ECF-HANFORD-20-0133
Revision 0

Cumulative Impact Evaluation Vadose Zone Model for the U-10 West Area, No Further Action Scenario

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

P.O. Box 1464
Richland, Washington 99352

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Cumulative Impact Evaluation Vadose Zone Model for the U-10 West Area, No Further Action Scenario

Document Type: ECF Program/Project: Cumulative Impact Evaluation (CIE)

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Date Published
July 2021

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APPROVED
By Sarah Harrison at 2:56 pm, Aug 12, 2021

Release Approval Date

ENVIRONMENTAL CALCULATION COVER PAGE

SECTION 1 - Completed by the Responsible Manager

Project: Hanford Site Cumulative Impact Evaluation	**RELEASE / ISSUE** DATE: Aug 12, 2021 HANFORD RELEASE
Date: 7/30/2021	
Calculation Title and Description: Cumulative Impact Evaluation Vadose Zone Model for the U-10 West Area, No Further Action Scenario	

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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Calculation Number: ECF-HANFORD-20-0133 | Revision Number: 0

Revision History

Revision No.	Description	Date	Affected Pages
0	Initial Issue.	7/30/2021	All

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Document Control:

Is the document intended to be controlled within the Document Management Control System (DMCS)? ◉ Yes ○ No

Does document contain scientific and technical information intended for public use? ◉ Yes ○ No

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08/02/2021 10:02 AM - The task for Nichols, William E was Approved by Nichols, William E. Comments:

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Contents

Appendices

Figures

Tables

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Terms

CA	Composite Analysis
CCUc	Cold Creek unit caliche
CCUsilt	Cold Creek unit upper silt and sand
CIE	cumulative impact evaluation
ECF	environmental calculation file
EHM	Equivalent Homogeneous Media
eSTOMP	exascale Subsurface Transport Over Multiple Phases
GIS	geographic information system
Hf1	Hanford formation unit 1
Hf2	Hanford formation unit 2
HSU	hydrostratigraphic unit
ICF	Integrated Computational Framework
K_d	partition coefficient
P2R	plateau to river
PA-TCT	power-averaging tensorial connectivity-tortuosity
RET	recharge evolution tool
RTD	remove, treat, and dispose
Rtf	Ringold Formation member of Taylor Flat
Rwie	Ringold Formation member of Wooded Island – unit E
STOMP	Subsurface Transport Over Multiple Phases
TCT	tensorial connectivity-tortuosity
WMA C	Waste Management Area C

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1 Purpose

The objectives of the vadose zone modeling for the Hanford Site Cumulative Impact Evaluation (CIE) as outlined by the CIE Technical Approach Document (DOE/RL-2018-69, *Cumulative Impact Evaluation Technical Approach Document*) are to simulate the flow and transport of water and contaminant releases from the surface through the vadose zone to the water table in the Hanford Site Central Plateau and to provide contaminant transfer rates to the CIE saturated zone model. This environmental calculation file (ECF) describes the contaminant transport under the CIE no further action (NFA) scenario, documented in CP-64711, *Hanford Site Disposition Baseline for the Cumulative Impacts Evaluation – No Further Action Scenario*. Water inputs to the vadose zone models include natural recharge and water discharged to the ground as a result of industrial processes associated with Hanford Site operations. Contaminant sources from liquid waste sites were included. Contaminant releases from solid wastes were not included. Releases from solid wastes are expected to impact groundwater quality at much lower concentrations than liquid waste releases and extend outside the timeframe of the CIE modeling and therefore were not included in this CIE effort (DOE/RL-2018-69). The CIE vadose zone model simulation time starts in 1943 and ends in 3070, which is 1,000 years after assumed Hanford Site closure in 2070. The contaminants considered for this modeling effort include both radiological and chemical contaminants (hereinafter, when the radiological and chemical contaminants are referred to collectively, they are referred to as "contaminants"). The contaminants are tritium (H-3), iodine-129 (I-129), strontium-90 (Sr-90), technetium-99 (Tc-99), cyanide (CN), nitrate (NO_3), and total uranium[1].

The parallel version of the Subsurface Transport Over Multiple Phases (STOMP[2]) simulator, officially named the exascale[3] Subsurface Transport Over Multiple Phases (eSTOMP), is used to simulate flow and transport for the vadose models. The documentation for the STOMP code is comprehensive. The theoretical and numerical approaches applied in the STOMP code are documented in a published theory guide (PNNL-12030, *STOMP: Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide*). The code has undergone a rigorous verification procedure against analytical solutions, laboratory-scale experiments, and field-scale demonstrations. The application guide (PNNL-11216, *STOMP: Subsurface Transport Over Multiple Phases Application Guide*) provides instructive examples in the application of the code to classical groundwater problems. The user's guide (PNNL-15782, *STOMP: Subsurface Transport Over Multiple Phases Version 4.0: User's Guide*) describes the general use, input file formatting, compilation, and execution of the code.

