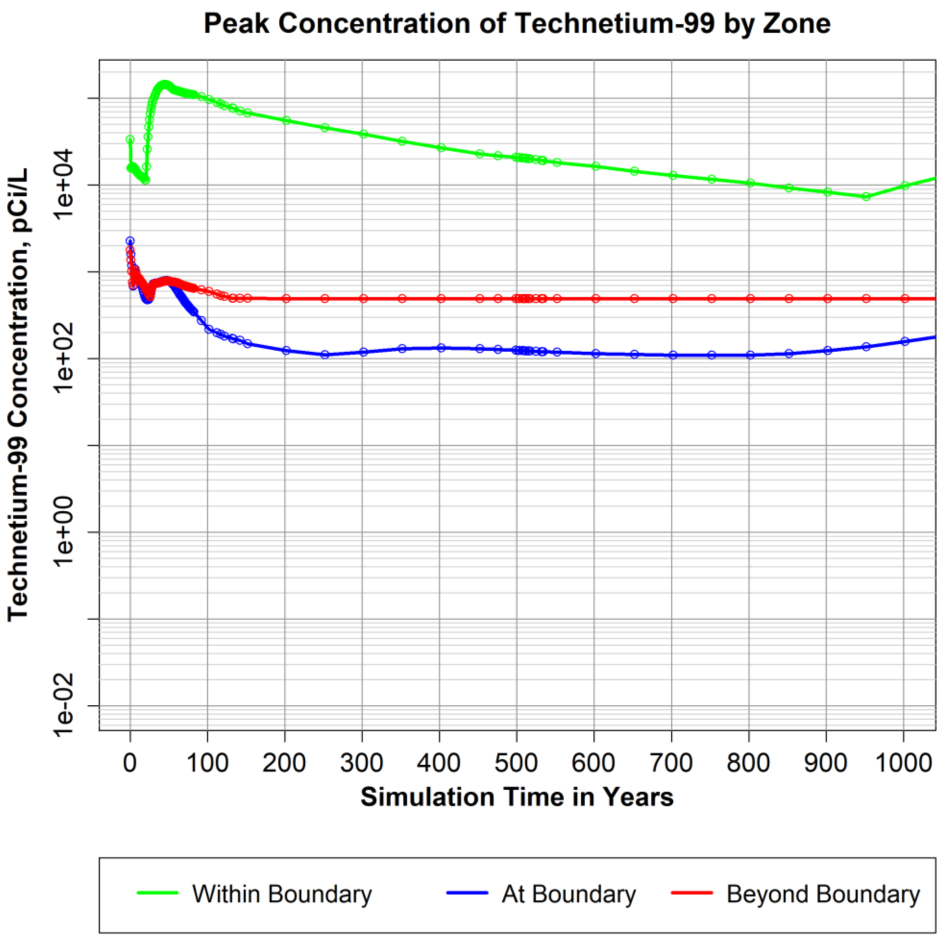

Figure 8. Peak Concentration of Technetium-99 from the Start of Simulation to the End of the Compliance Period Within, At, and Beyond the Compliance Boundary Assuming the Best Estimate Initial Concentration

7 Results/Conclusions

Three simulations were conducted to support the base case estimates for the Hanford Site CA. Table 6 provides a summary (including two simulations assuming the best estimate initial concentration and one simulation assuming the worst-case initial condition) of the estimated peak concentrations and the time in simulation years from the beginning of the simulation that the peak occurred. Charts and maps providing more detail and context to these values and discussed in Chapter 6 are provided in Appendix D.

Table 6. Summary of Peak Concentration Values Estimated for Zones within the P2R Model Boundary Domain

Initial Condition	Contaminant	Within_Boundary		At_Boundary		Beyond_Boundary	
		Time (yr)	Concentration (pCi/L)	Time (yr)	Concentration (pCi/L)	Time (yr)	Concentration (pCi/L)
Best Estimate	Tc-99	45	1.44E+05	0	2.27E+03	0	1.78E+03
	C-14	10052	2.79E+05	80	2.47E+03	117	2.35E+03
Worst Case	Tc-99	45	1.44E+05	0	2.27E+03	0	1.88E+03

Note: Plateau-to-River model boundary domain is shown in Figure 6.

8 References

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Appendix A

Copy of EMDT-DE-0006 Rev. 1 Coversheet

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CH2MHILL Plateau Remediation Company

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-DE-0006 **Revision No.:** 1

[Request EMDT number from Modeling Team Leader]

Title:* *Half-lives for Typical Hanford Site Radioactive Contaminants. **Date:** 18-May-2015

1. Data Description

Provide the description of data set or data type.

***Radioactive half-lives for reported radionuclides at Hanford site*.**

2. Data Intended Use

Identify the data's intended use. Describe the rationale for its selection and how the data will be incorporated into a model, report, or database. Include discussion of the extent to which the data demonstrate the properties of interest.

Numerical simulation of contaminant transport and fate

3. Data Sources

List databases, documents, etc. – provide sufficient detail to enable data to be located by independent reviewer

ICRP, 2008, Nuclear Decay Data for Dosimetric Calculations, International Commission on Radiological Protection (ICRP), Publication 107, Vol 38-3, ISBN 978-0-7020-3475-6.

4. Impact of Use or Nonuse of Data

Describe the importance of the data to the model, report, and/or conclusions which they support. Identify the value added and discuss the impacts of not using the data.

The half-life data are required to be consistent with PA studies and the model implementations in GoldSim and STOMP

5. Prior Uses

Identify the data's prior uses. Describe whether the data have been used in similar applications by the scientific or regulatory community. Include the associated verification processes and prior reviews and review results.

The ICRP Publication 107 data is used by the U.S. EPA calculation tool for radiation dose and risk.

CH2MHILL Plateau Remediation Company

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-DE-0006 **Revision No.:** 1

[Request EMDT number from Modeling Team Leader]

Title:* *Half-lives for Typical Hanford Site Radioactive Contaminants. **Date:** 18-May-2015

6. Data Acquisition Method(s)

Describe the data acquisition method and associated QA/QC, considering the following:

- *a. Qualifications of personnel or organizations generating the data;*
- *b. Technical adequacy of equipment and procedures used;*
- *c. Environmental and programmatic conditions if germane to the data quality;*
- *d. The extent to which acquisition processes reflect modeling requirements;*
- *e. The quality and reliability of the measurement control program;*
- *f. The degree to which independent audits of the process were conducted;*
- *g. Extent and reliability of the associated documentation.*

In addition to the listing tables in the ICRP publication 107 (ICRP, 2008), ICRP provides a database for electronic access. The database contains information on the half-lives, decay chains, yields and energies of radiations emitted in nuclear transformations of 1252 radionuclide isotopes of 97 elements. The database can be accessed by a user-defined software such as the Windows-based application provided by ICRP.

For databases, identify query language used to obtain data from database (SQL, etc.), briefly describe the query description and attach copy

The nuclear decay data are embodied in five formatted (hence can be viewed with an ASCII editor) direct-access files. Find a copy of text files and inquiry software: (P107JAICRP_38_3_Nuclear_Decay_Data_suppl_data.zip)

7. Corroborating Data

Identify and discuss any corroborating datasets. Provide any documentation that confirms the corroborating data substantiate existing parameter values, distributions, or data quality.

The ICRP half-lives were compared with three other sources that were listed in the rev 0 of this document. The best match to ICRP-P107 was source 2: DOE-STD-1196-2011, DOE Standard, Derived Concentration Technical Standard (April 2011). Differences were compared to four significant digits, while some half-lives were reported to only two significant digits.

8. Data Quality Considerations

Discuss data quality considerations not identified in other sections. Include discussion of data quality indicators (i.e., accuracy, precision, representativeness, completeness, and comparability).

For the radionuclides reported at the Hanford site, the ICRP half-life parameters match very closely the U.S. DOE standard DOE-STD-1196-2011, which is implemented in the U.S. EPA decay calculation tools. Additionally, the ICRP library is implemented in the GoldSim software that is approved for Hanford Site and used for PA's system models.

The %relative difference between the ICRP-P107 and the DOE-STD-1196-2011 data is less than 0.36% for all Hanford site radionuclides isotopes.

CH2MHILL Plateau Remediation Company

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-DE-0006 **Revision No.:** 1

[Request EMDT number from Modeling Team Leader]

Title: ***Half-lives for Typical Hanford Site Radioactive Contaminants.*** **Date:** 18-May-2015

9. Assumptions and Limitations on Data Use

Document known uncertainties, assumptions, constraints or limits on data.

The ICRP–P107 provides a reliable information on physical characteristics of a radionuclide (half-life, modes of decay, energies, intensities of the emitted radiations, etc.) that is the starting point in assessing the radiological significance of a radionuclide's presence in the workplace or in the environment. Uncertainties of these information would result from different limitation in accounting for the fraction of the available decay energy given to radiations of discrete energy (alpha particles, gamma rays, conversion electrons, Auger elections, and characteristic x rays) as well as the continuous energy spectra of beta particles. Accounting for such details requires very specific expertise and is a laborious task that is not needed for the subject calculation. The ICRP reported half-lifes provide adequate accuracy for the forward and backward decay calculations needed to accompany transport and fate studies of radionuclides in the environment and the associated risk.

Data Configuration Item Submittal:

Data Provider Submittal

Usama Zaher/ Environmental Engineer – Process Modeling Specialist
NAME/POSITION

Usama [signature]
SIGNATURE

6/12/2017
DATE

Data Configuration Item Review and Verification:

10. Verification Process

Describe steps taken to verify that these data are appropriate for intended use, noting any limitations

Implementation in 1st and 2nd order decay calculations in spread sheet. Initial and decayed state estimations was verified in both forward and backward (regrow) decay. The forward decay was also compared with the integration solution in GoldSim. Secular equilibrium is considered for the 2nd order calculations with rapidly decaying daughters relative to parents.

11. Summary of Data Review

The review shall ensure that the report meets the listed criteria. Consideration includes ensuring that the data collection method employed was appropriate for the type of data being considered and confidence in the data acquisition and subsequent processing methodology is warranted.

Is documentation technically adequate, complete, and correct?	[X] Yes	[ ] No
Are uncertainties and limitations on appropriate use of data discussed?	[X] Yes	[ ] No
Are the assumptions, constraints, bounds, or limits on the data identified?	[X] Yes	[ ] No

Data Reviewer Approval	*Approval of Data Configuration Item* M Lord / Senior Hydrogeologist (Signature by WE Nichols with attached email authorization from M Lord) NAME/POSITION [signature] 12 JUN 2017 SIGNATURE DATE

EMDT accepted for Composite Analysis input in Data Readiness Review on 12/2/2019.

signature authorization

Michael Lord

Mon 6/12/2017 4:03 PM

To:Will Nichols <wnichols@intera.com>;

I give Will Nichols authorization to sign for me the Environmental Modeling Data Transmittal Cover Page (EMDT) document in file EMDT-DE-00060rev1.docx. I have inspected the data for the radioactive half-lives for reported radionuclides at the Hanford site. My suggested edits to the data and the EMDT document were implemented and with this authorization I am signing my approval of the data configuration item.

Michael Lord

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Appendix B

HSS Package ICF Check-in Form

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ICF Submittal Data Form

Title: FY22 Maintenance HSSM package inputs for MT3D (CA)			**Date: 08/24/2022**
1. Data Name (for ICF database) *(to be filled in by QA Officer)*		**Work Product Name: HSSMCAM22**	
2. Data Version Number:	**v1.0**		
This numbering system will be used in the ICF database to distinguish between previous revisions, particularly in the case of provisional data that is being tracked with various renditions/versions of the same provisional data.			
3. Data Citation | Revision Number	**No.: N/A**		**Rev.: 0**
Where possible, all data should be tied to a final number that corresponds with its final QA/QC'd designation. If the data is documented (or will be documented) with an ECF, then that ECF and revision number should be captured here.			
3. QA/QC Flag (*What is the QA/QC status of the product?)*	**Not-Checked:** ☐	**Checked:** ☒	**Problem/Post-Check:** ☐
4. Disk Location of Data (*Where is this information stored?)*			
[redacted]			
5. Description of Data (*What is the general description of the data?)*			
Hydrocarbon Spill Screening Model (HSSM) packages for the Composite Analysis (CA) FY22 Maintenance. These packages are inputs to MT3D generated from the Vadose Zone data (VZ2SRI/SRI2SZ and PAPL2SZ) with C-14 and Tc-99 inventory modification for the B-63 Area (218-E-12B) and LLBG_200w_a Area (218-W-3A and 218-W-3AE) models (SRICAM22). For the rest of the models, the VZSRIREV v1.1 data are used.			
6. Corresponding Project			
Composite Analysis			
7. Parent Data *(Listing of pertinent parent data; if existing blockchain reference exists in the ICF, use this key and capture a snapshot from the ICF database)*			
SRICAREV1 (v1.0), P2RHDS (v2.0), P2RCAL (v8.3a), PAPL2SZ (v1.1), SRICAM22(v1.0)			
8. ICF Location *(to be filled in by QA Officer):*			
[redacted]			
Data Provider: Eugene O'Neil Powers Position: Software Engineer		Eugene O. Powers Digitally signed by Eugene O. Powers DN: cn=Eugene O. Powers, o=Intera, ou, email=npowers@intera.com, c=US Date: 2022.09.29 13:02:22 -07'00' *Signature* *Date*	
Data Reviewer: Sarah Wigginton Position: Hydrogeologist		Sarah Wigginton Digitally signed by Sarah Wigginton Date: 2022.09.29 13:01:18 -07'00' *Signature* *Date*	

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Appendix C

Cover Pages of EMDTs Covering PA Inputs

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Contents

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CH2MHILL

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-RE-0017 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Performance Assessment Results for Inclusion in Composite Analysis: Environmental Restoration Disposal Facility **Date:** 9/18/2017

1. Data Description

Provide the description of data set or data type.

The Environmental Restoration Disposal Facility (ERDF) stores low-level radioactive waste generated primarily from clean-up of contaminated sites at the Hanford Site, Washington. ERDF performance assessment (PA) evaluates potential exposure of disposed waste to humans and the environment after facility closure (2035). Data packaged in this transmittal page contains Excel spreadsheets, documents, and STOMP model inputs that were developed to complete the PA.

The primary data includes time varying contaminant mass flux (and water flux) estimates from the vadose zone to the water table under ERDF footprint (including berms). This data reflects the contaminant mass flux per unit Curie of inventory for the base case. The information on mass flux from ERDF including berms should be taken.

2. Data Intended Use

Identify the data's intended use. Describe the rationale for its selection and how the data will be incorporated into a model, report, or database. Include discussion of the extent to which the data demonstrate the properties of interest.

The intended use of the data is to provide contaminant mass flux from ERDF to the groundwater model used for Composite Analysis per unit Curie of inventory disposed. Therefore, this mass flux needs to be scaled up by the inventory disposed at ERDF.

3. Data Sources

List databases, documents, etc. – provide sufficient detail to enable data to be located by independent reviewer.

Data Folder: ERDF Flux to Water Table data is provided by ERDF PA team in a project directory, "Flux Spreadsheets".

- The 3-D flow and transport model, STOMP, was used to calculate radionuclide transport in the vadose zone surrounding the ERDF. The Excel Spreadsheet 'flux_to_water_table_9_all_erdf_berm.xlsm' provides the model results where solute flux to water table data are given for contaminants with Kd = 0 mL/g. In the worksheet called "At Water Table" the results from Column W through AF (marked as ERDF and Berm) should be used. Only the results for Tc-99, Nb-94, Mo-93, and Cl-36, should be used. Note that the solute flux is provided per unit Ci of inventory.
- The Excel spreadsheet 'Flux_to_water_table_9_all_erdf_berm_I129.xlsx' has the model results for contaminants with Kd > 0 mL/g. Only I-129 results have a non-zero value. In the worksheet 'flux_to_water_table_9_all_erdf_I-129" column AK provides the vadose zone solute flux to water table for I-129 (for ERDF including Berm). Note that the solute flux is provided per unit Ci of inventory.

3-D STOMP Model Input Data for ERDF PA is provided by ERDF PA team in the EMMA project directory, "compliance_110x76x59".

Data Folder: Data Packages, Exposure Scenarios, and Uncertainty Analysis Data are provided by ERDF PA team in the EMMA project directory, "ERDF-REV0".

Table 1 shows the inventory for radionuclides of concern for the ERDF analysis.

Table 1. Maximum Groundwater Concentration at 100m Downgradient from ERDF Over the Compliance and Post-Compliance Time Period.

Radionuclide	Maximum Concentration (pCi/L)	Post-Closure Time to Maximum Concentration (Rounded)	Initial Inventory (Ci)
Tc-99	731	7200	53
Nb-94	4.4	7200	0.38
Mo-93	1.9	6740	0.53
Cl-36	0.28	7200	0.02
I-129	4.0E-6	10000	0.02

NOTE: Time is given as simulated time for post-closure (from calendar year 2035) and all values are rounded to no more than 2 significant digits.

Verified with Table 3-2 WCH-520

4. Impact of Use or Nonuse of Data

Describe the importance of the data to the model, report, and/or conclusions which they support. Identify the value added and discuss the impacts of not using the data.

Resulting data impacts the outcome of the ERDF to meet the objectives of the Performance Assessment, as required by DOE M 435.1-1.

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Groundwater pathway analyses were calculated using the 3-D Subsurface Transport Over Multiple Phases (STOMP) model. Model results found that no radionuclides from ERDF enter the groundwater during the compliance period (2035 to 3035). The first indication of radionuclide occurs in year 4,420, (2,385 year after closure).

Without these data, conclusions regarding future projections of contamination from ERDF into the groundwater and surrounding environment would be difficult to obtain. Therefore, the necessary procedures to improve disposal methods and mitigate radionuclide transport would be overlooked.

5. Prior Uses

Identify the data's prior uses. Describe whether the data have been used in similar applications by the scientific or regulatory community. Include the associated verification processes and prior reviews and review results.

The datasets were developed as part of ERDF PA.

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Title: Performance Assessment Results for Inclusion in Composite Analysis: Environmental Restoration Disposal Facility **Date:** 9/18/2017

6. Data Acquisition Method(s)

Describe the data acquisition method and associated QA/QC, considering the following:

a. Qualifications of personnel or organizations generating the data;
b. Technical adequacy of equipment and procedures used;
c. Environmental and programmatic conditions if germane to the data quality;
d. The extent to which acquisition processes reflect modeling requirements;
e. The quality and reliability of the measurement control program;
f. The degree to which independent audits of the process were conducted;
g. Extent and reliability of the associated documentation.

a. Modeling staff and subcontractors are responsible to partake in modeler training, report software operations and verify model results.
b. STOMP software used to calculate vadose zone fate and transport meets NQA-1 -2000 and DOE O 414. 1D safety/software requirements.
c. Unknown at this time.
d. DOE/RL-2011-50 documents the capability of the STOMP code to meet identified attributes and criteria.
e. STOMP software is registered in the Hanford Information System Inventory, managed by CHPRC. The modeling software has been verified as acceptable for the purposes of the ERDF PA. PA modeling attributes are compliant with the following Quality Assurance documents:
    i. EPA *Guidance for Quality Assurance Project Plans for Modeling* (EPA/240/R-02/007)
    ii. CHPRC *Procedure for Controlled Software Management* (PRC-PRO-IRM-309)
    iii. DOE management expectations for compliance in *EM Quality Assurance Program* (EM-QA-001)
f. **LFRG review 2013**
g. Meets the QA requirements.

For databases, identify query language used to obtain data from database (SQL, etc.), briefly describe the query description and attach copy

N/A

7. Corroborating Data

Identify and discuss any corroborating datasets. Provide any documentation that confirms the corroborating data substantiate existing parameter values, distributions, or data quality.

N/A

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8. Data Quality Considerations

Discuss data quality considerations not identified in other sections. Include discussion of data quality indicators (i.e., accuracy, precision, representativeness, completeness, and comparability).

N/A

9. Assumptions and Limitations on Data Use

Document known uncertainties, assumptions, constraints or limits on data.

Several assumptions were made in the development of the conceptual model for the PA. Model assumptions can be grouped into the following categories listed below.

- Surface Barrier Assumptions
- Model Boundary Assumptions
- Representation of Geologic Units
- Infiltration and Recharge
- Geochemistry and Sorption
- Vadose Zone and Saturated Zone Flow and Transport
- Groundwater Concentration
- Post-closure Inventory Source Term
- State of ERDF at Closure

Descriptions of assumptions be found in Section 1.6 of *WCH-520 Performance Assessment for the Environmental Restoration Disposal Facility, Hanford Site, Washington.*

Several uncertainty and sensitivity analyses were also conducted for the PA. The groundwater pathway uncertainty analyses compares uncertainties between the STOMP model and conceptual model to determine which parameters that have the greatest influence on model outcomes. Uncertainties evaluated include, but are not limited to, the following:

- Recharge Rate Parameters
- Vadose Zone Hydraulic Parameters
- Incorporation of Various Hydro-Stratigraphic Units
- Flow Field and Transport Parameters
- 1-D Transport Modeling vs. 3-D STOMP

Additional detail regarding methods used to conduct and quantify model uncertainties can be found in sections 3.9 and 4.6 of WCH-520 *Performance Assessment for the Environmental Restoration Disposal Facility, Hanford Site, Washington.*

Data Configuration Item Submittal:

Data Provider Submittal	Avril Carter/Data Provider NAME/POSITION [signature] SIGNATURE 10/4/17 DATE

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[Request EMDT number from Modeling Team Leader]

Title: Performance Assessment Results for Inclusion in Composite Analysis: Environmental Restoration Disposal Facility — **Date:** 9/18/2017

Data Configuration Item Review and Verification:

10. Verification Process

Describe steps taken to verify that these data are appropriate for intended use, noting any limitations

- Data verified by comparing the mass flux history for Tc-99 against results presented in Figure 4-39 of WCH-520 document for the compliance case recharge rates and hydraulic properties based on the 3-D model for ERDF including Berms.
- COCs were Verified against Table 3-2 WCH-520
- Contaminant break through verified against break through curves in Table 9 Flux_to_water_table-9_all_erdf_berm-Excel worksheet Plots – At Water Table.
- 'Flux_to_water_table_9_all_erdf_berm_I129.xlsx' has the model results for contaminants with Kd > 0 mL/g. Only I-129 results have a non-zero value. Confirmed Table 3-13 ERDF PA WCH-520.
- Table 1 of this EMDT was verified against Table 3-2 WCH-520

11. Summary of Data Review

The review shall ensure that the report meets the listed criteria. Consideration includes ensuring that the data collection method employed was appropriate for the type of data being considered and confidence in the data acquisition and subsequent processing methodology is warranted.

Is documentation technically adequate, complete, and correct?	[x] Yes	[ ] No
Are uncertainties and limitations on appropriate use of data discussed?	[x] Yes	[ ] No
Are the assumptions, constraints, bounds, or limits on the data identified?	[x] Yes	[ ] No

Data Reviewer Approval

Approval of Data Configuration Item

Linda Lehman/ Senior Reviewer
NAME/POSITION

L. Lehman — 11/9/17
SIGNATURE — DATE

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Environmental Modeling Data Transmittal Cover Page

No.: EMDT-RD-0019 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Performance Assessment Results for Inclusion in Composite Analysis: Integrated Disposal Facility **Date:** 9/18/2017

1. Data Description

Provide the description of data set or data type.

Data packaged in this transmittal page contains selected Excel spreadsheets, documents, and STOMP model outputs that were developed to complete the 2017 performance assessment (PA) of the Hanford Integrated Disposal Facility (IDF) reported in RPP-RPT-59958 Revision B. The selected model outputs are fluxes of technetium-99 (Tc-99) and iodine-129 (I-129) to the water table from simulated contaminant releases from IDF in the PA model base case for a 10,000-year period following the assumed facility closure in calendar year 2051, and these outputs are extracted from a larger set of model output files archived with RPP-CALC-61032 Revision 0 in the Environmental Model Management Archive (EMMA). As of September 2017, these outputs provide the best information currently available on long-term groundwater impacts from future disposal of solid waste at IDF, given the objectives of the Hanford Site Composite Analysis.

In Fiscal Year 2017, the Department of Energy Office of River Protection and its subcontractors completed development of a PA for the near-surface disposal of low-level and mixed low-level waste at IDF. IDF is a double-lined landfill expected to be the disposal facility for the vitrified low-activity waste that will be produced at the Hanford Waste Treatment and Immobilization Plant (WTP). The IDF is also expected to receive secondary solid waste (SSW) generated by the WTP, SSW generated by the Effluent Treatment Facility (ETF), and other solid wastes from Hanford site remediation efforts. Phase 1 construction of IDF was completed between 2004 and 2006. The 2017 IDF PA uses computer models to assess the potential impacts of disposed waste to human health and the environment after facility closure for multiple exposure pathways, including a groundwater pathway. Contaminant fate and transport for the groundwater pathway is simulated in a three-dimensional finite difference model of the vadose zone and saturated zone at IDF and the surrounding area using the Subsurface Transport Over Multiple Phases (STOMP) simulator described in PNNL-15782. Although the 2017 IDF PA has not completed all of its regulatory reviews and is not yet publicly available, it is appropriate to include its outputs in the Hanford Site Composite Analysis, because a 2013 Record of Decision ("Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington: Record of Decision", 78 FR 75913) designated IDF as the permanent disposal destination for significant inventories of contaminants, and because the 2017 IDF PA incorporates changes in assumptions developed at or since that time which supersede past PA analyses of WTP wastes or of preconstruction concepts of the IDF.

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Title: Performance Assessment Results for Inclusion in Composite Analysis: Integrated Disposal Facility **Date:** 9/18/2017

2. Data Intended Use

Identify the data's intended use. Describe the rationale for its selection and how the data will be incorporated into a model, report, or database. Include discussion of the extent to which the data demonstrate the properties of interest.

The intended use of the data is to provide contaminant mass flux from IDF to the Hanford Composite Analysis (CA) groundwater model.

The 2013 Record of Decision ("Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington: Record of Decision", 78 FR 75913) designates IDF as the permanent disposal destination for low activity waste generated by the WTP (among other wastes). Consistent with numerous other Hanford Site PAs and modeling analyses, the 2017 IDF PA (RPP-RPT-59958 Revision B) determined that Tc-99 and I-129 are by far the dominant IDF waste contaminants contributing to radiological risk for the groundwater pathway. Simulation results indicating Tc-99 does not arrive at the water table during the compliance timeframe of 1,000 years following facility closure while assuming Tc-99 is a non-sorbing solute support a conclusion that no other contaminants would arrive at the water table within the compliance timeframe. The 2017 IDF PA base case simulated I-129 with a Kd of 0.1 mL/g. The PA also reported uncertainty and sensitivity analyses with a small range of I-129 soil Kd values based on PNNL – 13037 Rev. 2. The STOMP simulation results for flux of Tc-99 and I-129 released by IDF to the water table are the most directly useful form of IDF-related input for the CA groundwater model.

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3. Data Sources

List databases, documents, etc. – provide sufficient detail to enable data to be located by independent reviewer

The base case inventory was adopted from Inventory Case 7 in RPP- ENV- 58562 Rev.3

The 2017 IDF PA model base case outputs are extracted from output files archived with RPP-CALC-61032 Revision 0 and transmitted as follows.

Data Folder: IDF Base case input and raw output "surface" files selected for transmittal were placed in a .zip file

- Input and output files were provided by IDF PA team in file "IDF_PA_basecase.zip"
- This .zip file contains base case runs that simulate mass flux of combined waste forms from IDF to the groundwater table. Individual subfolders for radionuclides I-129 and Tc-99 contain files needed to execute simulations. The subfolder names match the base case simulation IDs used for the PA files in RPP-CALC-61032:
  - Vzp00_Infd06_gwp15_all_I-129_Ph1-2_kd1
  - Vzp00_Infd06_gwp15_all_Tc-99_Ph1-2

Data Folder: Post-processed STOMP results

- Post-processed STOMP results provided in a project directory, " STOMP Model Results".
- This folder contains .dat files that were converted from raw surface files in order to view base case results in a user-friendly format. Initial conversion was done with the Perl script surfaceTo.pl distributed with STOMP. The .dat files were then converted to 2 Excel (.xlsx) files for Tc-99 and I-129 results. Within each spreadsheet, highlighted columns A and F represent calendar year (assuming facility closure in 2051) and solute flux to the water table, respectively.

4. Impact of Use or Nonuse of Data

Describe the importance of the data to the model, report, and/or conclusions which they support. Identify the value added and discuss the impacts of not using the data.

Base case results for groundwater pathway were calculated using the 3-D STOMP model of the vadose zone and saturated zone at IDF.

Performance assessment results can be used to support decisions regarding best management practices (ALARA) and cost-benefit analysis during future operation on the IDF. Because the IDF is currently in pre-operational stages, PA conclusions could also influence final design features of the facility.

The 2013 Record of Decision ("Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington: Record of Decision", 78 FR 75913) designated IDF as the permanent disposal destination for significant inventories of Hanford Site contaminants, therefore nonuse of the data from the 2017 IDF PA from the Composite Analysis would constitute an unacceptable omission from the site-wide contaminant mass inventory.

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5. Prior Uses

Identify the data's prior uses. Describe whether the data have been used in similar applications by the scientific or regulatory community. Include the associated verification processes and prior reviews and review results.

The data were used in the 2017 performance assessment (PA) of the Hanford Integrated Disposal Facility (IDF) reported in RPP-RPT-59958 Revision B. The data are from model outputs documented in RPP-CALC-61032 Revision 0.

As documented in RPP-CALC-61032, the simulations were performed, checked, and internally reviewed in accordance with 10 CFR 830, "Nuclear Safety Management," and Subpart A, "Quality Assurance"; DOE O 414.1D, "Quality Assurance"; ASME-NQA-1-2008 with 2009 addenda; other State and Federal environmental regulations; and associated quality assurance procedures by Washington River Protection Solutions, LLC (WRPS) for preparation and issuance of Environmental Model Calculation Files, which are equivalent to the procedures used by CH2M Hill Plateau Remediation Company. Among other measures, implementation of these procedures included verification of inputs, rerunning base case simulations, and verification of post-processing by an independent checker not involved in preparation of the model files and use of an internal senior reviewer. RPP-CALC-61032 and RPP-RPT-59958 were also externally reviewed by subject matter experts at Pacific Northwest National Laboratory, Savannah River National Laboratory, and Savannah River Site. An LFRG review is currently scheduled to be initiated in October 2017.

Note that as of September 2017, the 2017 IDF PA has not completed all of its regulatory reviews including the DOE-mandated review by an LFRG committee. Therefore, the documentation is not publicly available and base case assumptions and results are subject to change. The LFRG Review is scheduled to be initiated in October 2017.

6. Data Acquisition Method(s)

Describe the data acquisition method and associated QA/QC, considering the following:

- *a. Qualifications of personnel or organizations generating the data;*
- *b. Technical adequacy of equipment and procedures used;*
- *c. Environmental and programmatic conditions if germane to the data quality;*
- *d. The extent to which acquisition processes reflect modeling requirements;*
- *e. The quality and reliability of the measurement control program;*
- *f. The degree to which independent audits of the process were conducted;*
- *g. Extent and reliability of the associated documentation.*

The data development and management used for the IDF PA adheres to EPA and DOE guidance and requirements provided in Section 10 of the IDF PA.

a. Modeling staff are required to participate in training to ensure QA/QC processes and requirements for model development are communicated and followed. Selection of PA modelers, authors, checkers, and reviewers is based on qualification by education and professional experience as documented in attachments to RPP-RPT-59958 and RPP-CALC-61032.

b. STOMP software used to calculate vadose fate and transport meets safety and software requirements of ASME-NQA-1-2008 with 2009 addenda and DOE O 414.1D. Technical assumptions and inputs were reviewed by an internal senior reviewer and external peer reviewers.

c. RPP-RPT-59958 describes environmental conditions and uncertainties associated with the numerous inputs to the 2017 IDF PA models and the assumptions adopted in the base case simulations. In 2013, 78 FR 75913 designated IDF as the permanent disposal destination for low activity waste from WTP and other secondary waste. Phase 1 construction of IDF was completed in 2006, but construction of further phases assumed in the PA is dependent on actual waste generated by WTP, which is not yet operational in 2017. Disposal of waste in IDF requires authorization via updates to the existing RCRA permit and DOE Disposal Authorization Statement issued prior to the 2013 Record of Decision. As of September 2017, the 2017 IDF PA has not completed all regulatory reviews required to approve the PA or obtain such authorizations. Future programmatic conditions may differ from those assumed in the 2017 IDF PA in ways that could affect the nature, quantity, or spatial arrangement of wastes in IDF and thus affect the simulated contaminant releases and impacts to groundwater.

d. DOE/RL-2011-50 documents the capability of the STOMP code to meet identified attributes and criteria. Technical assumptions and inputs were reviewed by an internal senior reviewer and external peer reviewers.

e. Quality of underlying data used in model input is addressed in multiple data packages cited in RPP-RPT-59958. STOMP software is registered in the Hanford Information Systems Inventory, under controlled management by CHPRC. PA modeling attributes are compliance with the following Quality Assurance documents:
   - i. EPA *Guidance for Quality Assurance Project Plans for Modeling (*EPA/240/R-02/007)
   - ii. CHPRC *Procedure for Controlled Software Management* (PRC-PRO-IRM-309)
   - iii. DOE management expectations for compliance in *EM Quality Assurance Program* (EM-QA-001)

f. Simulation inputs and outputs were checked by an independent checker who did not participate in preparing the model input files. Simulation inputs and results were reviewed by an internal senior reviewer and external peer reviewers. In accordance with TFC-PLN-155, WRPS quality assurance personnel provided oversight including two independent surveillances and multiple work site assessments.

g. The 2017 IDF PA results are documented in RPP-RPT-59958 Revision A, RPP-CALC-61032 Rev. 0, and associated model package reports, environmental model calculation files, data packages, environmental modeling data transmittals, and other documents cited therein. The documentation is verified by independent checkers and reviewed by internal senior reviewers and external peer reviewers. As of September 2017, the 2017 IDF PA has not completed all regulatory reviews including review by an LFRG committee.

For databases, identify query language used to obtain data from database (SQL, etc.), briefly describe the query description and attach copy

Not applicable.

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[Request EMDT number from Modeling Team Leader]

Title: Performance Assessment Results for Inclusion in Composite Analysis: Integrated Disposal Facility **Date:** 9/18/2017

7. Corroborating Data

Identify and discuss any corroborating datasets. Provide any documentation that confirms the corroborating data substantiate existing parameter values, distributions, or data quality

Data Packages, reports, and literature with corroborating data referenced in the vadose zone and saturated zone fate and transport modeling included:

PNNL – 13037 Rev.2, PNNL 14744, PNNL-14960, PNNL – 15237, PNNL- 23711, RPP- 20691 Rev.1 and RPP-58562 Rev.3.

Fayer, M.J. and G.W. Gee, 2006, "Multiple-Year Water Balance of Soil Covers in a Semiarid Setting." *Journal of Environmental Quality*, Vol. 35, No. 2, pp.366-377.

Zhang, Z.F. and R. Khaleel, 2010, "Simulating field-scale moisture flow using a combined power-averaging and tensional connectivity-tortuosity approach," *Water Resources Research*, Vol.46, W09505, pp. 1-14

xc8. Data Quality Considerations

Discuss data quality considerations not identified in other sections. Include discussion of data quality indicators (i.e., accuracy, precision, representativeness, completeness, and comparability).

RPP-RPT-59958 reports sensitivity and uncertainty analyses of the inputs and assumptions of the 2017 IDF PA model base case and includes discussion of accuracy, representativeness, etc. of the simulation results. Fluxes to the water table are calculated with high precision but are accurate to only 2 or 3 significant digits at the most and subject to conceptual uncertainties affecting the first digit, typical of other PA simulation results. Simulation times are specified exactly, however the cumulative uncertainties in the contaminant transport calculations imply timing of results over the 1,000-year timeframe is likely uncertain to the nearest decade or more. Assumptions adopted for the base case parameterization ranged from representative to reasonable conservative. The base case does not represent a central tendency or most likely case, although as shown in the probabilistic uncertainty analyses the base case results are similar to the mean of the probabilistic results. It is the responsibility of the data user to determine whether those assumptions are reasonably consistent with those of other inputs for the Composite Analysis.

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9. Assumptions and Limitations on Data Use

Document known uncertainties, assumptions, constraints or limits on data.

Summaries of key uncertainties and key assumptions can be found in Sections 1.9 and 2.8 of the IDF PA, respectively. Base case assumptions are detailed in Section 5.2.1 of the PA. Significance of key assumptions is discussed in Section 8.4. As of September 2017, the 2017 IDF PA has not completed all regulatory reviews including review by an LFRG committee. Therefore, the documentation is not publicly available, and base case assumptions and results are subject to change.

Data Configuration Item Submittal:

Data Provider Submittal

Avril Carter / Data Provider
NAME/POSITION

[signature]
SIGNATURE

10-11-17
DATE

Data Configuration Item Review and Verification:

10. Verification Process

Describe steps taken to verify that these data are appropriate for intended use, noting any limitations

Reviewed all citations and section numbers provided, requested additional detail be provided in some areas.

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Title: Performance Assessment Results for Inclusion in Composite Analysis: Integrated Disposal Facility **Date:** 9/18/2017

11. Summary of Data Review

The review shall ensure that the report meets the listed criteria. Consideration includes ensuring that the data collection method employed was appropriate for the type of data being considered and confidence in the data acquisition and subsequent processing methodology is warranted.

Is documentation technically adequate, complete, and correct? [x] Yes [ ] No

Are uncertainties and limitations on appropriate use of data discussed? [x] Yes [ ] No

Are the assumptions, constraints, bounds, or limits on the data identified? [x] Yes [ ] No

Data Reviewer Approval

Approval of Data Configuration Item

LINDA LEHMAN, SCIENTIST
NAME/POSITION

L. Lehman
SIGNATURE

10/11/17
DATE

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-RE-0026 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Environmental Impact Statement Results for Inclusion in the Composite Analysis: US Ecology Low-Level Waste Disposal Site **Date:** 9/18/2017

1. Data Description

Provide the description of data set or data type.

US Ecology operates a low-level radioactive waste disposal facility (LLRW) on the Hanford Site, Washington. A draft Environmental Impact Statement (DEIS) was developed by the Washington State Department of Health (WSDOH) for the site in 2000. The WSDOH requested an updated EIS from the U.S. Ecology since the draft was published. As a part of the updated EIS, a groundwater analysis for radioactive waste stored in the LLRW was conducted.

The groundwater analysis results were published in the *Groundwater Concentration and Drinking Water Doses with Uncertainty for the U.S. Ecology Low-Level Radioactive Waste Disposal Facility, Richland Washington*, February, 2004 (groundwater report). The contents of this transmittal document contains results and supporting data of the groundwater analysis that were used in the EIS. (Section 5.2 in the EIS discussed the groundwater and surface water conditions at the LLRW site based on the groundwater analysis.)
The information sought for the CA modeling effort is the radionuclide flux from the vadose zone to the saturated zone. This information was provided by Art Rood, Author if th WSDOH reference cited above. The computer files were sent via email to Will Nichols and Linda Lehman on February 27, 2018 and are now stored in EMMA. The files were annotated as follows:
Radionuclide fluxes from the vadose zone to the saturated zone are presented in the six attached ASCII files. There are six groups of radionuclides. The first group has fission and activation products while the next five groups are actinides.

Some radionuclides have an "mf" suffix (e.g. U-238mf). This refers to the mobile fraction of the radionuclide that has a different release rate and transport time than most of the inventory.

Actinides that are not mobile fractions have a letter suffix like Pu-238a, U-234a, Th-230a, and Ra-226a. The letter designation refers to the decay chain of the progeny. For example U-234a is U-234 derived from Pu-238a and Ra-226a refers to Ra-226 derived from Pu-238.

Release rate units are Ci/yr, Time units are in years from the start of the simulation. The simulation starts in 1965.

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No.: EMDT-RE-0026 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Environmental Impact Statement Results for Inclusion in the Composite Analysis: US Ecology Low-Level Waste Disposal Site **Date:** 9/18/2017

2. Data Intended Use

Identify the data's intended use. Describe the rationale for its selection and how the data will be incorporated into a model, report, or database. Include discussion of the extent to which the data demonstrate the properties of interest.

Conclusions derived from the groundwater analysis were incorporated into the Environmenta l Impact Statement for the Commercial Low-level Radioactive Waste Disposal Site in the Hanford, Washington Area (EIS). This data will be implemented into the Composite Analysis for the Hanford Site. The data files received On February 27, 2018 are t0 be read directly int0 the CA m0del 0f the Saturated z0ne if p0ssible. This will eliminate having t0 recreate the rad flux 0f c0ntaminants 0f c0ncern 0ver time.

The figure below shows a timeline of radionuclides stored in the US Ecology facility from 1965-2005.

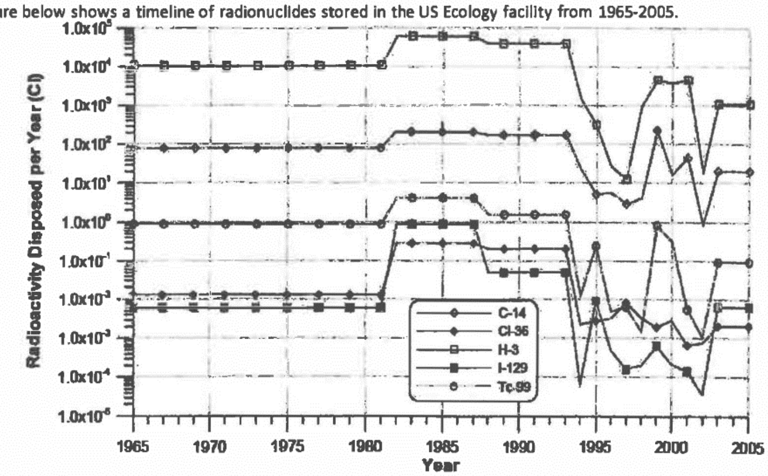

Figure 12. Radioactivity disposed in the US Ecology LLRW facility as a function of time for C-14, Cl-36, H-3, I-129, and Tc-99.

3. Data Sources

List databases, documents, etc. – provide sufficient detail to enable data to be located by independent reviewer

- US Ecology Groundwater Analysis and EIS files were provided by PA team in data folder "Final Reports"
    - Final Environmental Impact Statement (EIS)
    - Groundwater Concentrations and Drinking Water Doses with Uncertainty for the U.S. Ecology Low-Level Radioactive Waste Disposal Facility, Richland Washington (Groundwater Report) Computer Files of rad flux over time were provided by Art Rood.

No model data or codes were located for this analysis.

Example data curves from the analysis, illustrating radionuclide (U-238) and water flux as a function of time, are shown below

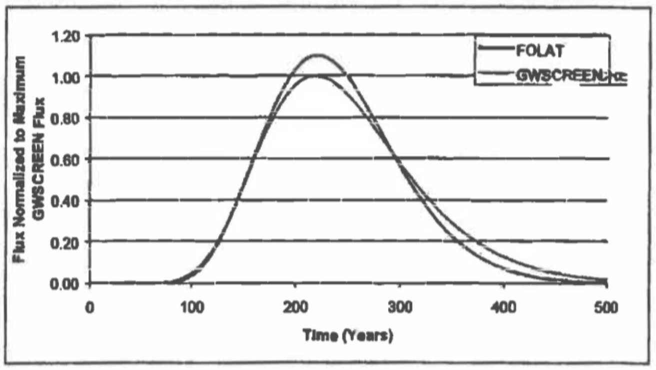

Figure 7. GWSCREEN and FOLAT flux to groundwater normalized to the maximum flux predicted by GWSCREEN for an 82.3 m unsaturated thickness and 4 m dispersivity.

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[Request EMDT number from Modeling Team Leader]

Title: Environmental Impact Statement Results for Inclusion in the Composite Analysis: US Ecology Low-Level Waste Disposal Site **Date:** 9/18/2017

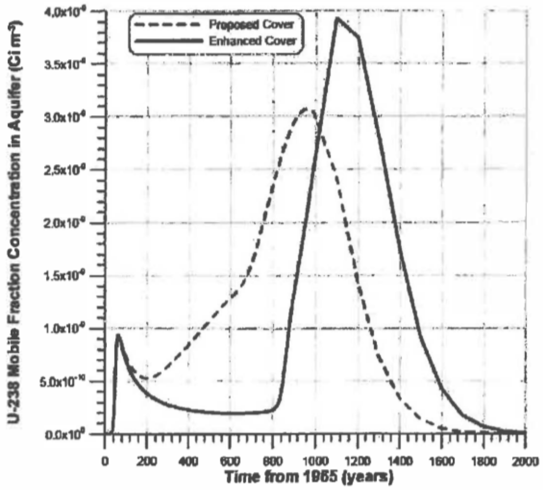

Figure 18. Graph showing U-238 mobile fraction aquifer concentrations for the enhanced and proposed covers. Concentrations while the cover remains intact are lower for the enhanced cover but are higher after cover failure. The area under the two curves is the same.

4. Impact of Use or Nonuse of Data

Describe the importance of the data to the model, report, and/or conclusions which they support. Identify the value added and discuss the impacts of not using the data.

The groundwater concentration analysis data is a key component to the Final EIS, which represents the changes in Hanford site operations since the draft EIS. Without this data, the Final EIS will inaccurately represent the current radionuclide inventory and transport activity within the groundwater table.

Utilization of the model data files directly will save time and money. The radionuclide flux will not have to be recreated, or somehow estimated from concentration data.

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No.: EMDT-RE-0026 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Environmental Impact Statement Results for Inclusion in the Composite Analysis: US Ecology Low-Level Waste Disposal Site **Date:** 9/18/2017

5. Prior Uses

Identify the data's prior uses. Describe whether the data have been used in similar applications by the scientific or regulatory community. Include the associated verification processes and prior reviews and review results.

Computer files were previously adopted as the Groundwater Report supporting the EIS mentioned above.

6. Data Acquisition Method(s)

Describe the data acquisition method and associated QA/QC, considering the following:

a. Qualifications of personnel or organizations generating the data;
b. Technical adequacy of equipment and procedures used;
c. Environmental and programmatic conditions if germane to the data quality;
d. The extent to which acquisition processes reflect modeling requirements;
e. The quality and reliability of the measurement control program;
f. The degree to which independent audits of the process were conducted;
g. Extent and reliability of the associated documentation.

a. N/A
b. The models FOLAT (First Order Leach and Transport), GWSCREEN, and Disposal Unit Source Term (DUST) models were for the groundwater analysis.
    i. A summary description these models can be found on pp.19-22 of the groundwater report.
c. N/A
d. N/A
e. N/A
f. Groundwater analyses were conducted both FOLAT and GWSCREEN models, then compared. Results indicate no major difference between results produced by both models.
g. N/A

For databases, identify query language used to obtain data from database (SQL, etc.), briefly describe the query description and attach copy

N/A

7. Corroborating Data

Identify and discuss any corroborating datasets. Provide any documentation that confirms the corroborating data substantiate existing parameter values, distributions, or data quality.

N/A

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Environmental Modeling Data Transmittal Cover Page

No.: EMDT-RE-0026 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Environmental Impact Statement Results for Inclusion in the Composite Analysis: US Ecology Low-Level Waste Disposal Site as **does the Ascii files recieved on February 27, 2018 from Rood.** **Date:** 9/18/2017

8. Data Quality Considerations

Discuss data quality considerations not identified in other sections. Include discussion of data quality indicators (i.e., accuracy, precision, representativeness, completeness, and comparability).

Utilization of the model files from the Groundwater report and their incorporation into the EIS ensures that the output of rad flux from the vadose ~~zone into the saturated zone is comparable to that of the EIS.~~

9. Assumptions and Limitations on Data Use

Document known uncertainties, assumptions, constraints or limits on data.

The methodology and results of the uncertainty and sensitivity analyses can be found on pp.62-70 of the groundwater report.

Data Configuration Item Submittal:

Data Provider Submittal

Avril Carter, Data Provider

NAME/POSITION

[signature] 11-8-17

SIGNATURE DATE

Data Configuration Item Review and Verification:

10. Verification Process

Describe steps taken to verify that these data are appropriate for intended use, noting any limitations

11. Summary of Data Review

The review shall ensure that the report meets the listed criteria. Consideration includes ensuring that the data collection method employed was appropriate for the type of data being considered and confidence in the data acquisition and subsequent processing methodology is warranted.

Is documentation technically adequate, complete, and correct?	[x] Yes	[ ] No
Are uncertainties and limitations on appropriate use of data discussed?	[x] Yes	[ ] No
Are the assumptions, constraints, bounds, or limits on the data identified?	[x] Yes	[ ] No

Data Reviewer Approval

Approval of Data Configuration Item

Linda Lehman, Senior Reviewer

NAME/POSITION

Environmental Modeling Data Transmittal Cover Page			
No.: EMDT-RE-0026 *[Request EMDT number from Modeling Team Leader]*		**Revision No.:**	0
Title: Environmental Impact Statement Results for Inclusion in the Composite Analysis: US Ecology Low-Level Waste Disposal Site		**Date:**	9/18/2017
L. Lehman SIGNATURE			11/9/17 DATE

EMDT accepted for Composite Analysis input after Data Readiness Review's provisions on 11/20/2017 were met on 10/2/2018.

EMDT accepted for Composite Analysis input in Data Readiness Review on 10/2/2018.

CH2MHILL **Environmental Modeling Data Transmittal Cover Page**

No.: EMDT- EMDT-RE-0018 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Performance Assessment Results for Inclusion in Composite Analysis: Waste Management Area C **Date:** 9/28/2017

1. Data Description

Provide the description of data set or data type.

Waste Management Area C (WMA C) is located in the 200 East Area of the Central Plateau at the Hanford Site in southcentral Washington and is one of 12 tank farms grouped into 7 WMAs (A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U) containing 149 SSTs and ancillary equipment built from 1943 to 1964 In preparation for the WMA C closure in 2020, a performance assessment (PA) is required to evaluate future fate and transport of radionuclides from the tank residuals into the surrounding environment. 3-D flow and transport model, STOMP, was used to calculate radionuclide transport in the vadose zone surrounding the facility. This data transmittal documents the data inputs and results used to complete the PA.

The primary data includes time varying contaminant mass flux estimates from the vadose zone to the water table under WMA C.

2. Data Intended Use

Identify the data's intended use. Describe the rationale for its selection and how the data will be incorporated into a model, report, or database. Include discussion of the extent to which the data demonstrate the properties of interest.

The intended use of the data is to provide contaminant mass flux from WMA C to the groundwater model used for Composite Analysis.

3. Data Sources

List databases, documents, etc. – provide sufficient detail to enable data to be located by independent reviewer

Data Folder: WMAC PA Documents are located in file directory "PA-WMAC-files"

STOMP Model Data folder: This directory includes input and post-processed surface files for solutes occurring at the water table. Data provided by WMA C team in folder "Flux to Water Table WMA C PA".

4. Impact of Use or Nonuse of Data

Describe the importance of the data to the model, report, and/or conclusions which they support. Identify the value added and discuss the impacts of not using the data.

Conclusions from this PA can be used to refine current contamination dose estimates and exposure analyses for residual wastes left in tanks and ancillary equipment at WMA C. The analysis conducted at the WMA C facility is an integral component to the Composite Analysis. Failing to include WMA C data will neglect a significant amount of Hanford Site contaminants within the site wide inventory.

CH2M HILL **Environmental Modeling Data Transmittal Cover Page**

No.: EMDT- EMDT-RE-0018 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Performance Assessment Results for Inclusion in Composite Analysis: Waste Management Area C **Date:** 9/28/2017

5. Prior Uses

Identify the data's prior uses. Describe whether the data have been used in similar applications by the scientific or regulatory community. Include the associated verification processes and prior reviews and review results.

Datasets were developed for the WMA C PA.

6. Data Acquisition Method(s)

Describe the data acquisition method and associated QA/QC, considering the following:

- *a. Qualifications of personnel or organizations generating the data;*
- *b. Technical adequacy of equipment and procedures used;*
- *c. Environmental and programmatic conditions if germane to the data quality;*
- *d. The extent to which acquisition processes reflect modeling requirements;*
- *e. The quality and reliability of the measurement control program;*
- *f. The degree to which independent audits of the process were conducted;*
- *g. Extent and reliability of the associated documentation.*

- a. Modeling staff and subcontractors are responsible to partaking in modeler training and additional responsibilities to manage software operations and verify model results.
- b. STOMP software used to calculate vadose zone fate and transport meets ASME NQA-1-2008 and DOE O 414.1D safety software/quality assurance requirements.
- c. Unknown at this time.
- d. DOE/RL-2011-50 documents the capability of the STOMP code to meet identified attributes and criteria.
- e. STOMP software is registered in the Hanford Information System Inventory, managed by CHPRC. The modeling software has been verified as acceptable for the purposes of the ERDF PA. PA modeling attributes are compliant with the following Quality Assurance documents:
    - i. EPA *Guidance for Quality Assurance Project Plans for Modeling* (EPA/240/R-02/007)
    - ii. CHPRC *Procedure for Controlled Software Management* (PRC-PRO-IRM-309)
    - iii. DOE management expectations for compliance in *EM Quality Assurance Program* (EM-QA-001)
- f. The model was implemented on 2 independent computer systems, GREEN Linux and Tellus Subsurface Simulation Platform.
- g. . Much information was developed through the Battelle Pacific Northwest Laboratory and is considered to be of good quality.

For databases, identify query language used to obtain data from database (SQL, etc.), briefly describe the query description and attach copy

N/A

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Environmental Modeling Data Transmittal Cover Page

No.: EMDT- EMDT-RE-0018 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Performance Assessment Results for Inclusion in Composite Analysis: Waste Management Area C **Date:** 9/28/2017

7. Corroborating Data

Identify and discuss any corroborating datasets. Provide any documentation that confirms the corroborating data substantiate existing parameter values, distributions, or data quality.

Information contained in several documents supports the information contained in the WMAC PA, such as:

DOE/EIS-0391, 2012, "Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington," U.S. Department of Energy, Washington, D.C.

PNNL-15503, 2008, "Characterization of Vadose Zone Sediments Below the C Tank Farm: Borehole C4297 and RCRA Borehole 299-E27-22," Rev. 1, Pacific Northwest National Laboratory, Richland, Washington

Ye, M., R. Khaleel, T. J. Yeh, 2005, "Stochastic analysis of moisture plume dynamics of a field 22 injection experiment," Water Resources Research, Vol. 41, W03013.

WMP-22922, 2004, "Prototype Hanford Features, Events, and Processes (HFEP) Graphical User Interface," Rev. 0, Fluor Hanford, Inc., Richland, Washington.

8. Data Quality Considerations

Discuss data quality considerations not identified in other sections. Include discussion of data quality indicators (i.e., accuracy, precision, representativeness, completeness, and comparability).

Except as noted, BBI estimates with radionuclides decayed to January 1, 2020 were used as source terms for the PA. The BBI is developed using applicable output from the Tank Characterization Database, Automated Statistics tool, Automated Vector creation tool and BBI Model tool.

The BBI was developed in accordance with RPP-7625, "Guidelines for Updating Best-Basis Inventory" and TFC-ENG-CHEM-P-53, "Best-Basis Inventory Evaluations." BBI Model tool output was downloaded to a spreadsheet which was reviewed and checked in accordance with internal WRPS procedures used in the preparation and review of engineering calculations and incorporated into RPP-RPT-42323.

9. Assumptions and Limitations on Data Use

Document known uncertainties, assumptions, constraints or limits on data.

A summary of key assumptions can be found in Appendix A of RPP-ENV-58782, Rev. 0 *Performance Assessment of Waste Management Area C, Hanford Site, Washington.*

Description of the uncertainty and sensitivity analyses for WMA C can be found in Section 8.0 of RPP-ENV-58782, Rev. 0 *Performance Assessment of Waste Management Area C, Hanford Site, Washington.*

Data Configuration Item Submittal:

Data

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Environmental Modeling Data Transmittal Cover Page

No.: EMDT- EMDT-RE-0018 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Performance Assessment Results for Inclusion in Composite Analysis: Waste Management Area C **Date:** 9/28/2017

Provider Submittal

Avril Carter, Data Provider
NAME/POSITION

[signature]
SIGNATURE

11-9-17
DATE

Data Configuration Item Review and Verification:

10. Verification Process

Describe steps taken to verify that these data are appropriate for intended use, noting any limitations

Checked Figures and sections as well as Figures and statements.

11. Summary of Data Review

The review shall ensure that the report meets the listed criteria. Consideration includes ensuring that the data collection method employed was appropriate for the type of data being considered and confidence in the data acquisition and subsequent processing methodology is warranted.

Is documentation technically adequate, complete, and correct?	[x] Yes	[ ] No
Are uncertainties and limitations on appropriate use of data discussed?	[x] Yes	[ ] No
Are the assumptions, constraints, bounds, or limits on the data identified?	[x] Yes	[ ] No

Data Reviewer Approval

Approval of Data Configuration Item

Linda Lehman, Senior Reviewer
NAME/POSITION

L. Lehman
SIGNATURE

11/9/17
DATE

CH2MHILL

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-RE-0034 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Past Leaks Evaluation Results for Inclusion the Composite Analysis: Waste Management Area C **Date:** 05/10/2019

1. Data Description

Provide the description of data set or data type.

Waste Management Area C (WMA C) is located in the 200 East Area of the Central Plateau at the Hanford Site in southcentral Washington and is one of 12 tank farms grouped into 7 WMAs (A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U) containing 149 SSTs and ancillary equipment built from 1943 to 1964. In preparation for the WMA C closure in 2020, a Past Leaks Evaluation is required to evaluate the contaminant mass flux from the WMA C into the surrounding environment. The 3-D flow and transport model, STOMP, was used to calculate vadose and saturated zone flow and contaminant transport. The results of the flow and transport model are used to approximate the current and future concentrations in groundwater of various radionuclides and non-radiological contaminants from these past releases.

This data transmittal documents the data inputs and results used to complete the Past Leaks Evaluation.

2. Data Intended Use

Identify the data's intended use. Describe the rationale for its selection and how the data will be incorporated into a model, report, or database. Include discussion of the extent to which the data demonstrate the properties of interest.

The intended use of the data is to provide contaminant mass flux from WMA C to the groundwater model used for Composite Analysis.

3. Data Sources

List databases, documents, etc. – provide sufficient detail to enable data to be located by independent reviewer

Data Folder: WMAC past leaks assessment documents are located in file directory "Emma\WRPS\Models\EMCF_RPP-CALC-60793_Past_Leaks_Analysis_WMA_C\rev1"

STOMP Model Data folder: The directory includes subfolders with the model data. A document titles "ReadMe_directory_structure.docx" describes the data in the subfolders.

4. Impact of Use or Nonuse of Data

Describe the importance of the data to the model, report, and/or conclusions which they support. Identify the value added and discuss the impacts of not using the data.

Conclusions from the past leaks evaluation for WMA C can be used to refine current contamination dose estimates and exposure analyses for past leak events at WMA C. The analysis conducted at the WMA C facility is an integral component to the Composite Analysis. Failing to include WMA C past leaks results will neglect a significant amount of Hanford Site contaminants within the site wide inventory.

5. Prior Uses

Identify the data's prior uses. Describe whether the data have been used in similar applications by the scientific or regulatory community. Include the associated verification processes and prior reviews and review results.

Datasets were developed for the WMA C Past Leaks Assessment.

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-RE-0034 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Past Leaks Evaluation Results for Inclusion the Composite Analysis: Waste Management Area C **Date:** 05/10/2019

6. Data Acquisition Method(s)

Describe the data acquisition method and associated QA/QC, considering the following:

a. Qualifications of personnel or organizations generating the data;
b. Technical adequacy of equipment and procedures used;
c. Environmental and programmatic conditions if germane to the data quality;
d. The extent to which acquisition processes reflect modeling requirements;
e. The quality and reliability of the measurement control program;
f. The degree to which independent audits of the process were conducted;
g. Extent and reliability of the associated documentation.

Responses:

a. Modeling staff and subcontractors are responsible to partaking in modeler training and additional responsibilities to manage software operations and verify model results.
b. STOMP software used to calculate vadose zone fate and transport meets ASME NQA-1-2008 and DOE O 414.1D safety software/quality assurance requirements.
c. Unknown at this time.
d. DOE/RL-2011-50 documents the capability of the STOMP code to meet identified attributes and criteria.
e. STOMP software is registered in the Hanford Information System Inventory, managed by CHPRC. The modeling software has been verified as acceptable for the purposes of the ERDF PA. PA modeling attributes are compliant with the following Quality Assurance documents:
   i. EPA *Guidance for Quality Assurance Project Plans for Modeling (*EPA/240/R-02/007)
   ii. CHPRC *Procedure for Controlled Software Management* (PRC-PRO-IRM-309)
   iii. DOE management expectations for compliance in *EM Quality Assurance Program* (EM-QA-001)
f. The model was implemented on 2 independent computer systems, GREEN Linux and Tellus Subsurface Simulation Platform.
g. Unknown at this time.

For databases, identify query language used to obtain data from database (SQL, etc.), briefly describe the query description and attach copy

Not applicable.

7. Corroborating Data

Identify and discuss any corroborating datasets. Provide any documentation that confirms the corroborating data substantiate existing parameter values, distributions, or data quality.

Not applicable.

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-RE-0034 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Past Leaks Evaluation Results for Inclusion the Composite Analysis: Waste Management Area C **Date:** 05/10/2019

8. Data Quality Consideration

Discuss data quality considerations not identified in other sections. Include discussion of data quality indicators (i.e., accuracy, precision, representativeness, completeness, and comparability).

The results of the past leaks evaluation are accepted based on the quality assurance process applied under WRPS environmental modeling plans and procedures in the development of this calculation and its inputs. Software was used under NQA-1 standards applied to comply with DOE O 414.1d, Quality Assurance. Environmental calculations were prepared, checked, and reviewed under the WRPS's general quality plan for environmental models and environment model file calculation preparation and issue procedure.

9. Assumptions and Limitations on Data Use

Document known uncertainties, assumptions, constraints or limits on data.

A summary of key assumptions can be found in Section 4 of the RPP-CALC-60973 Rev. 1 *WMA C Flow and Contaminant Transport Model Simulations Supporting Scoping Analysis and Future Projected Impacts of Past Waste Releases, Hanford Site, Washington.*

Description of the uncertainty and sensitivity analyses for WMA C can be found in Section 3 of the RPP-CALC-60973 Rev. 1 *WMA C Flow and Contaminant Transport Model Simulations Supporting Scoping Analysis and Future Projected Impacts of Past Waste Releases, Hanford Site, Washington.*

Data Configuration Item Submittal:

Data Provider Submittal	Theresa Landewe/Senior Water Resources Scientist NAME/POSITION	
	Theresa Landewe SIGNATURE	5/10/2019 DATE

Data Configuration Item Review and Verification:

CH2MHILL

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-RE-0034 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Past Leaks Evaluation Results for Inclusion the Composite Analysis: Waste Management Area C **Date:** 05/10/2019

10. Verification Process

Describe steps taken to verify that these data are appropriate for intended use, noting any limitations

WMAC past leaks assessment documents located in file directory "Emma\WRPS\Models\EMCF_RPP-CALC-60793_Past_Leaks_Analysis_WMA_C\rev1 were substantiated and the verification process is described below.

- Table 3-1a and Table 3-1b in RPP-CALC-60793 were checked against RPP-RPT-42294 Rev 2 and wmac_source_card.xlsx [redacted]
- WMA source card data (file and location described above) were reviewed for any errors.
- Table 3-2 in RPP-CALC-60793 was evaluated against Table 6-1 in RPP-RPT-42294 Rev 2 to ensure the waste releases matched.
- Endpoints listed in Table 3-4 RPP-CALC-60793 were confirmed (lower and upper bound Tc99 and leak volumes). Assumptions outlined in Table 3-4 such as recharge rates were reviewed for appropriateness for the intended case study and the changes were incorporated into the input file.
- Data in Table 4-1 (RPP-CALC-60793) were checked against the referenced documents (RPP-RPT-56356, CP-47631, RPP-RPT-58949, RPP-RPT-42294, RPP-CALC-60448, and RPP-ENV-58782).
- Moisture contents per strata were confirmed against RPP-CALC-60345.
- Values in Table 4-2 were checked against RPP-CALC-60345, RPP-ENV-58782, BHI-011, and Uncertainty_VZ_Parameters_7_7_2015.xlsx [redacted]
- Model input files were briefly reviewed for suitability and that the data were consistent with the objective of the case study.

11. Summary of Data Review

The review shall ensure that the report meets the listed criteria. Consideration includes ensuring that the data collection method employed was appropriate for the type of data being considered and confidence in the data acquisition and subsequent processing methodology is warranted.

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Environmental Modeling Data Transmittal Cover Page

No.: EMDT-RE-0034 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Past Leaks Evaluation Results for Inclusion the Composite Analysis: Waste Management Area C **Date:** 05/10/2019

Is documentation technically adequate, complete, and correct?	[X] Yes	[ ] No
Are uncertainties and limitations on appropriate use of data discussed?	[X] Yes	[ ] No
Are the assumptions, constraints, bounds, or limits on the data identified?	[X] Yes	[ ] No

Data Reviewer Approval

Approval of Data Configuration Item

Kimberly Ralston-Hooper/Environmental Risk Assessor

NAME/POSITION

Kimberly Ralston-Hooper 2/20/20

SIGNATURE DATE

Appendix D

Simulated Concentration Charts and Contour Maps for all Simulations

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Figures

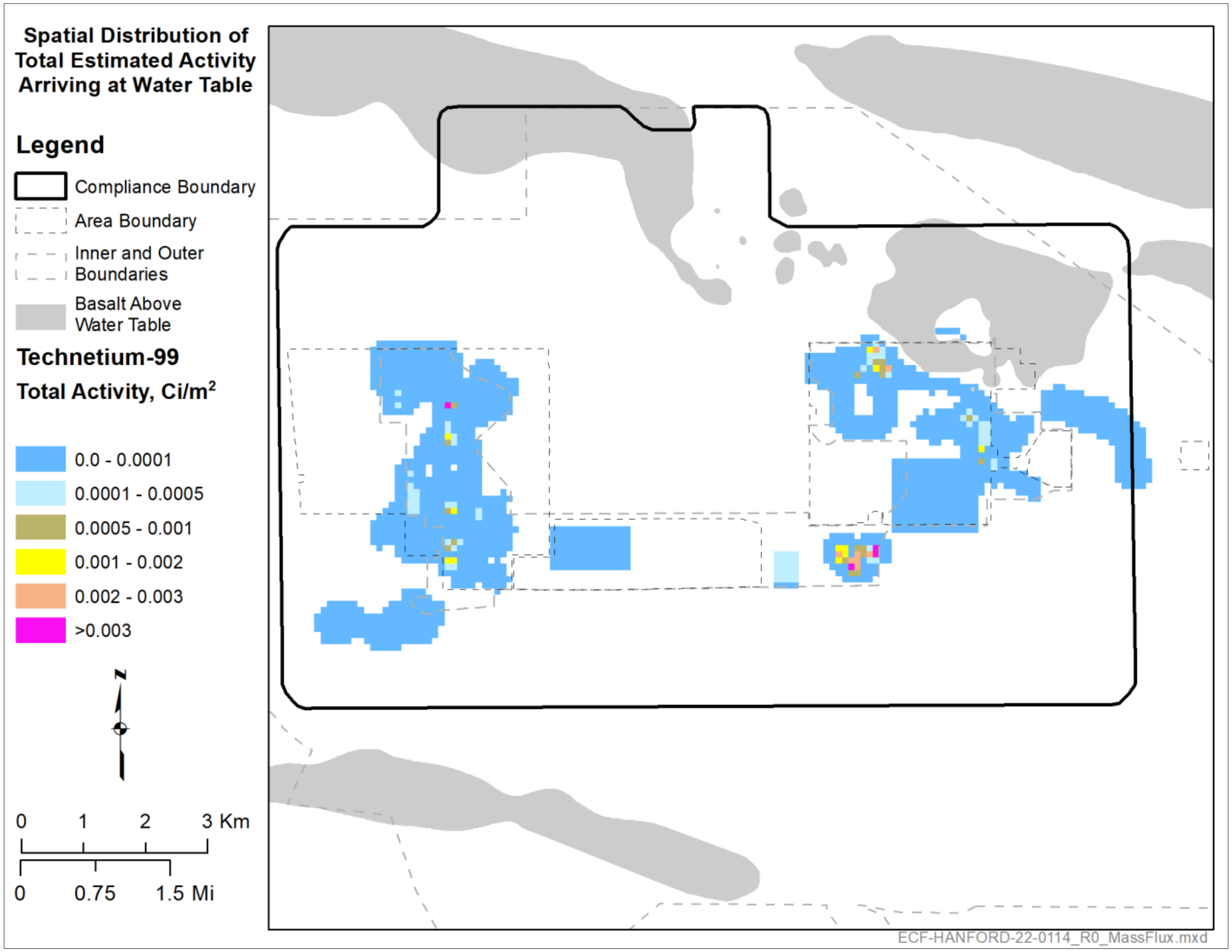

Figure D-1. Spatial distribution of Technetium-99 that Enters the Saturated Zone from the Vadose Zone over the Entire Simulation Length

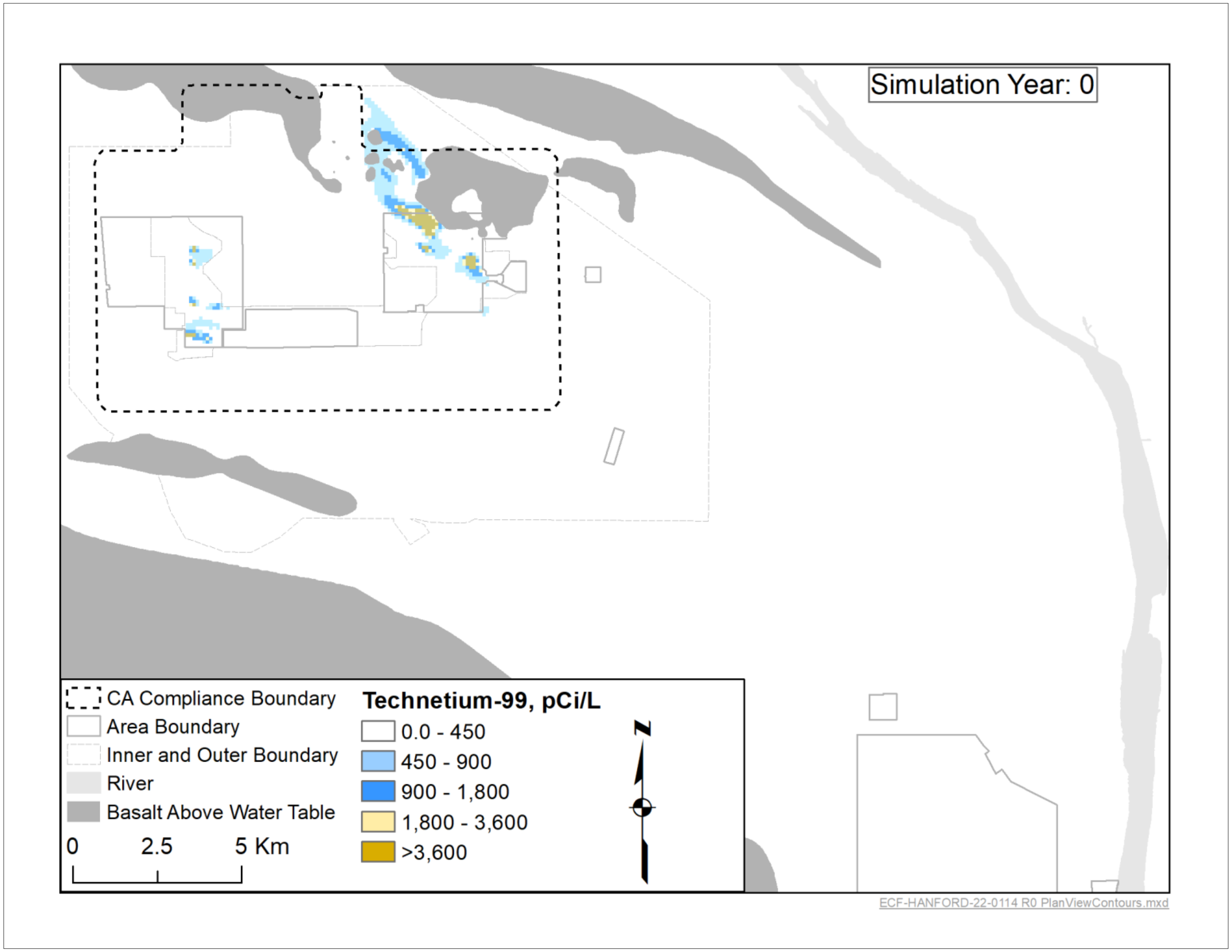

Figure D-2. Plan View Contours of Technetium-99 Concentration Simulated 0 Years from the Start of Simulation Assuming the Best Estimate Initial Concentration

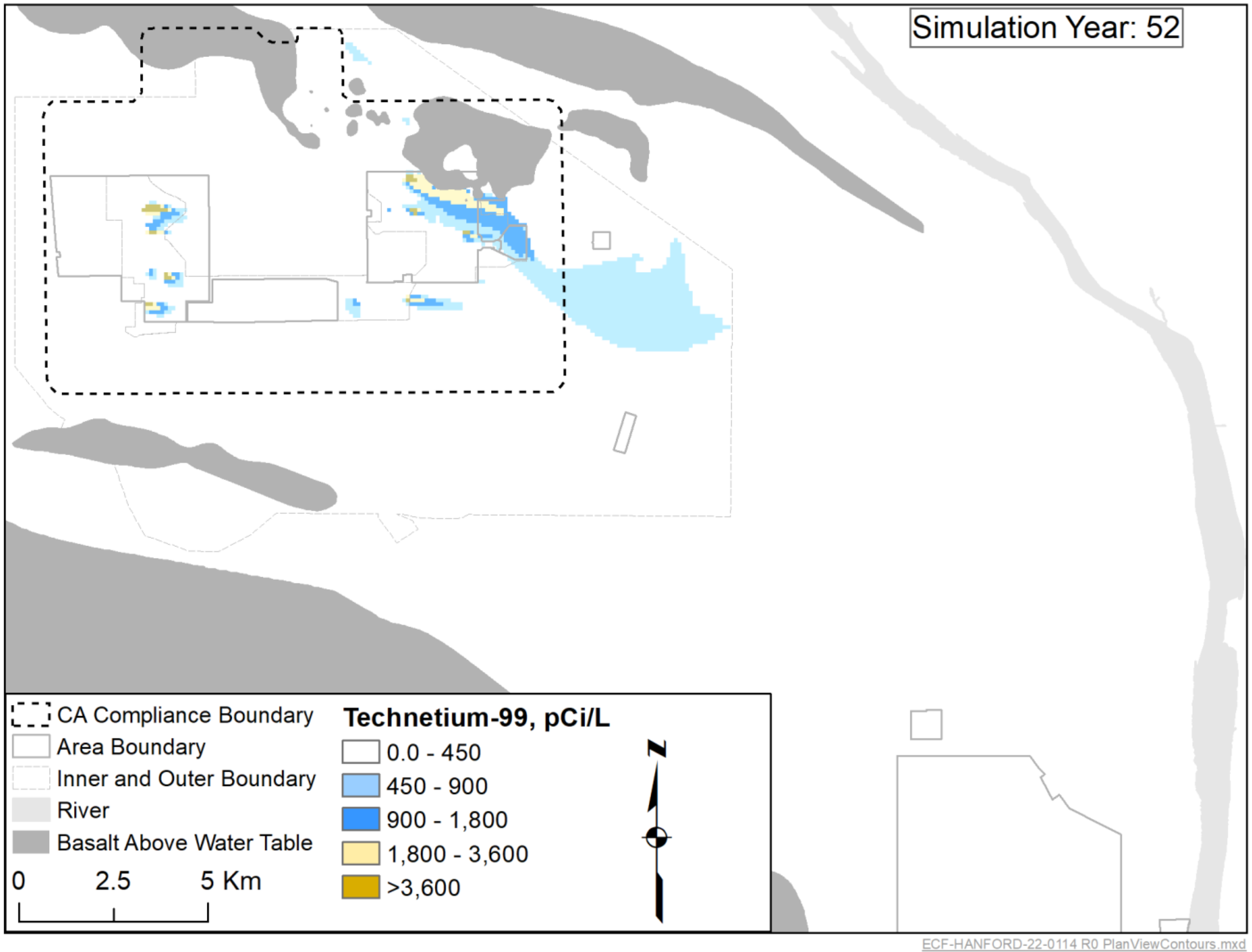

Figure D-3. Plan View Contours of Technetium-99 Concentration Simulated 52 Years from the Start of Simulation Assuming the Best Estimate Initial Concentration

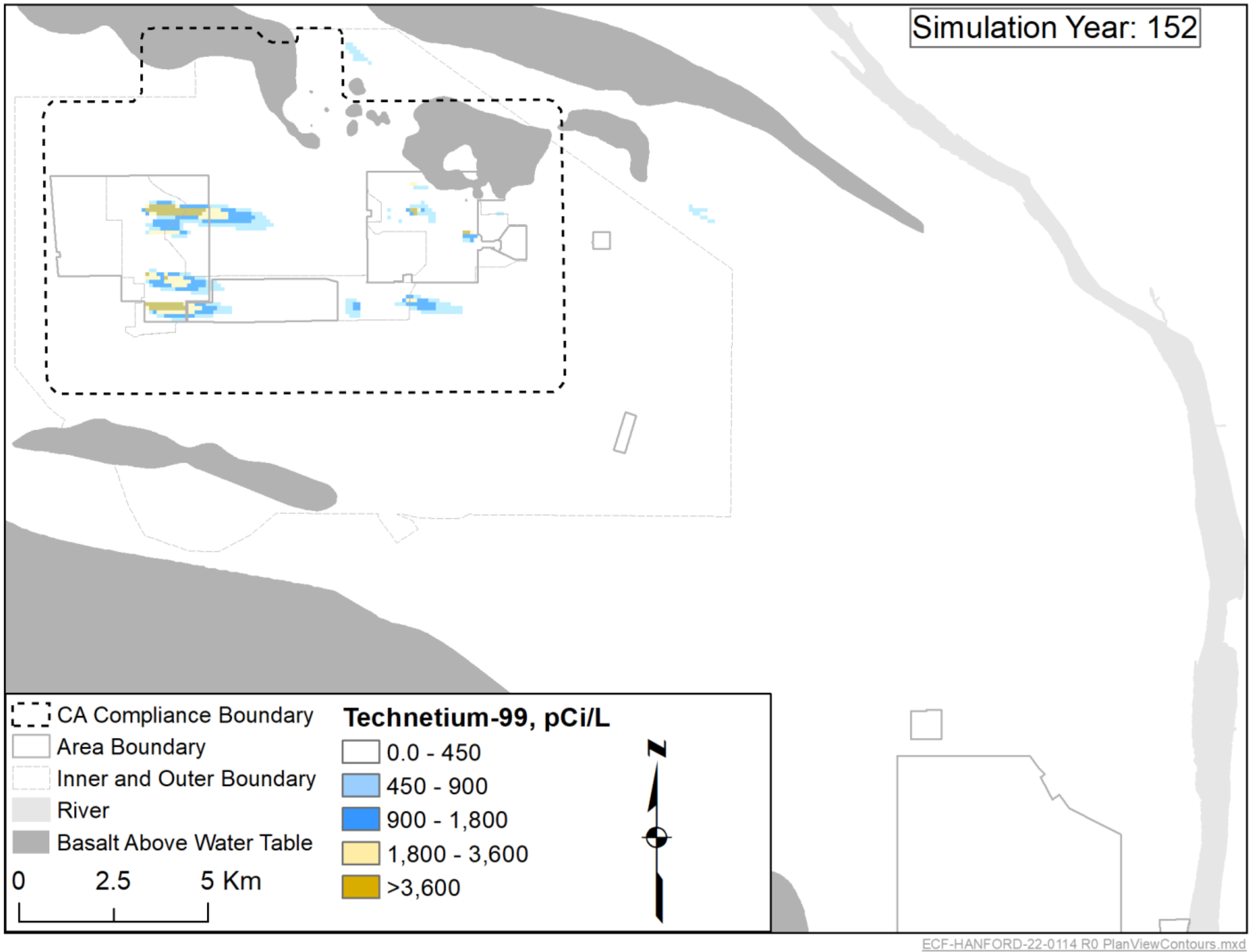

Figure D-4. Plan View Contours of Technetium-99 Concentration Simulated 152 Years from the Start of Simulation Assuming the Best Estimate Initial Concentration

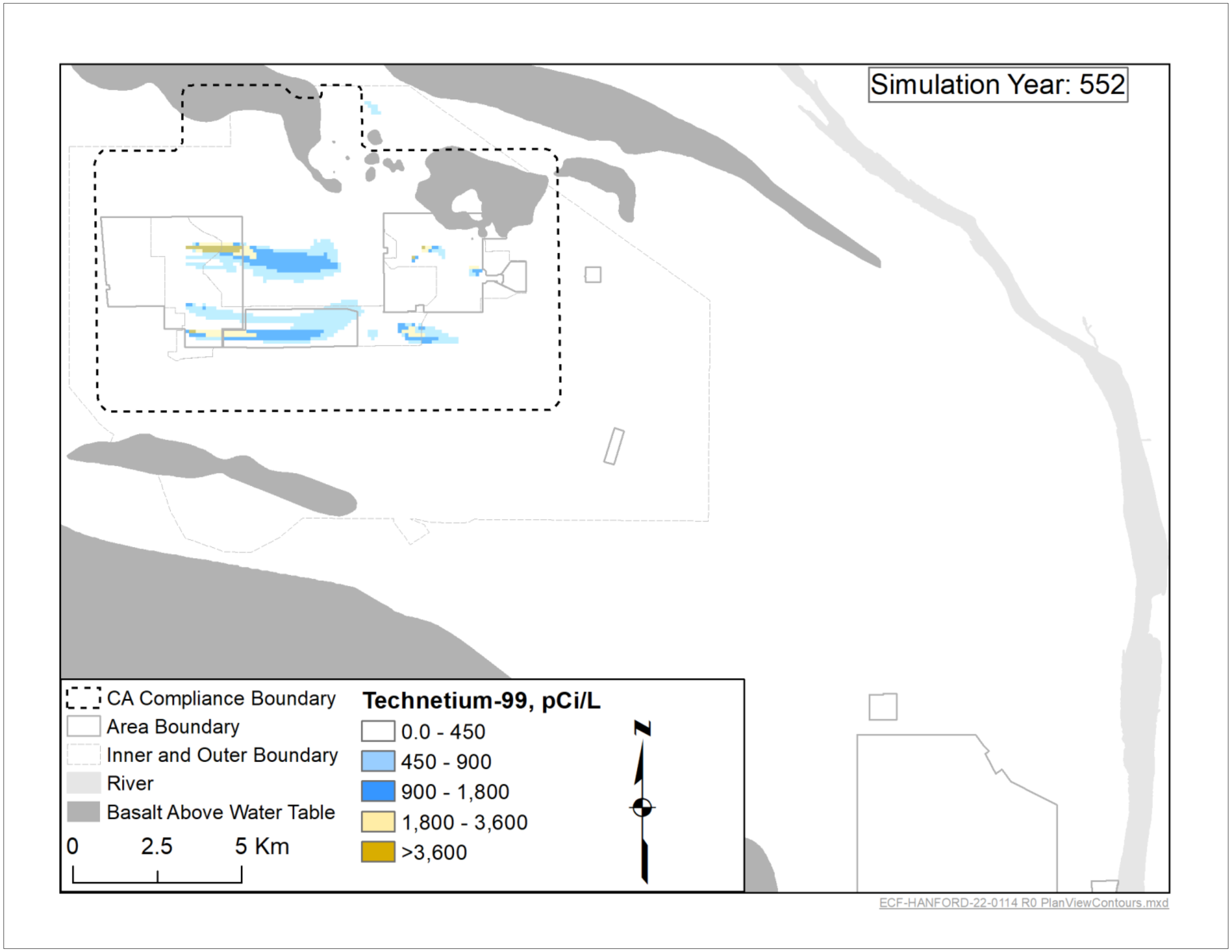

Figure D-5. Plan View Contours of Technetium-99 Concentration Simulated 552 Years from the Start of Simulation Assuming the Best Estimate Initial Concentration

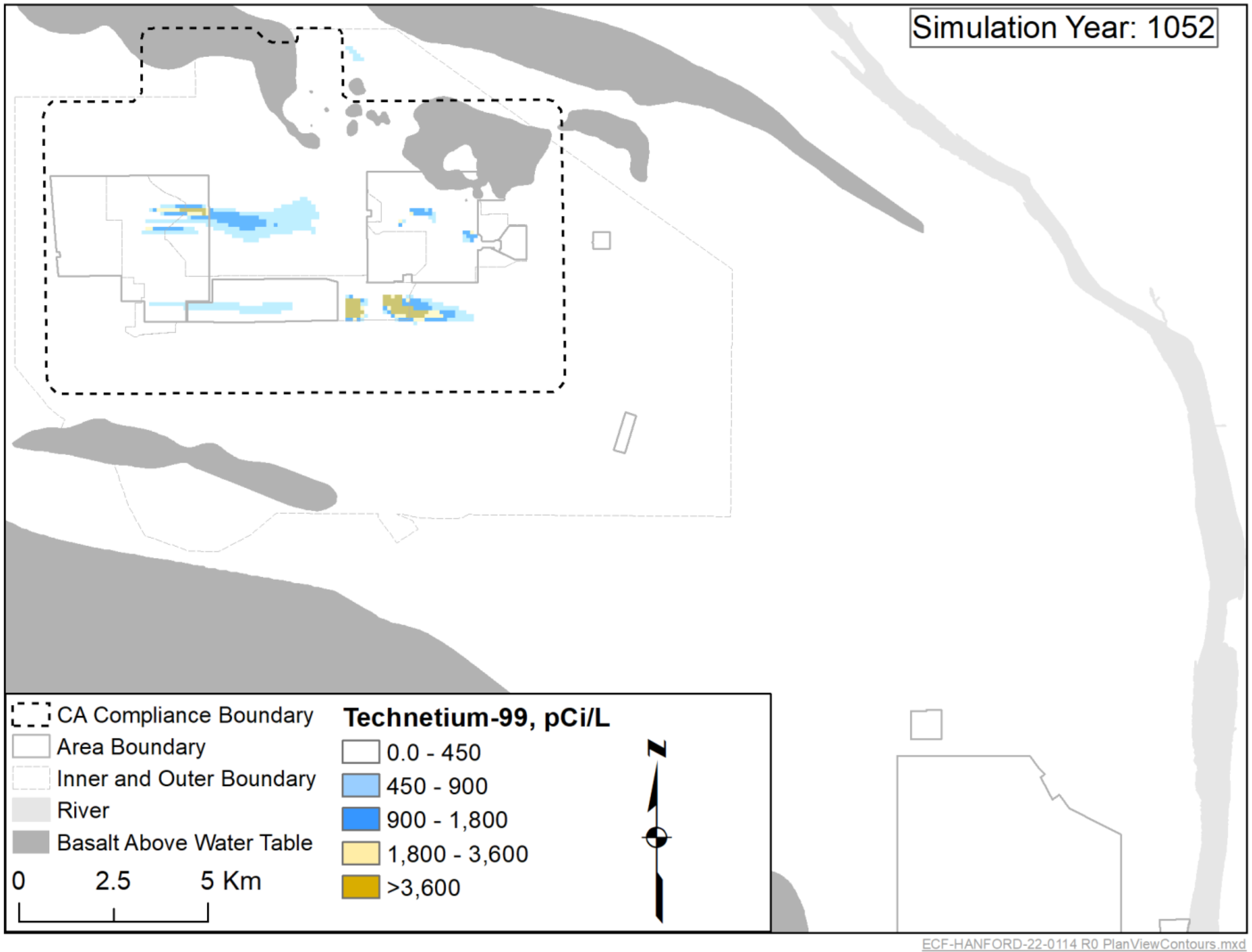

Figure D-6. Plan View Contours of Technetium-99 Concentration Simulated 1052 Years from the Start of Simulation Assuming the Best Estimate Initial Concentration

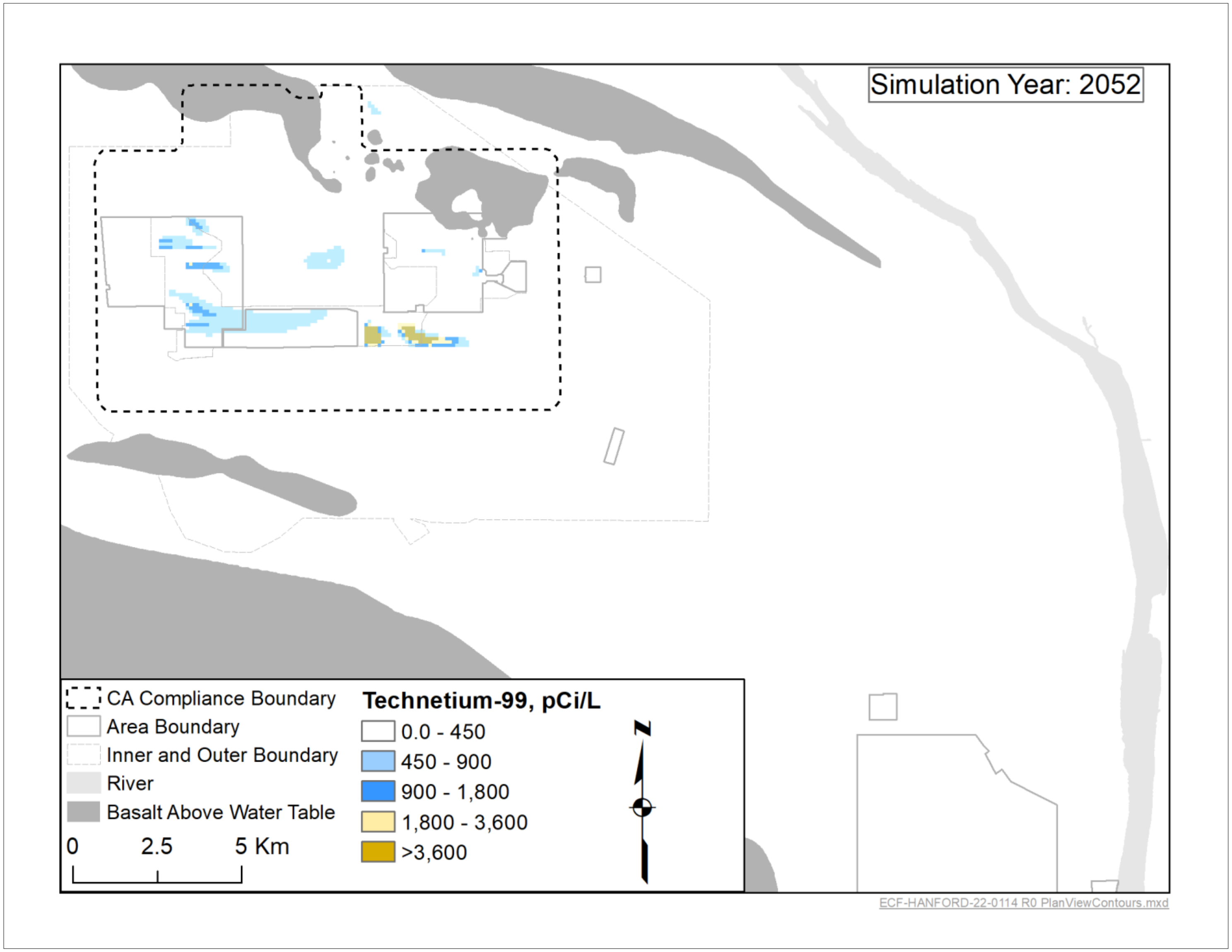

Figure D-7. Plan View Contours of Technetium-99 Concentration Simulated 2052 Years from the Start of Simulation Assuming the Best Estimate Initial Concentration

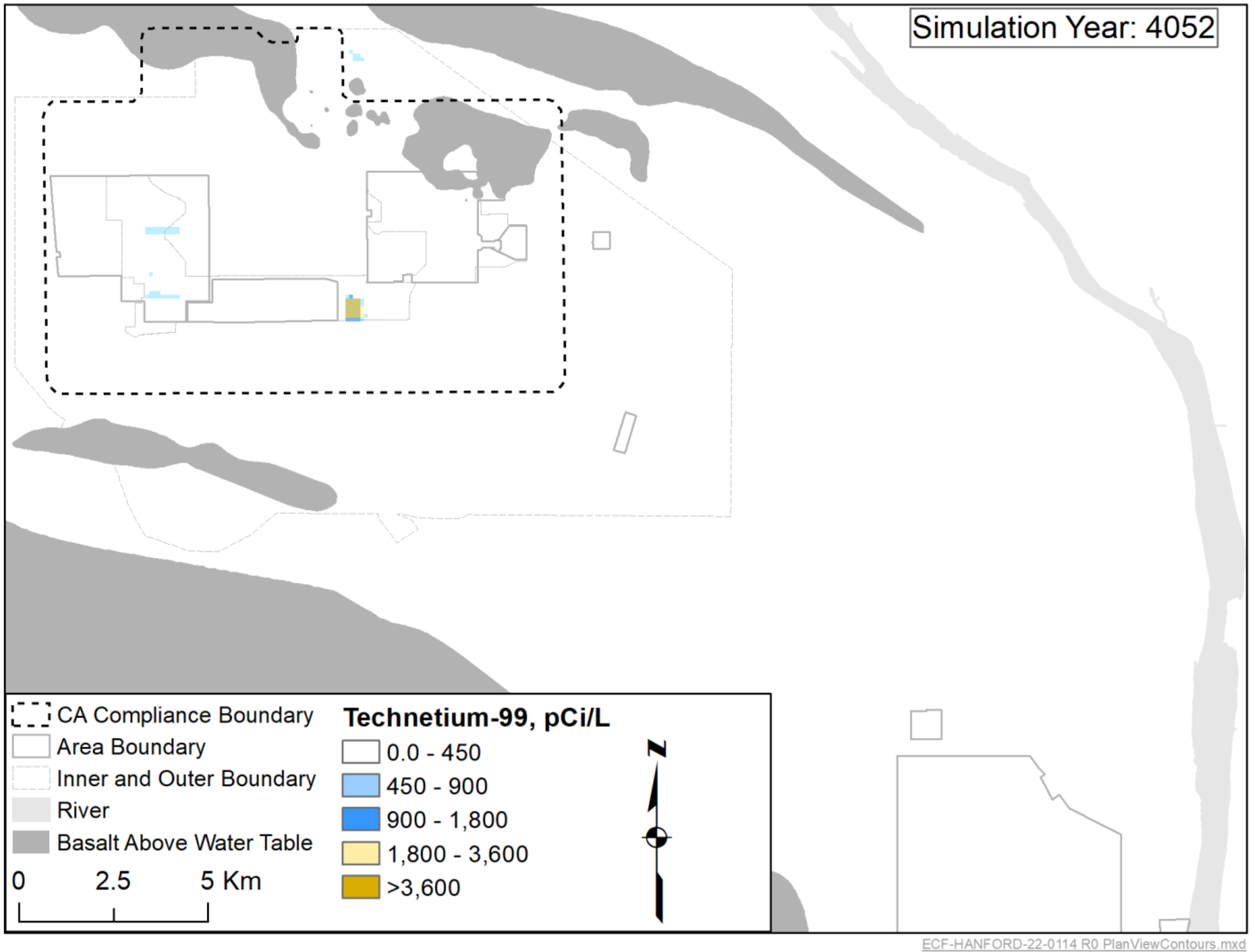

Figure D-8. Plan View Contours of Technetium-99 Concentration Simulated 4052 Years from the Start of Simulation Assuming the Best Estimate Initial Concentration

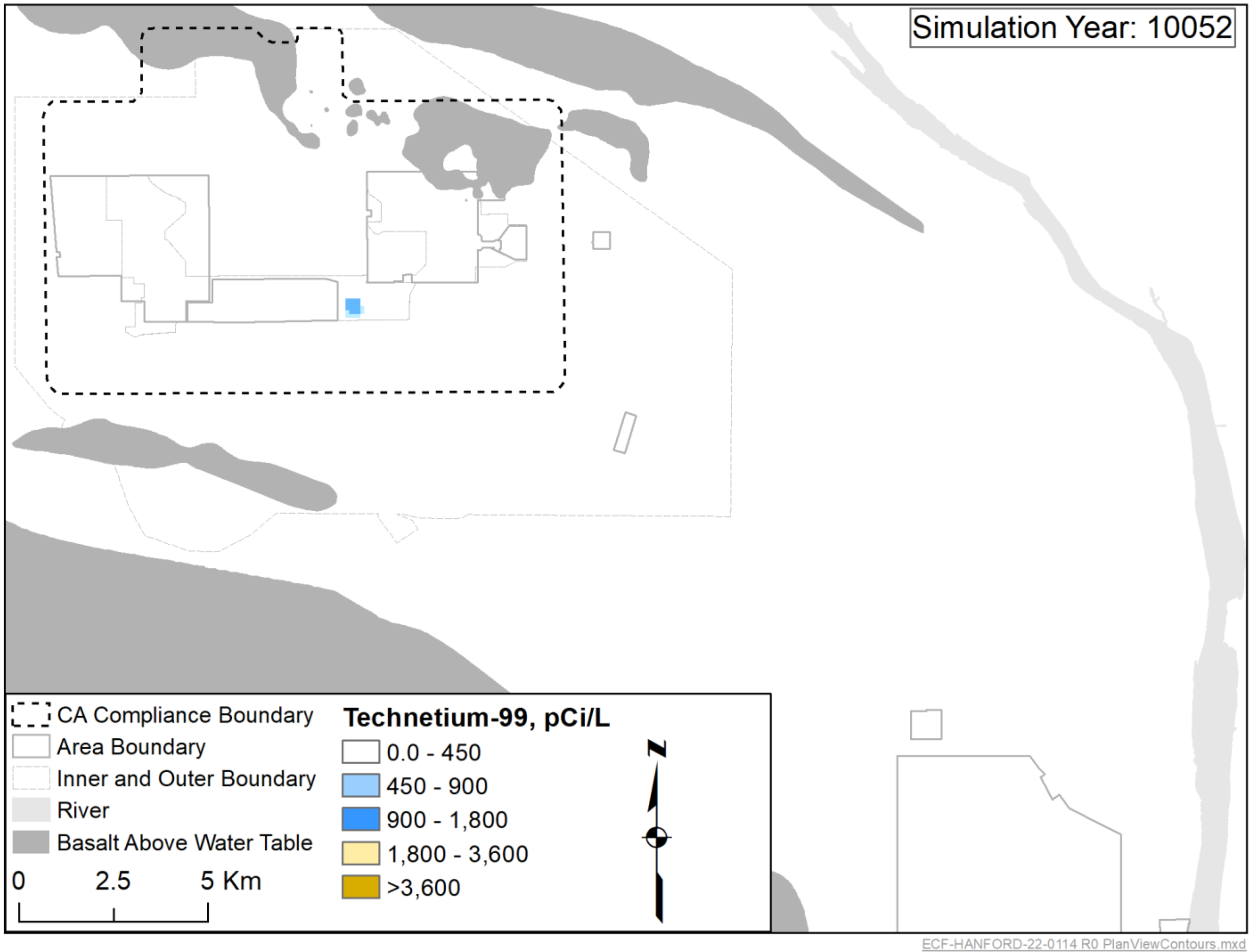

Figure D-9. Plan View Contours of Technetium-99 Concentration Simulated 10052 Years from the Start of Simulation Assuming the Best Estimate Initial Concentration

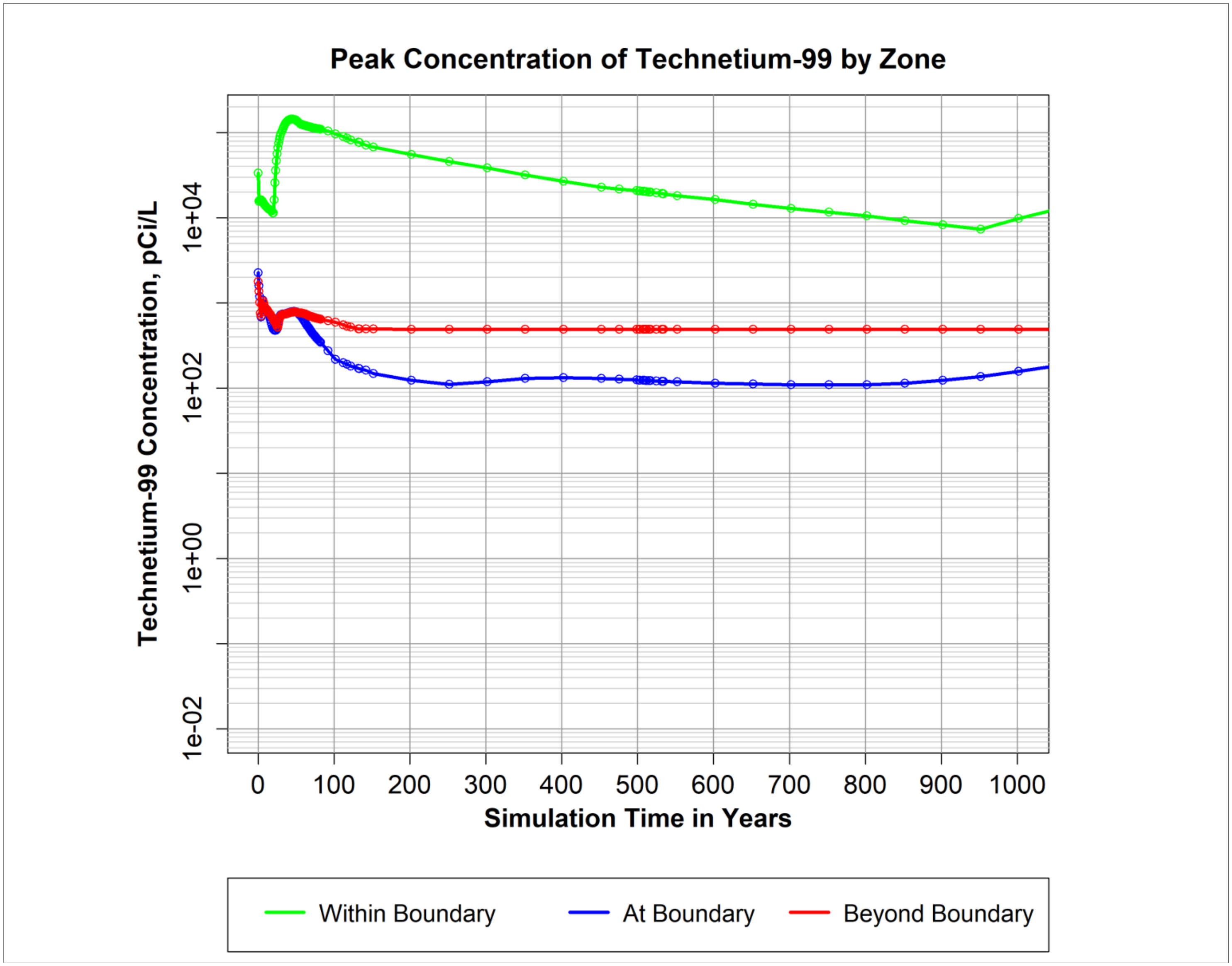

Figure D-10. Peak Concentration of Technetium-99 from the Start of Simulation to the End of the Compliance Period Within, At, and Beyond the Compliance Boundary Assuming the Best Estimate Initial Concentration

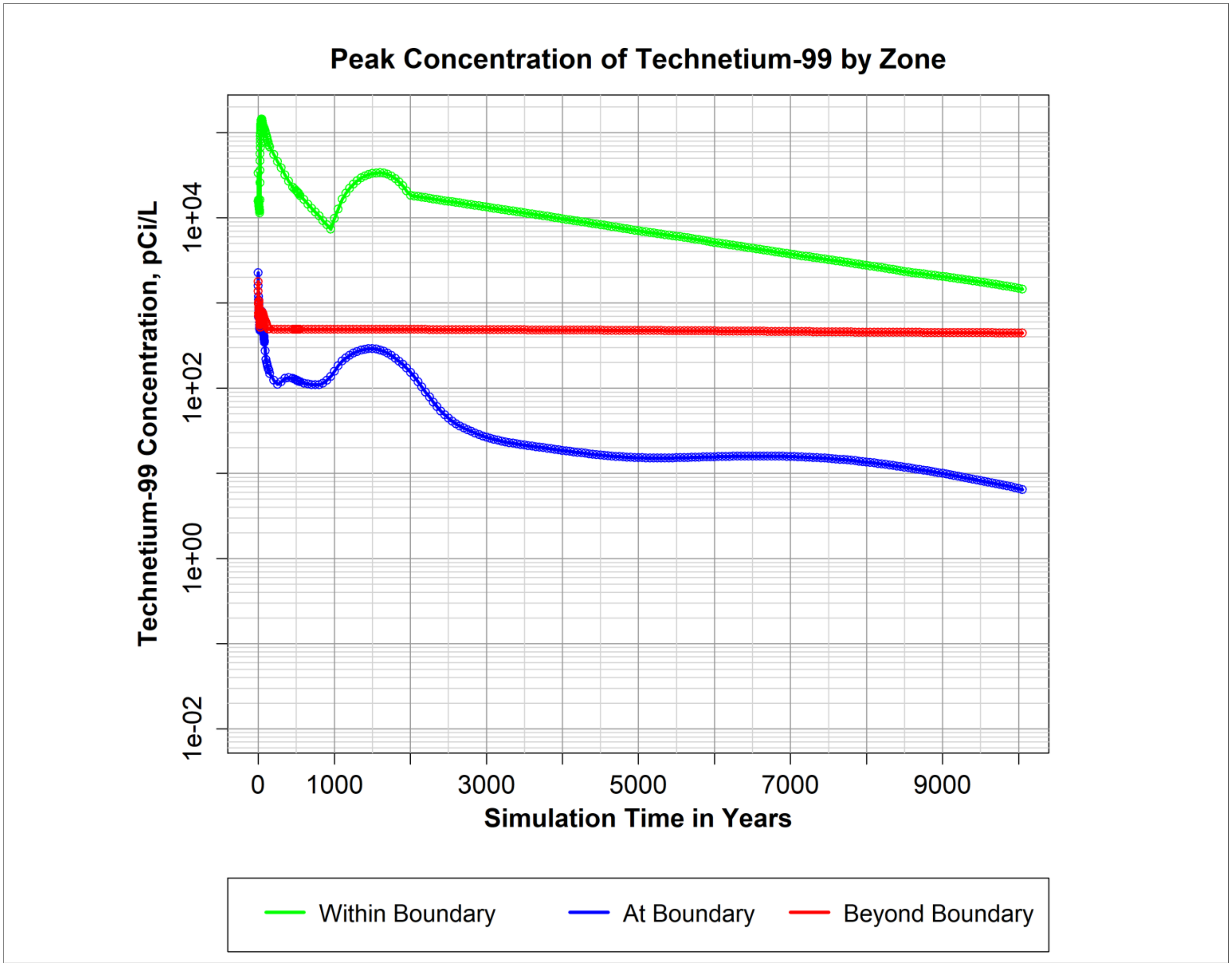

Figure D-11. Peak Concentration of Technetium-99 from the Start of Simulation to the End of the Simulation Within, At, and Beyond the Compliance Boundary Assuming the Best Estimate Initial Concentration

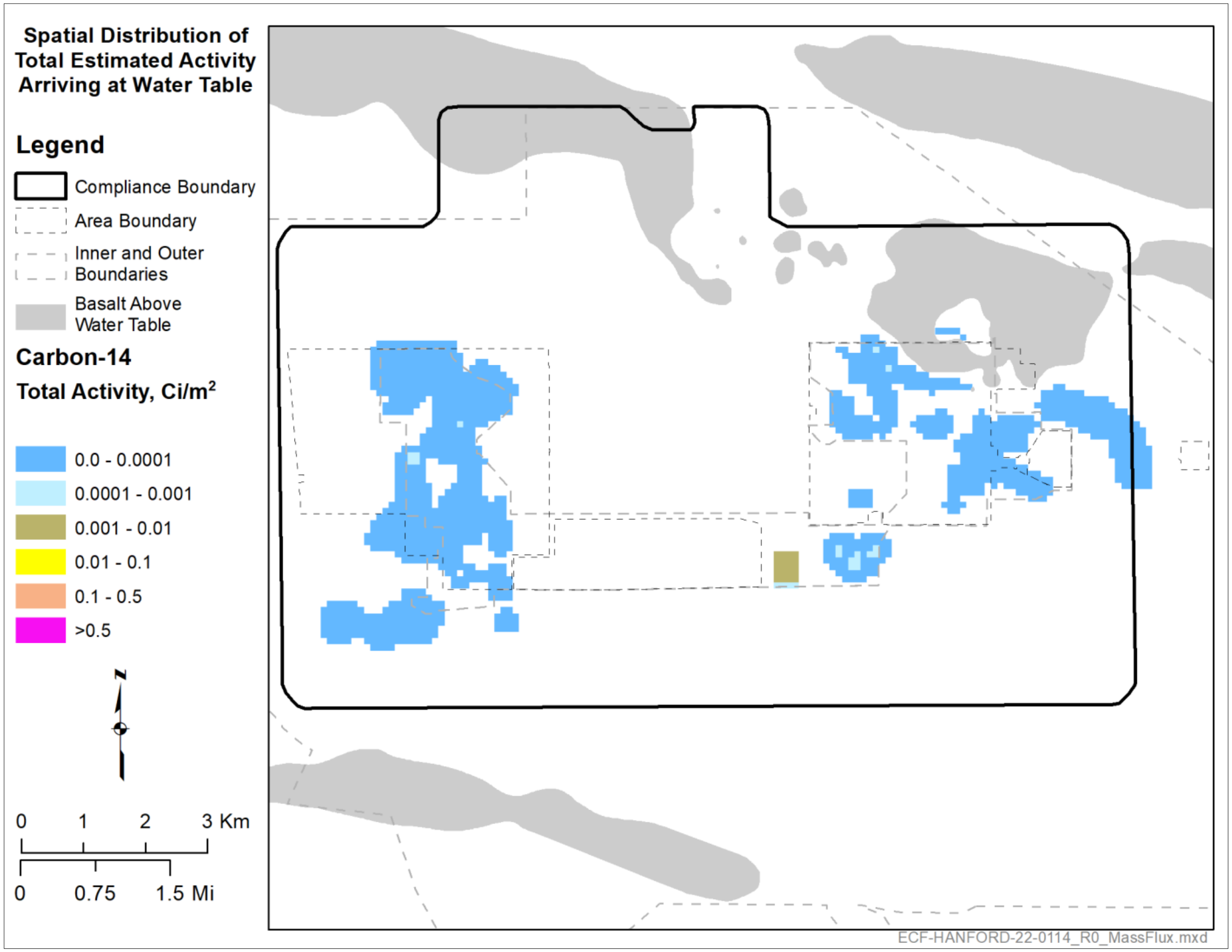

Figure D-12. Spatial distribution of Carbon-14 that Enters the Saturated Zone from the Vadose Zone over the Entire Simulation Length

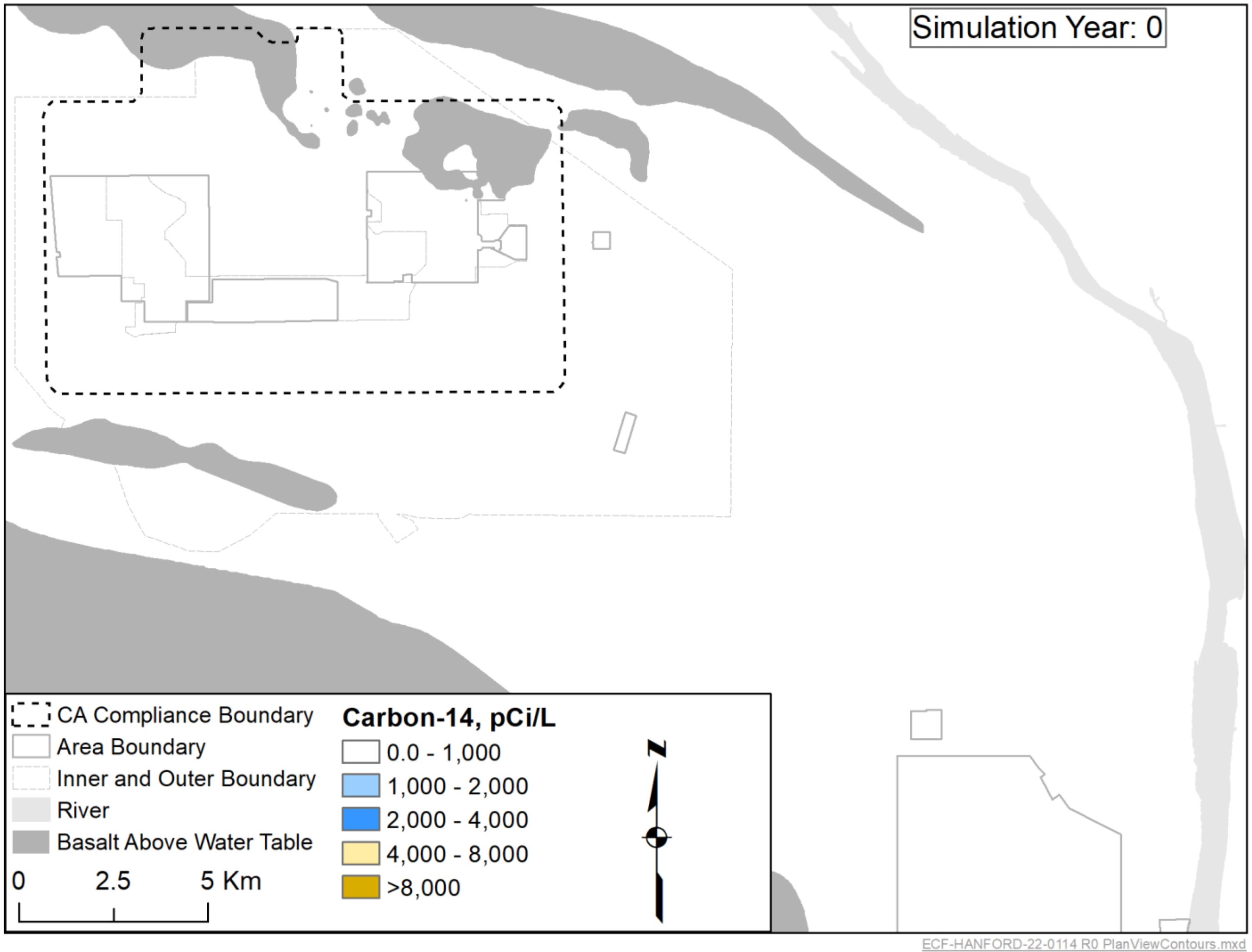

Figure D-13. Plan View Contours of Carbon-14 Concentration Simulated 0 Years from the Start of Simulation Assuming a Pristine Initial Concentration

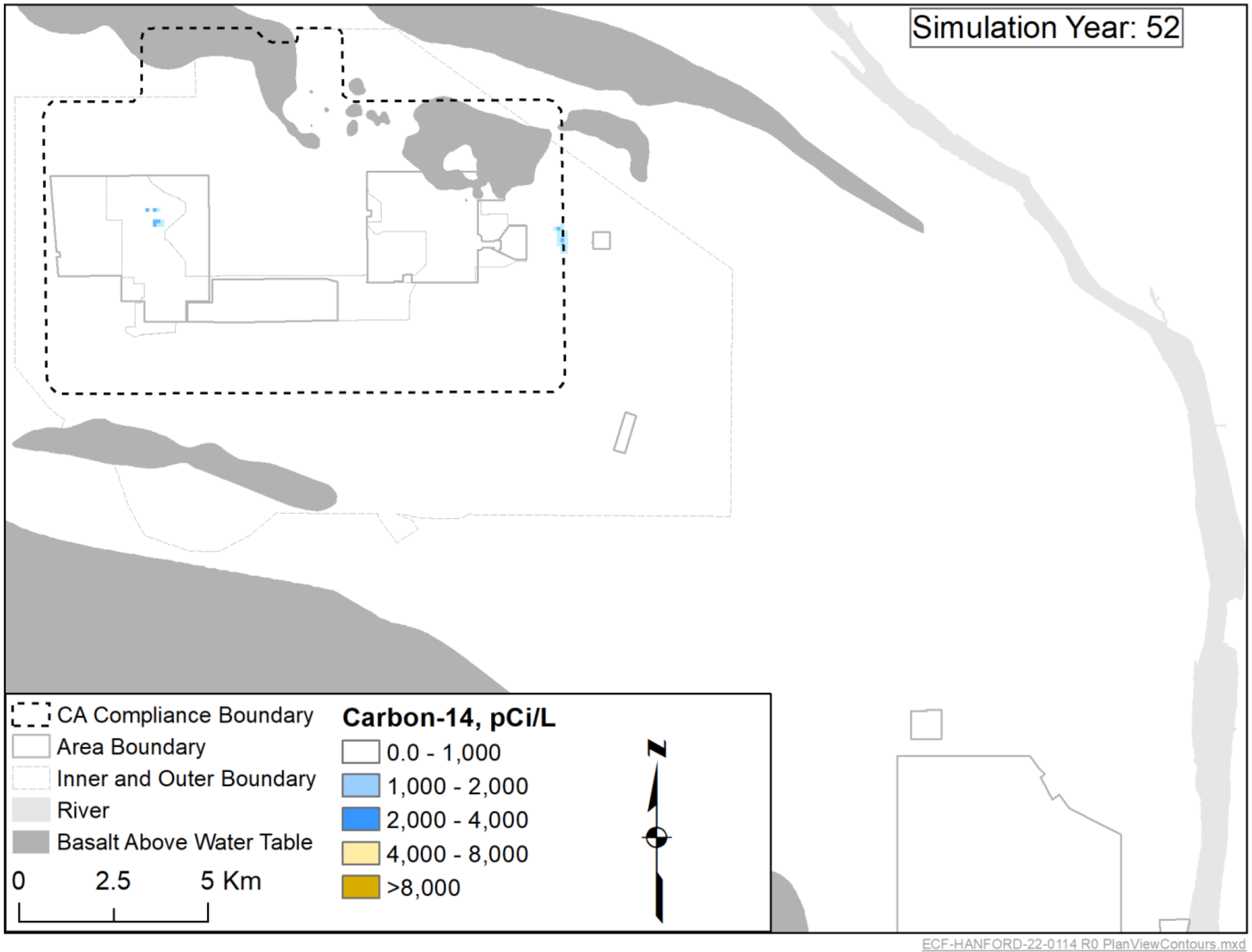

Figure D-14. Plan View Contours of Carbon-14 Concentration Simulated 52 Years from the Start of Simulation Assuming a Pristine Initial Concentration

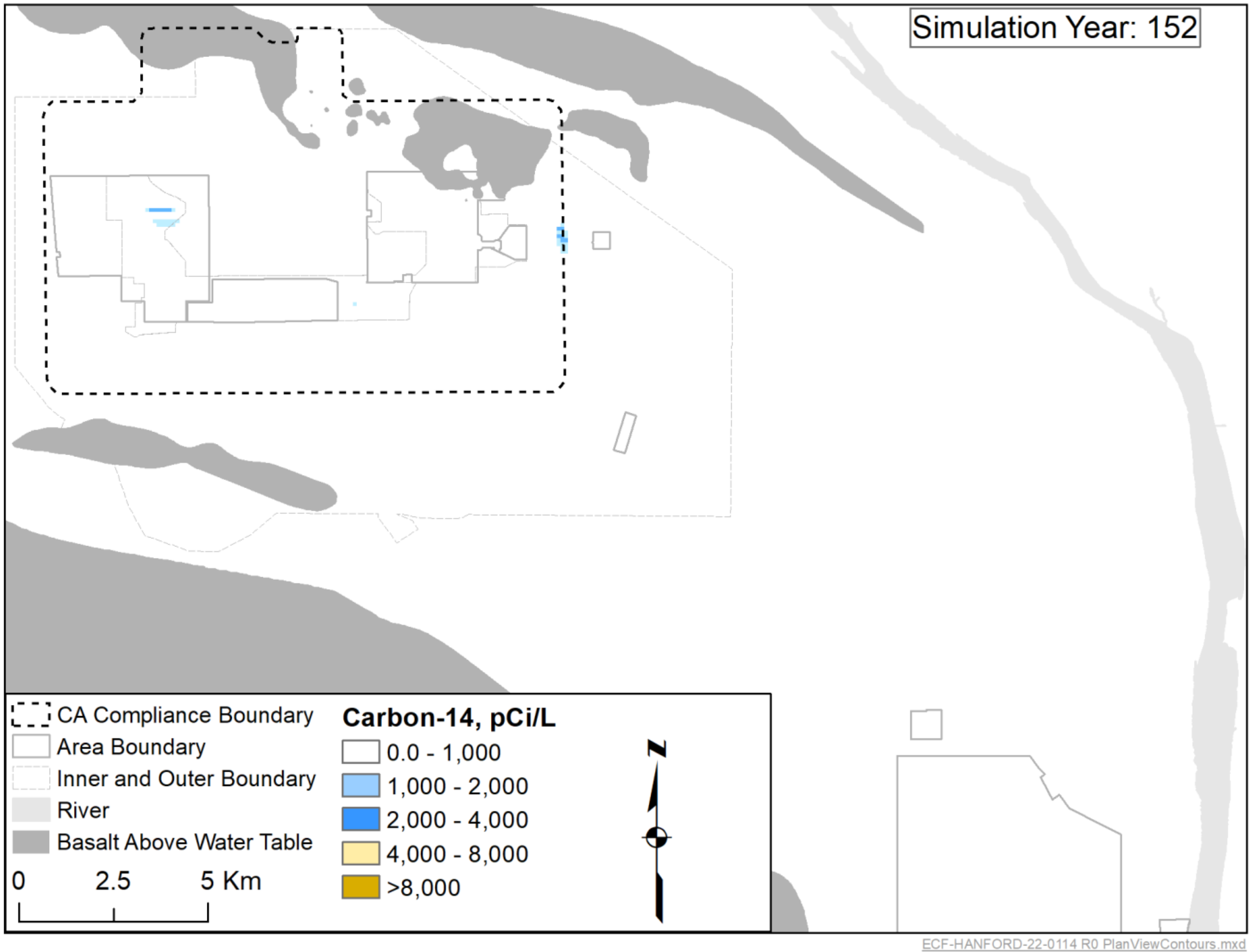

Figure D-15. Plan View Contours of Carbon-14 Concentration Simulated 152 Years from the Start of Simulation Assuming a Pristine Initial Concentration

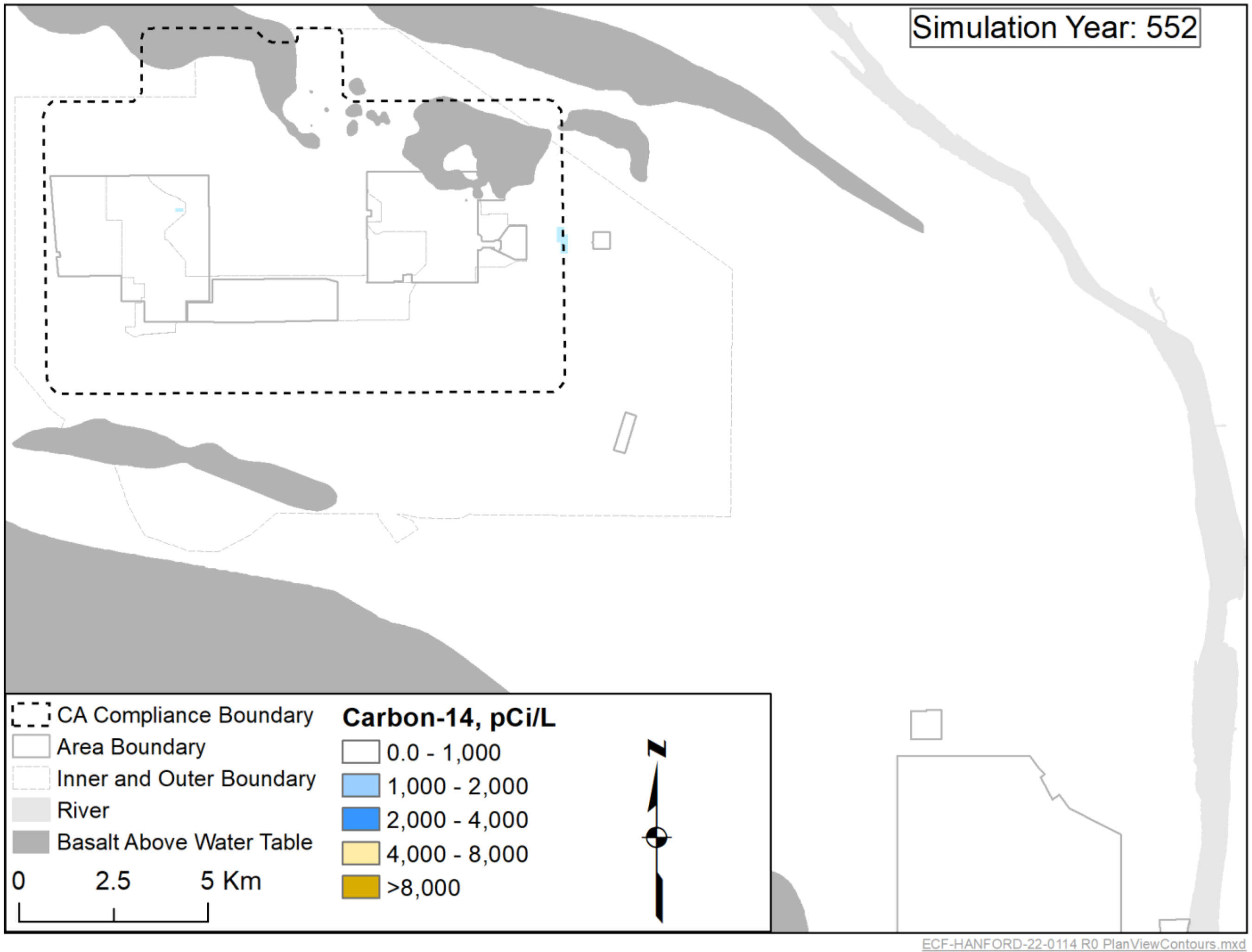

Figure D-16. Plan View Contours of Carbon-14 Concentration Simulated 552 Years from the Start of Simulation Assuming a Pristine Initial Concentration

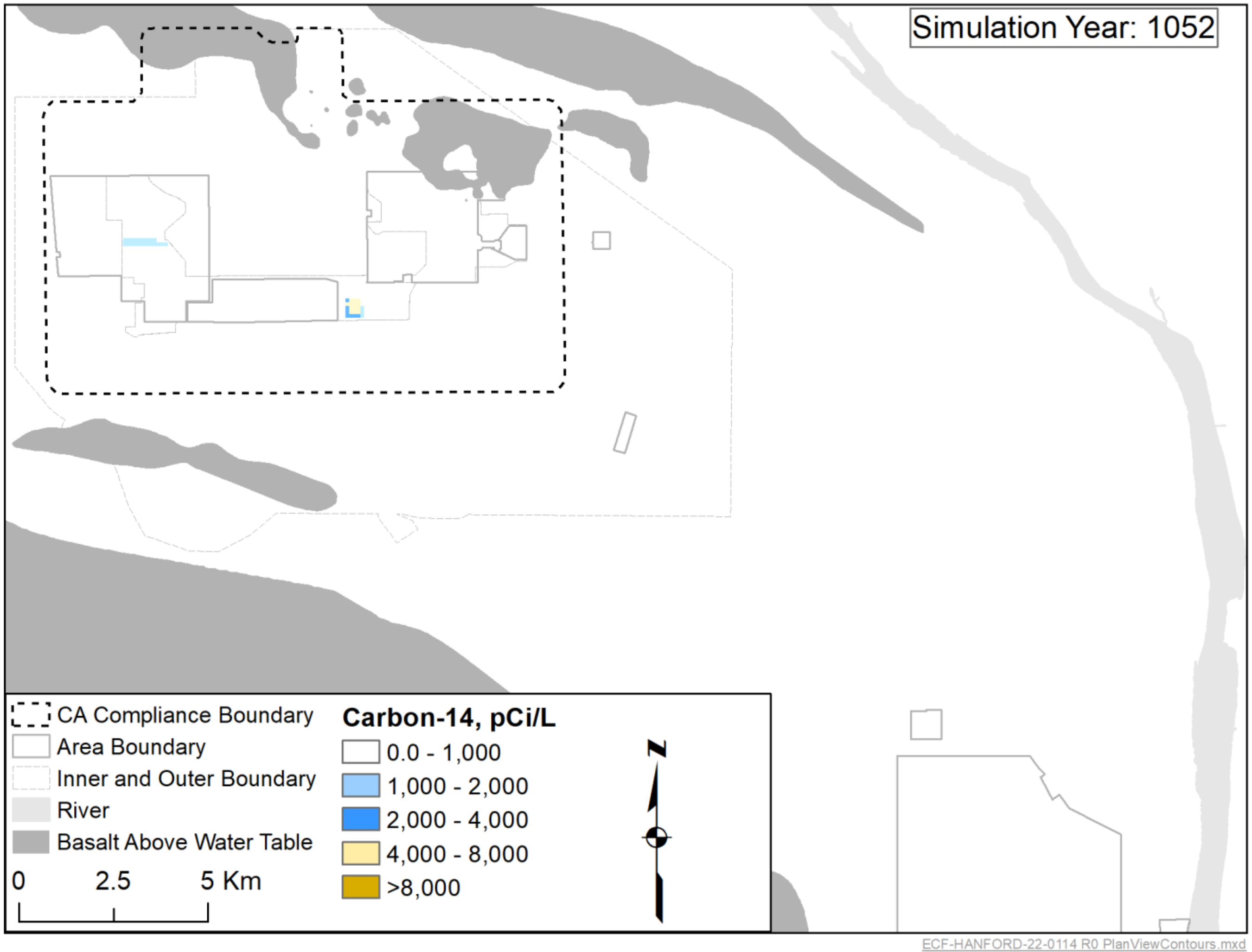

Figure D-17. Plan View Contours of Carbon-14 Concentration Simulated 1052 Years from the Start of Simulation Assuming a Pristine Initial Concentration

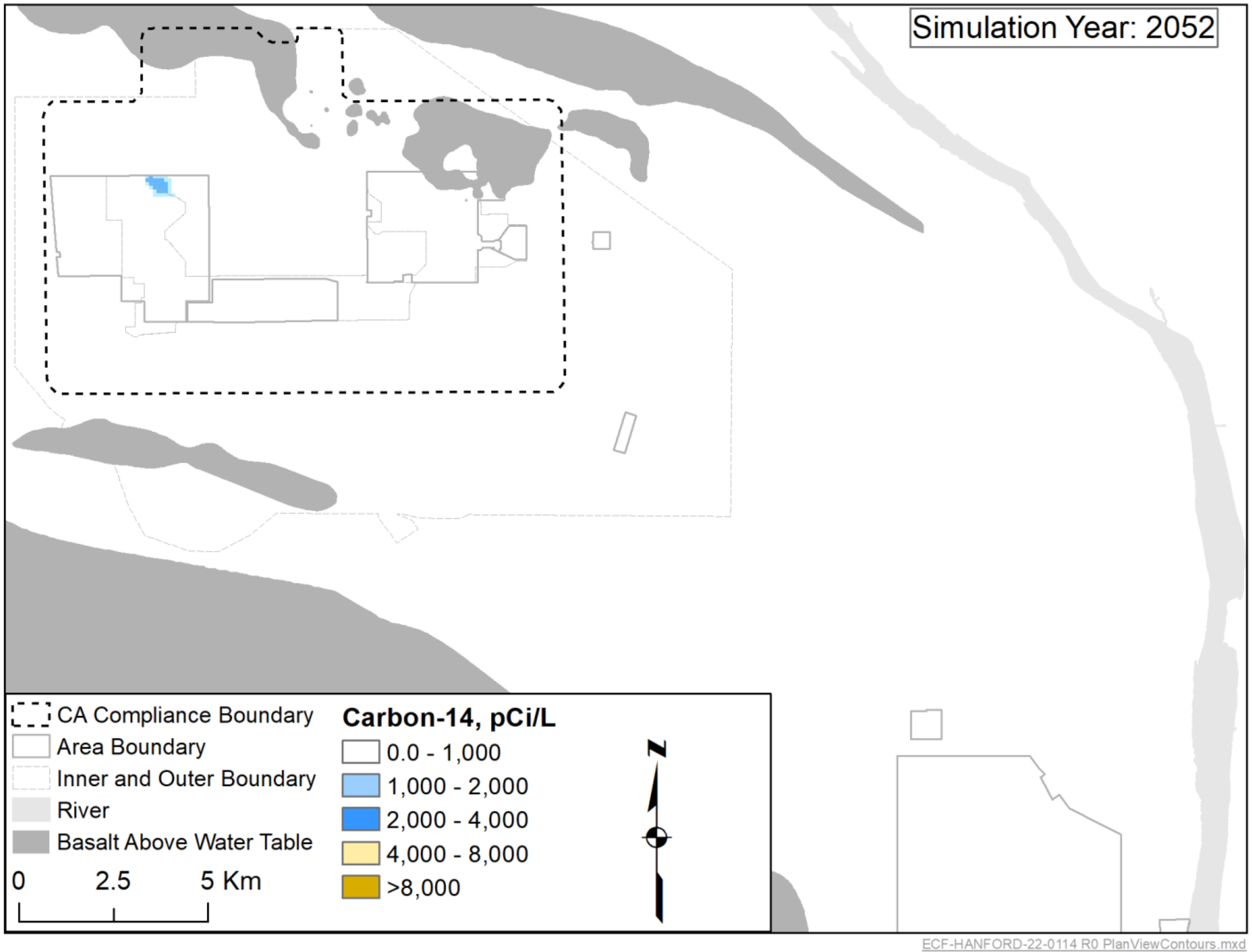

Figure D-18. Plan View Contours of Carbon-14 Concentration Simulated 2052 Years from the Start of Simulation Assuming a Pristine Initial Concentration

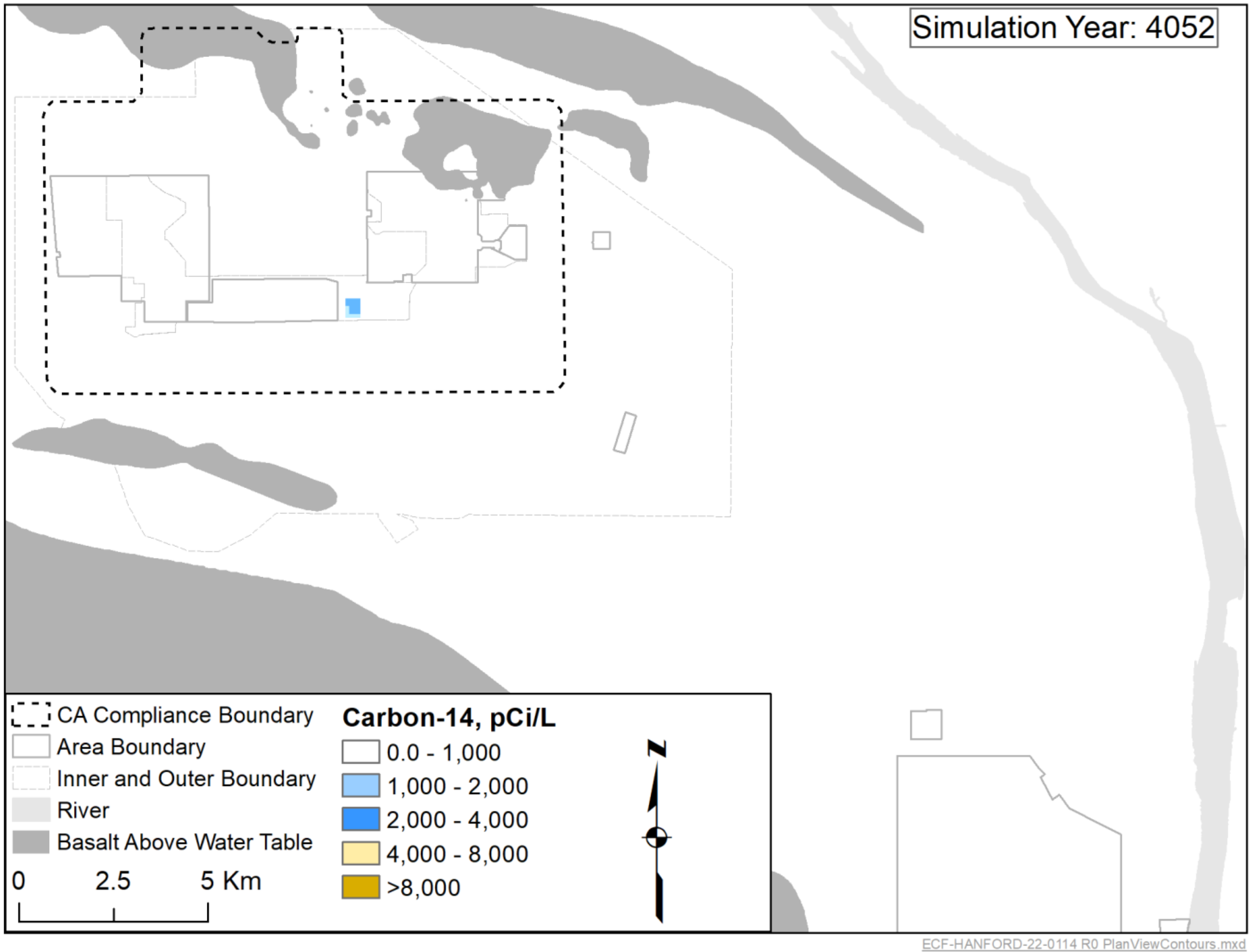

Figure D-19. Plan View Contours of Carbon-14 Concentration Simulated 4052 Years from the Start of Simulation Assuming a Pristine Initial Concentration

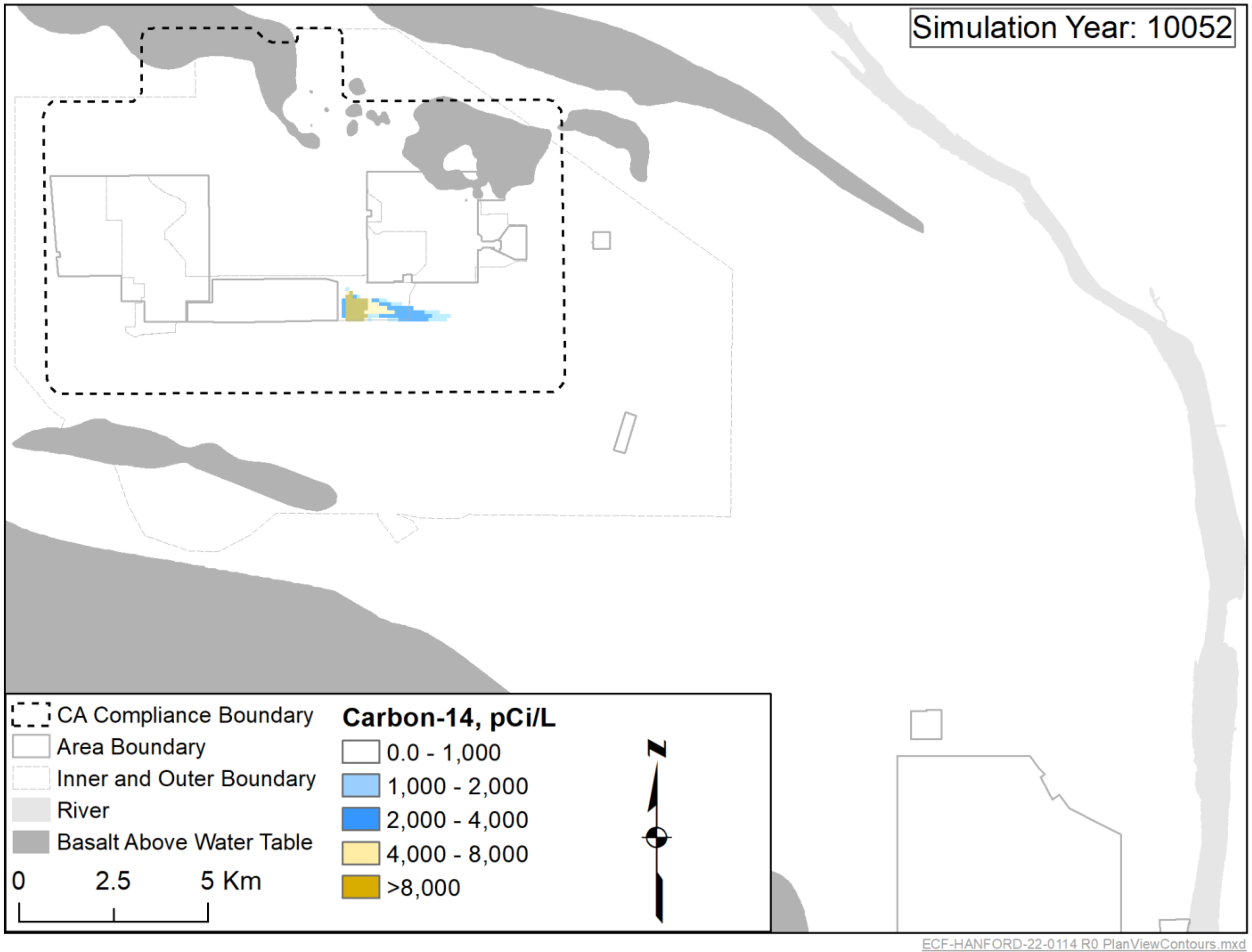

Figure D-20. Plan View Contours of Carbon-14 Concentration Simulated 10052 Years from the Start of Simulation Assuming a Pristine Initial Concentration

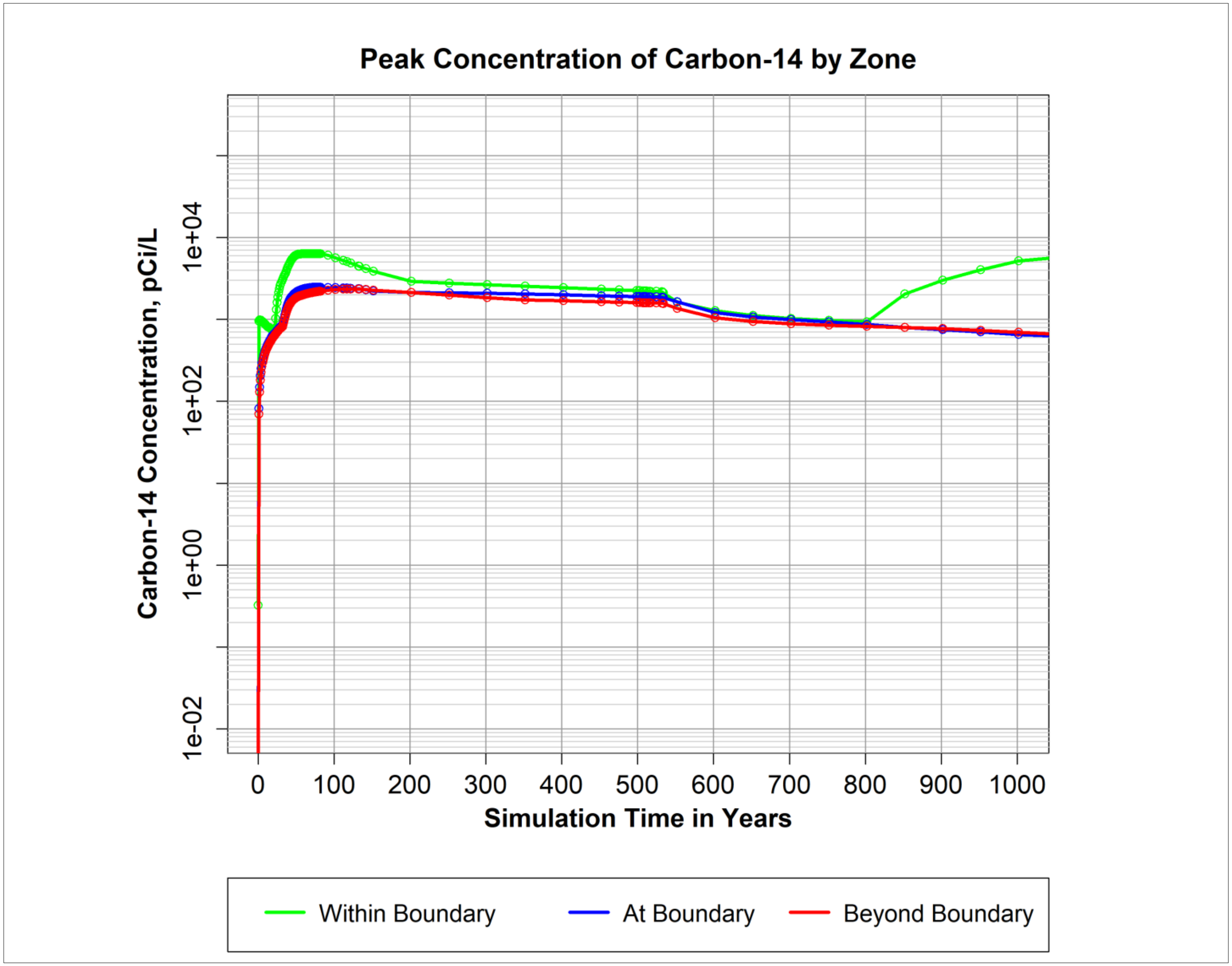

Figure D-21. Peak Concentration of Carbon-14 from the Start of Simulation to the End of the Compliance Period Within, At, and Beyond the Compliance Boundary Assuming a Pristine Initial Concentration

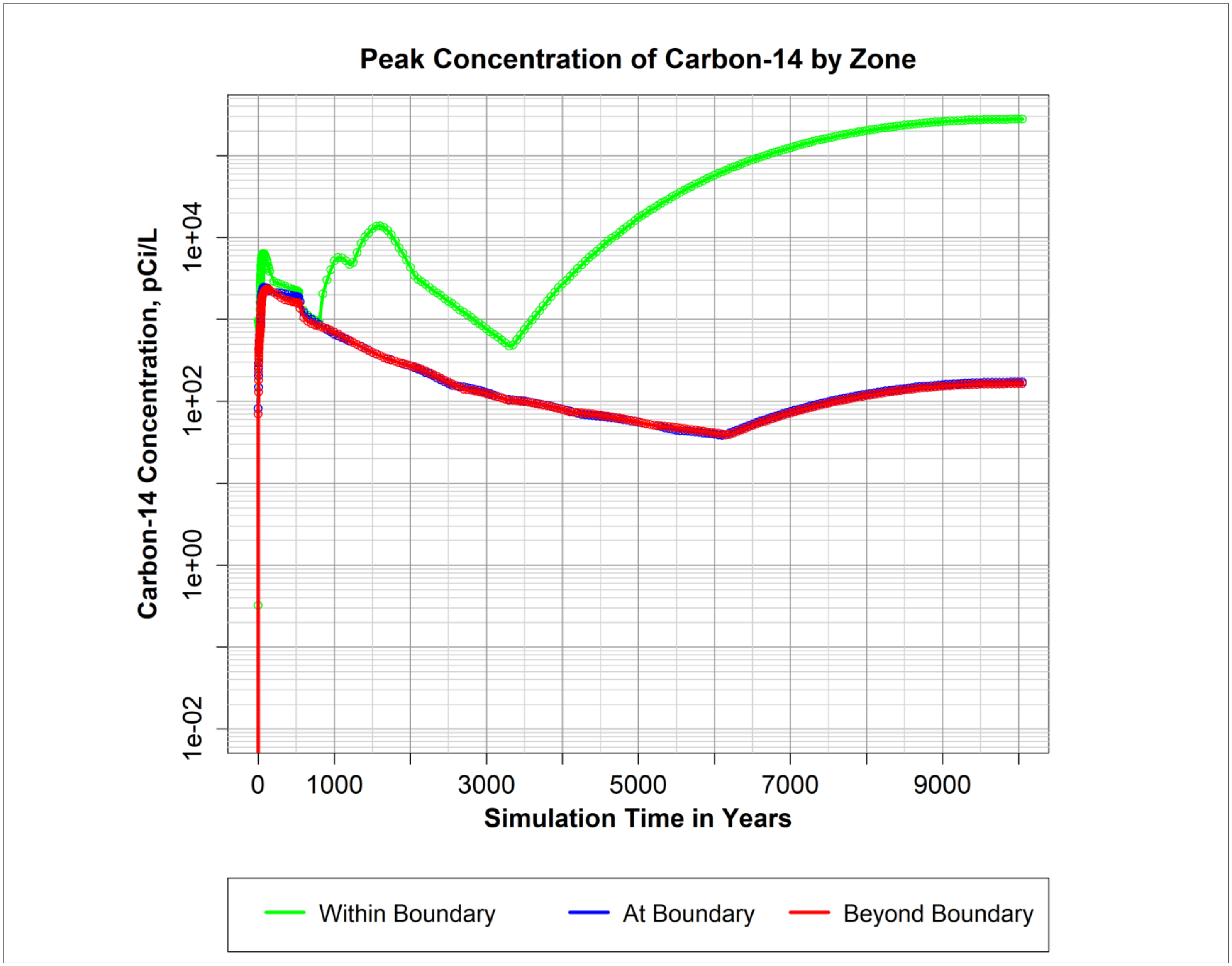

Figure D-22. Peak Concentration of Carbon-14 from the Start of Simulation to the End of the Simulation Within, At, and Beyond the Compliance Boundary Assuming a Pristine Initial Concentration

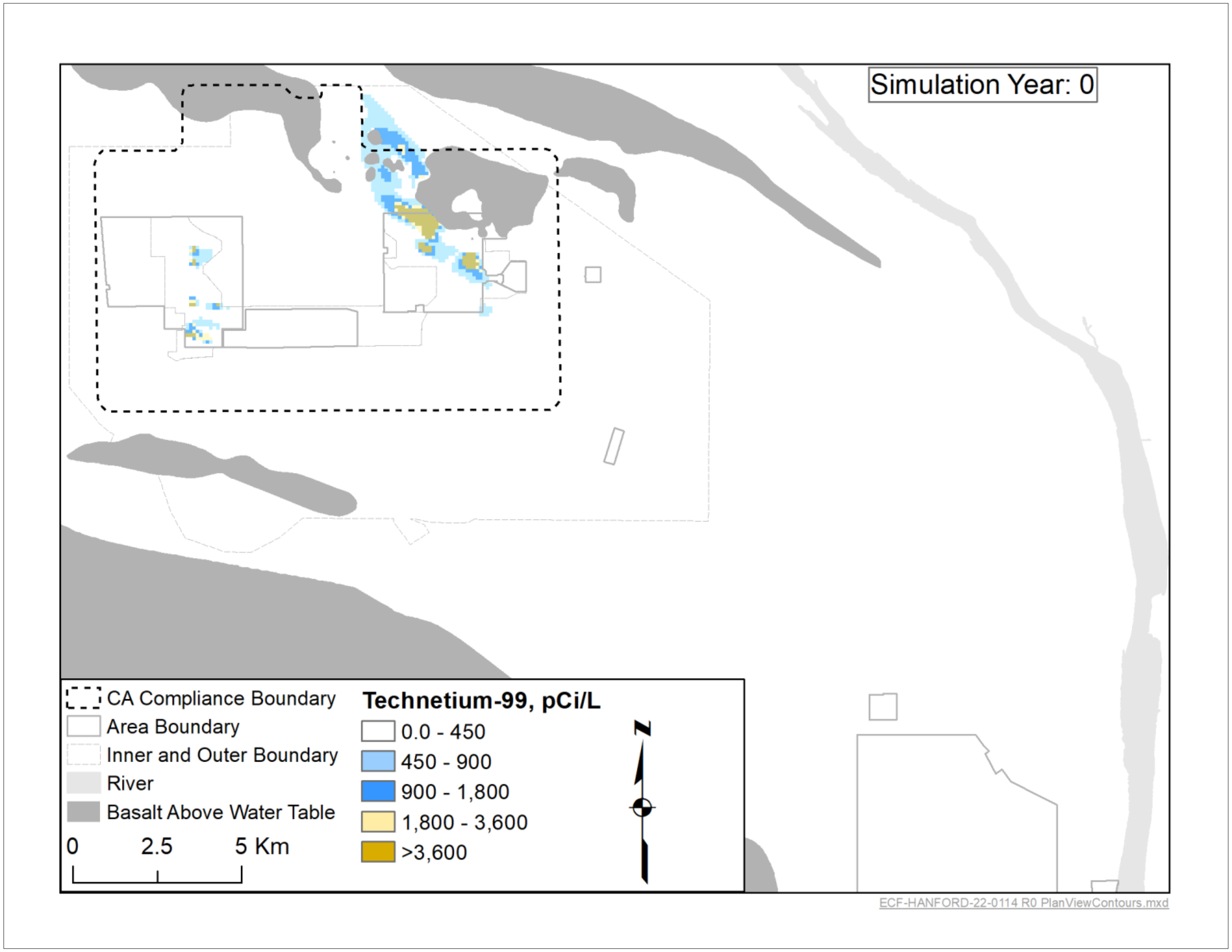

Figure D-23. Plan View Contours of Technetium-99 Concentration Simulated 0 Years from the Start of Simulation Assuming the Worst Case Initial Concentration

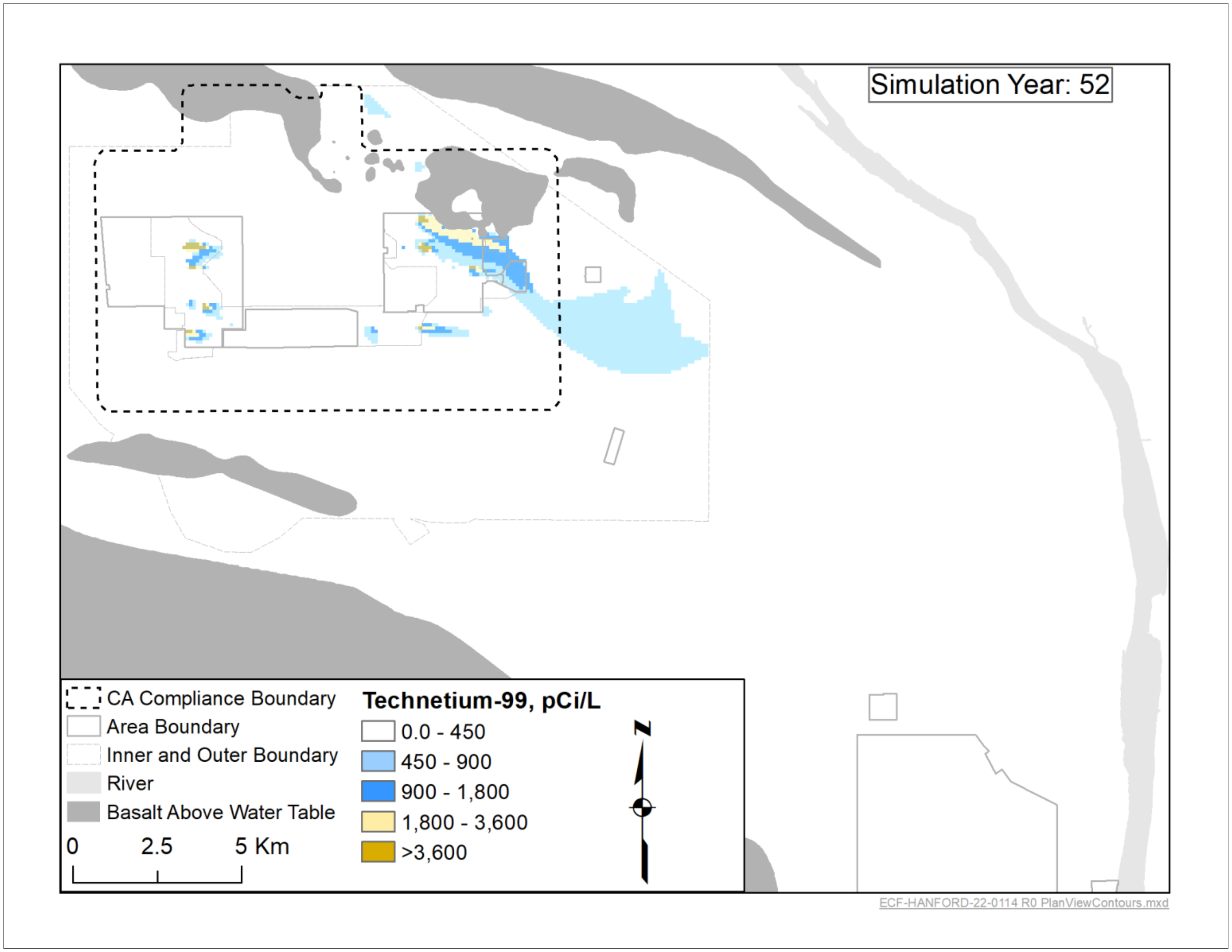

Figure D-24. Plan View Contours of Technetium-99 Concentration Simulated 52 Years from the Start of Simulation Assuming the Worst Case Initial Concentration

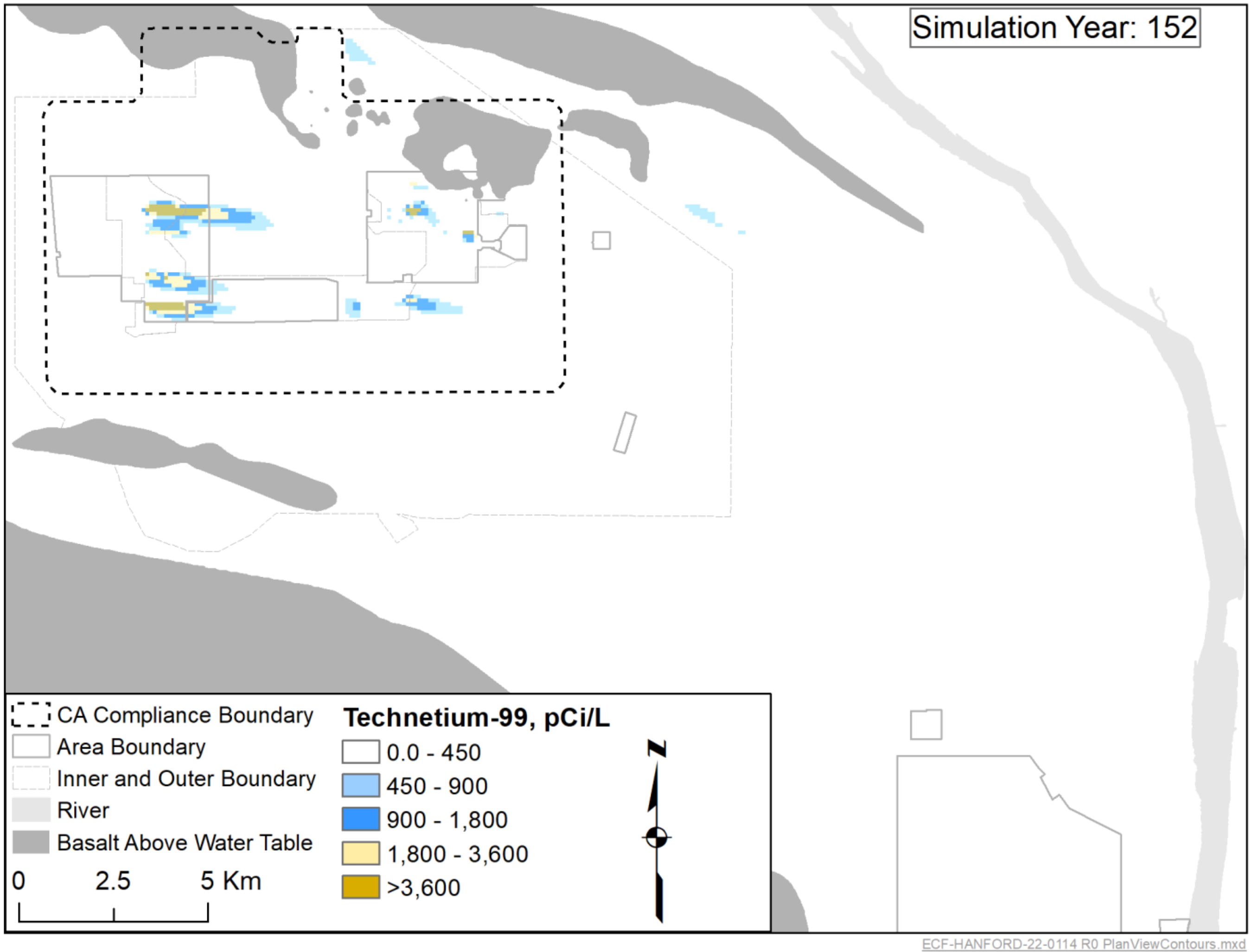

Figure D-25. Plan View Contours of Technetium-99 Concentration Simulated 152 Years from the Start of Simulation Assuming the Worst Case Initial Concentration

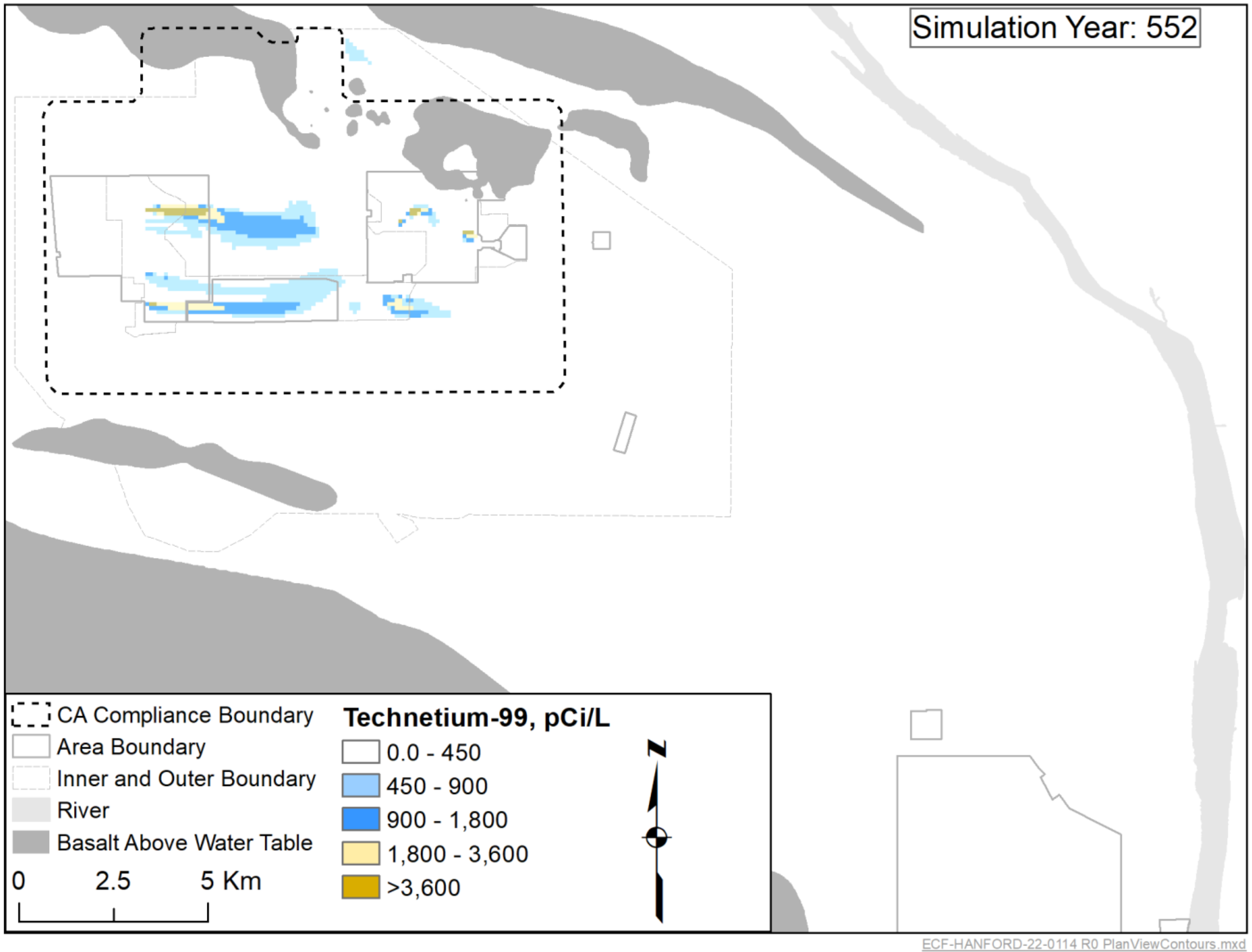

Figure D-26. Plan View Contours of Technetium-99 Concentration Simulated 552 Years from the Start of Simulation Assuming the Worst Case Initial Concentration

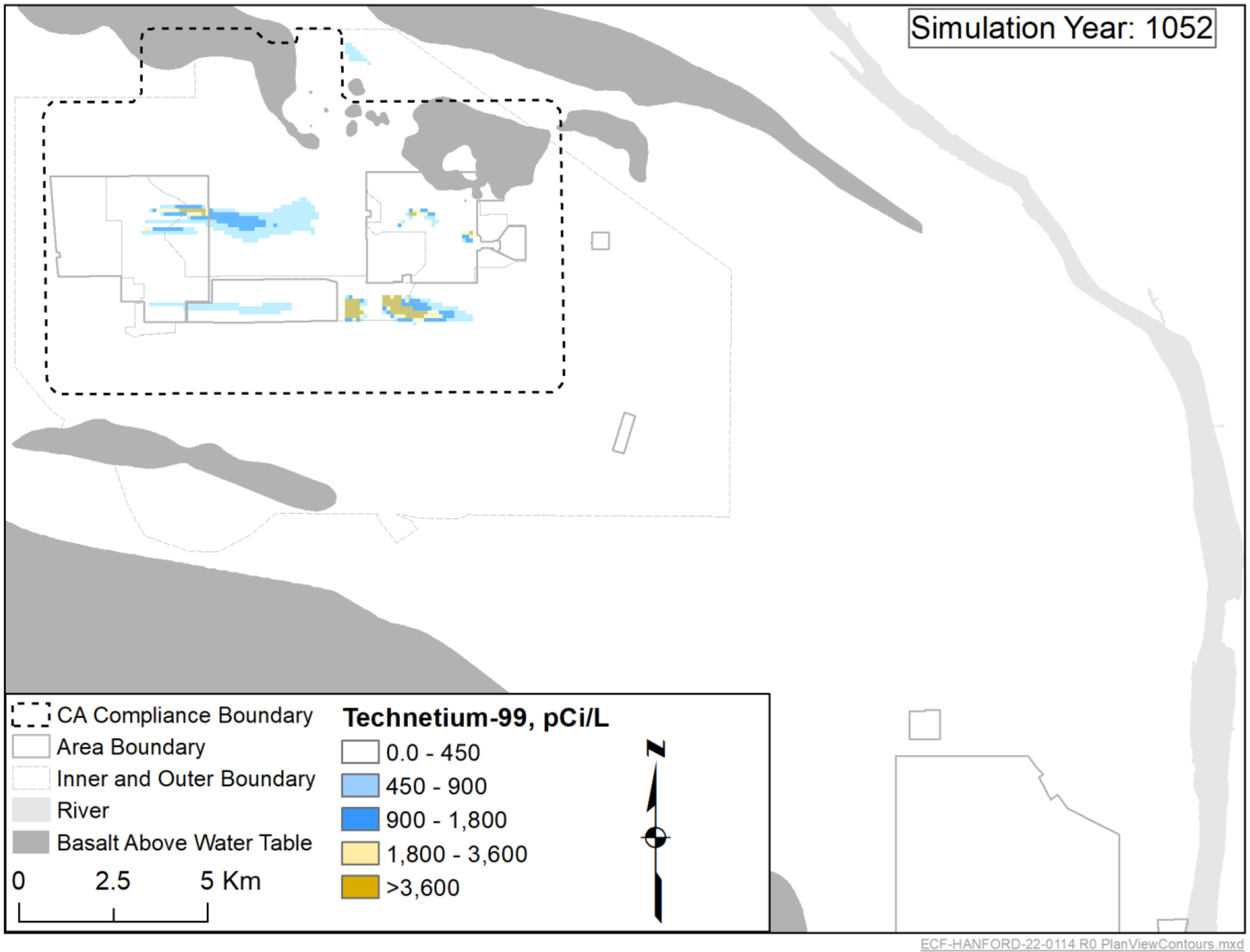

Figure D-27. Plan View Contours of Technetium-99 Concentration Simulated 1052 Years from the Start of Simulation Assuming the Worst Case Initial Concentration

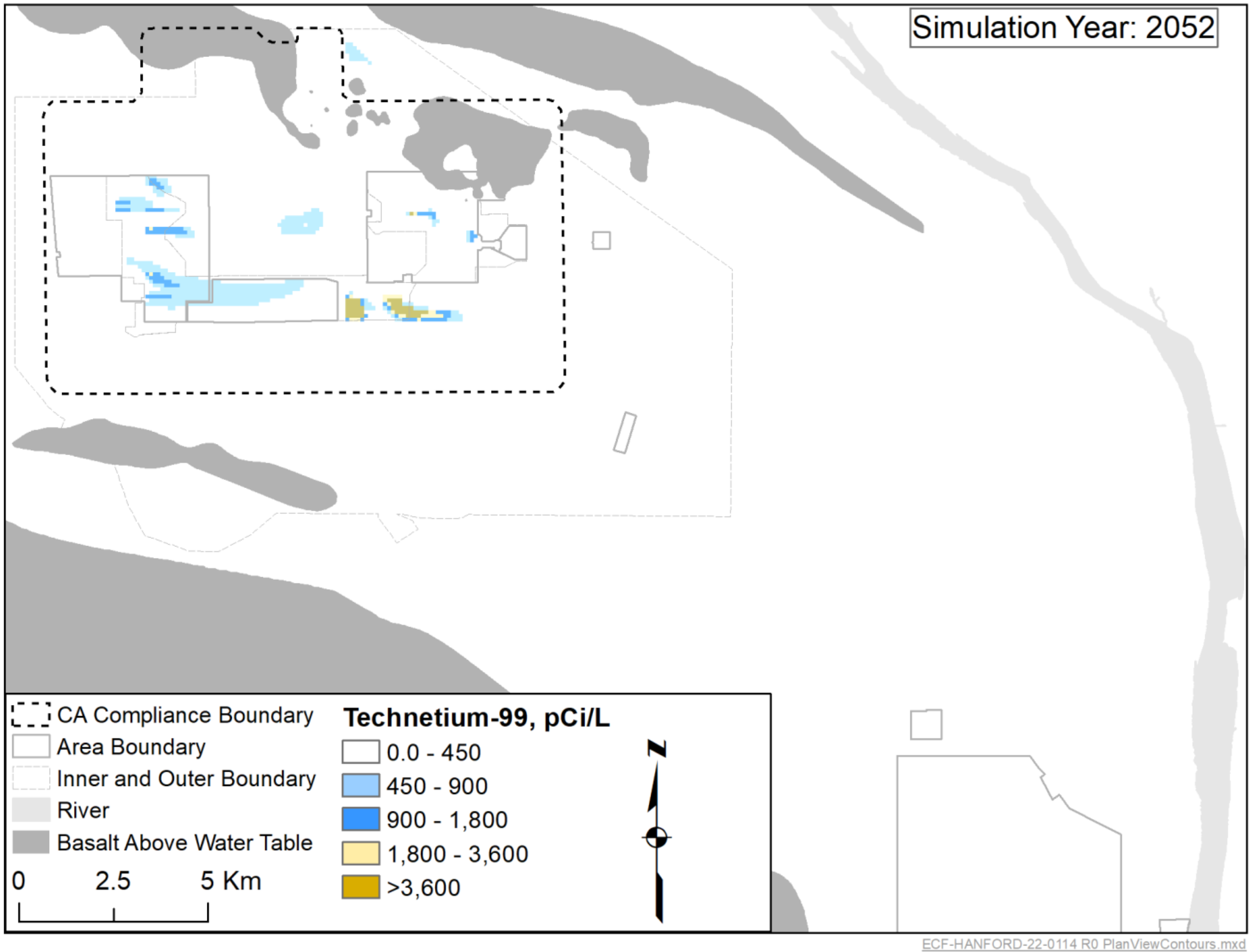

Figure D-28. Plan View Contours of Technetium-99 Concentration Simulated 2052 Years from the Start of Simulation Assuming the Worst Case Initial Concentration

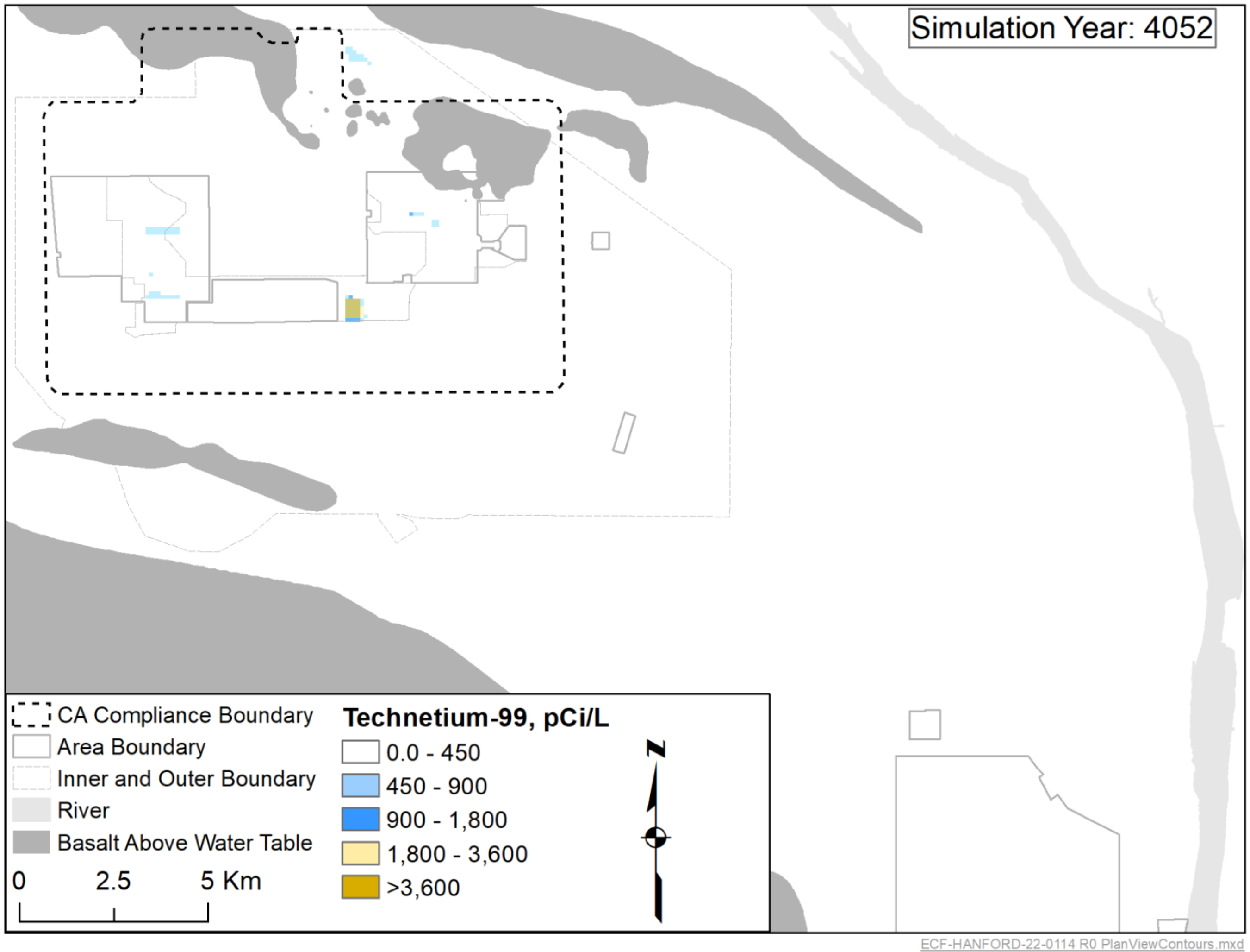

Figure D-29. Plan View Contours of Technetium-99 Concentration Simulated 4052 Years from the Start of Simulation Assuming the Worst Case Initial Concentration

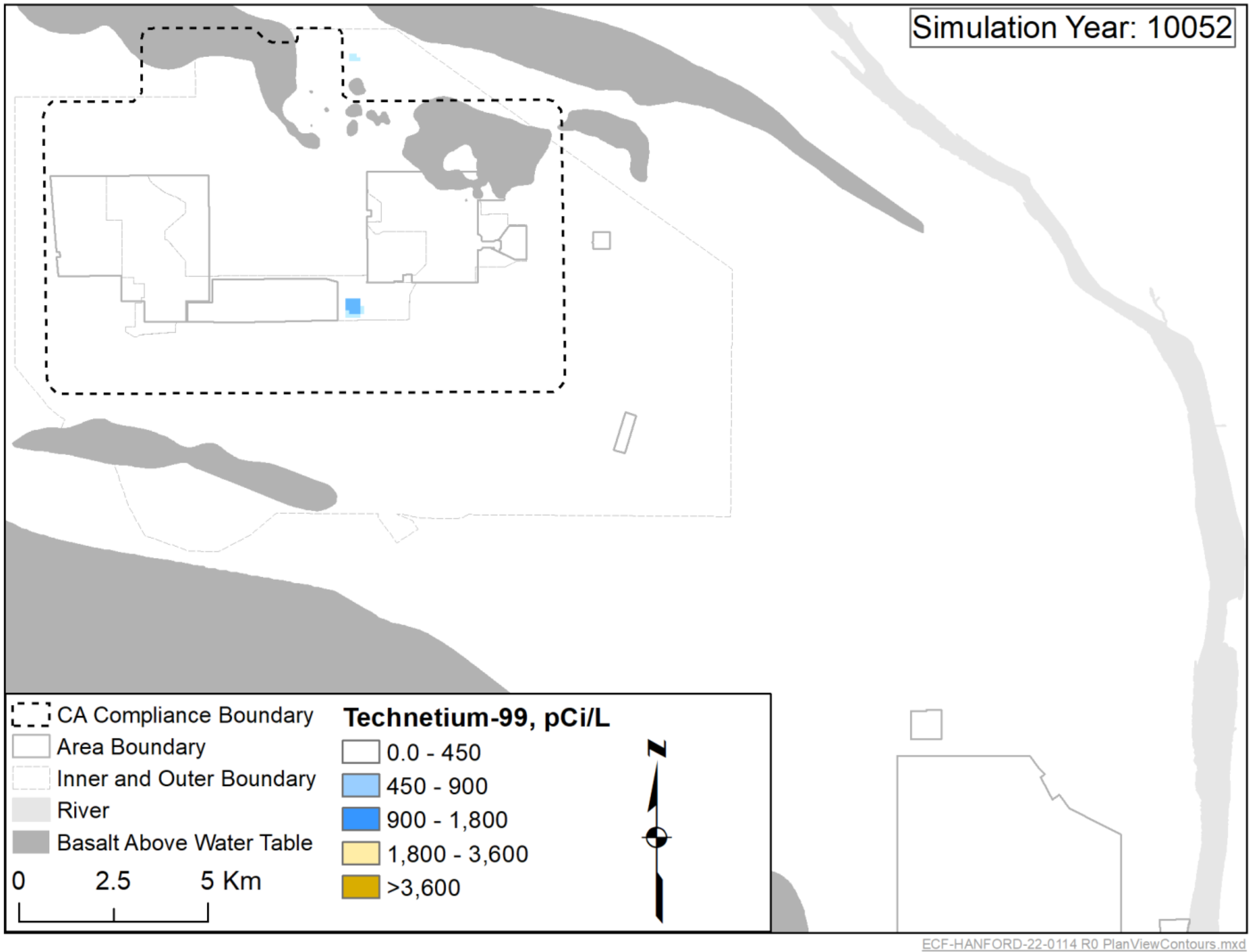

Figure D-30. Plan View Contours of Technetium-99 Concentration Simulated 10052 Years from the Start of Simulation Assuming the Worst Case Initial Concentration

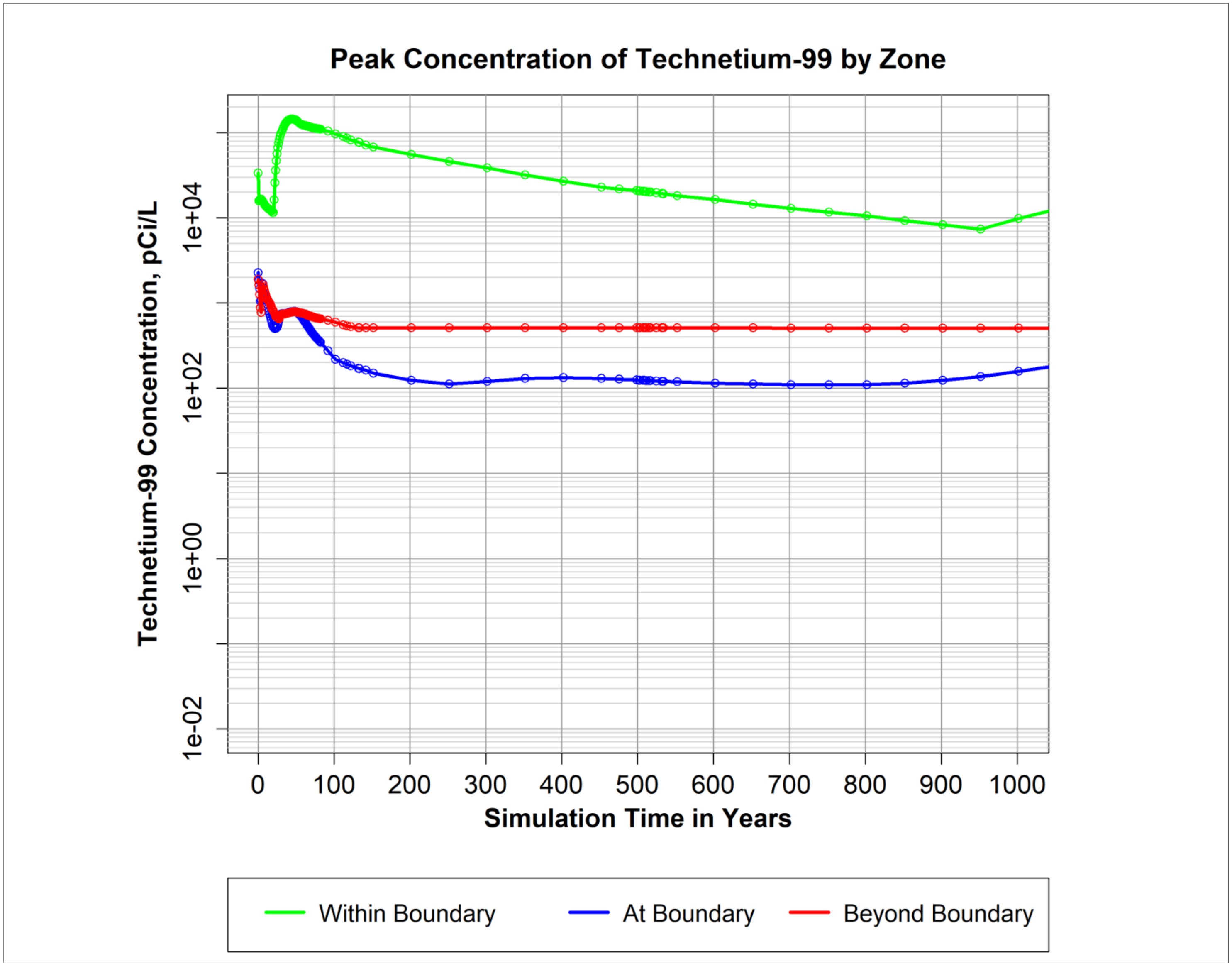

Figure D-31. Peak Concentration of Technetium-99 from the Start of Simulation to the End of the Compliance Period Within, At, and Beyond the Compliance Boundary Assuming the Worst Case Initial Concentration

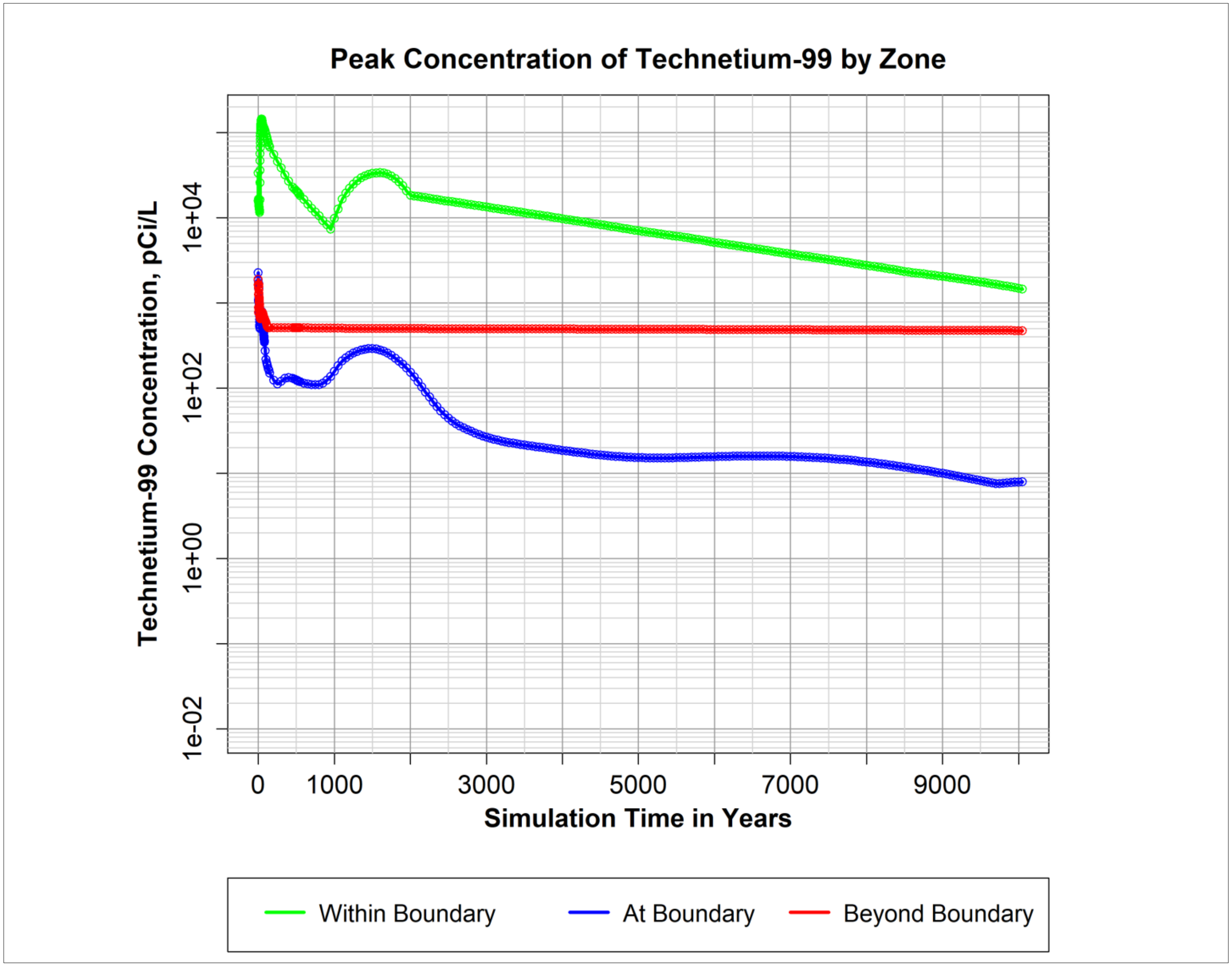

Figure D-32. Peak Concentration of Technetium-99 from the Start of Simulation to the End of the Simulation Within, At, and Beyond the Compliance Boundary Assuming the Worst Case Initial Concentration

Appendix E

Software Installation and Checkout Forms

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: MODFLOW & Related Codes — Software Version No.: Bld 8

EXECUTABLE INFORMATION:

2. Executable Name (include path):

The following executable files in directory: /bin on head node and each compute node (compute-0-0 through compute-0-10, inclusive)

```
MD5 Signature (unique ID)          Executable File Name   Code
--------------------------------   --------------------   -------------------------
8b0b28c5e102e63df95de542d83d013b   mf2k-chprc08spl.x      MODFLOW-2000 single precision
2fade33e27978063a9a70ff8605e4c0c   mf2k-chprc08dpl.x      MODFLOW-2000 double precision
d879defafdc5ad25be51a484d73ea65d   mf2k-mst-chprc08spl.x  MODFLOW-2000-MST single precis.
80d670658425653bf5bcbb97ad2a2730   mf2k-mst-chprc08dpl.x  MODFLOW-2000-MST double precis.
8b0b28c5e102e63df95de542d83d013b   mf2k-chprc08spl.x      MT3DMS single precision
2fade33e27978063a9a70ff8605e4c0c   mf2k-chprc08dpl.x      MT3DMS double precision
2d0a8a4c480318763b6aaaa0f880348a   mt3d-mst-chprc08spl.x  MT3DMS-MST single precision
1e468c4409ac913843ce783aabed819c   mt3d-mst-chprc08dpl.x  MT3DMS-MST double precision
```

3. Executable Size (bytes): MD5 signatures above uniquely identify each executable file

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

INTERA Austin Linux(R) Cluster

5. Operating System (include version number):

Linux head.cluster 2.6.32-358.11.1.el6.centos.plus.x86_64 #1 SMP Wed Jun 12 19:12:17 UTC 2013 x86_64 x86_64 x86_64 GNU/Linux

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

Gaia Subsurface Transport Modeling Linux Platform

7. Operating System (include version number):

Linux gaia1.rl.gov 3.10.0-1160.25.1.el7.x86_64 #1 SMP Wed Apr 28 21:49:45 UTC 2021 x86_64 x86_64 x86_64 GNU/Linux

8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

:/modflow/build-8-a on head node and each compute node

10. Procedure(s):

CHPRC-00259 Rev. 3, MODFLOW and Related Codes Software Test Plan

11. Libraries

N/A (static linking)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: MODFLOW & Related Codes   Software Version No.: Bld 8

12. Input Files:

Per CHPRC-00259 Rev. 3

13. Output Files:

Found in test subdirectories

14. Test Cases:

MF-ITC-1 (both standard and MST versions of MODFLOW); run both single & double precision
MT-ITC-1 run for single and double precision, multiple solvers

15. Test Case Results:

All PASS, All Tests, on all nodes of Gaia. Test log attached.

16. Test Performed By: WE Nichols

17. Test Results: (●) Satisfactory, Accepted for Use   ( ) Unsatisfactory

18. Disposition (include HISI update):

This is a retest of the installation following system outage of June 1 to June 15, 2021 to update the Operating System on all nodes and apply all pending vulnerability patches. No change to HISI entries. This constitutes operational testing per the SMP.

Prepared By:

19. Christopher Farrow (digitally signed) — Software Owner (Signature) | Chris Farrow — Print | Date

20. Test Personnel:

WILLIAM NICHOLS (Affiliate) Digitally signed by WILLIAM NICHOLS (Affiliate) Date: 2021.06.15 10:49:24 -07'00' — Sign | William Nichols — Print | Date

Sign | Print | Date

Sign | Print | Date

Approved By:

21. Software SME (Signature) | N/R (CHPRC-00258 Rev. 3) — Print | Date

A-6005-149 (REV 0)