The primary output of the vadose zone modeling is the contaminant transfer rates to the groundwater for input into the saturated zone model, also referred to as the Plateau to River (P2R) model (ECF-HANFORD-21-0005, *Predictive Contaminant Transport Simulation with the P2R Model for the Cumulative Impact Evaluation No Further Action Scenario*, CP-57037, *Model Package Report: Plateau to River Groundwater Model Version 8.3*). The rates discharged from the vadose zone models will be summed over the 100 by 100 m saturated zone model grid cells that fall within the vadose zone model

---

[1] The discharged inventory of uranium isotopes, reported in terms of activity, is converted to mass and summed as total uranium for fate and transport modeling for CIE (CP-64710, *Inventory Data Package for the Hanford Site Composite Analysis*). The conversion and summation to total uranium are consistent with the approach in Hanford Site groundwater monitoring reports (e.g., DOE/RL-2019-66, *Hanford Site Groundwater Monitoring Report for 2019*).

[2] STOMP is a copyright of Battelle Memorial Institute, Columbus, Ohio, and used under the Limited Government License.

[3] The use of the word "exascale" in this software title is employed artistically, not literally, and is meant to highlight that this version of STOMP can execute many calculations in parallel. Exascale computing refers to supercomputer systems with the capacity of executing at least 10^{18} floating point operations per second. As of January 2021, no computer has been able to perform at this level.

source domains. DOE/RL-2018-69 indicates that where a performance assessment or past leaks analysis has been completed, the relevant data will be used as direct inputs to the saturated zone model.

The Hanford Site Central Plateau was subdivided into 24 individual vadose zone models, with 12 in the 200 East Area and 12 in the 200 West Area, as shown in Figure 1-1. Model domain extents were chosen large enough to assess geographic areas where comingling is likely to occur in the vadose zone, while keeping extents small enough to allow a basic grid discretization that sufficiently represents the contaminant sources and hydrostratigraphy (DOE/RL-2018-69). Each of the vadose zone models is documented in separate ECFs. This ECF describes the U-10 West Area model. The scope of this ECF is to document the development and results of the U-10 West Area vadose zone model.

CP-63515, *Model Package Report: Central Plateau Vadose Zone Models*, and DOE/RL-2018-69 describe the approach, assumptions, process of determining the number of models required and domain of each model, input data, and processing common to all the models. The vadose zone models in the CIE modeling effort share many similarities with the vadose zone models for the Composite Analysis (CA) modeling effort. The CA and CIE serve different purposes (CP-63515). This difference manifests in several aspects of the modeling setup, including the simulation end time (12070 for the CA vs. 3070 for the CIE), the types of waste release considered (the CA includes solid waste release while the CIE includes only liquid waste releases), and the contaminants included (the CA includes sixteen radionuclides, while the CIE considers four radionuclides and four chemicals). However, there are many respects in which the vadose zone models for these two projects are identical, and work done to support the CA therefore also supports the CIE. This includes material properties, hydrostratigraphy, and in many cases model grid spacing. Work done to support ECF-HANFORD-19-0062, *Vadose Zone Model for U-10 West Area for Composite Analysis*, also supports this model.

Additionally, the following documents support inputs to the models:

- CP-60925, *Model Package Report: Central Plateau Vadose Zone Geoframework*, describes the hydrostratigraphic framework.
- Inventory data are sourced from two documents: CP-61786, *Inventory Data Package for the Hanford Site Composite Analysis*, and CP-64710, *Inventory Data Package for the Hanford Site Cumulative Impacts Evaluation*. Appendix F of CP-61786 and appendix B of CP-64710 provide the inventory for the radionuclide and chemical data, respectively. The inventory for solid waste sites is not included.
- CP-63883, *Vadose Zone Flow and Transport Parameters Data Package for the Hanford Site Composite Analysis*, describes the process of assigning material properties to the hydrostratigraphic units (HSUs).
- ECF-HANFORD-15-0019, *Hanford Site-wide Natural Recharge Boundary Condition for Groundwater Models*, describes the recharge evolution tool (RET) used to calculate the natural recharge.
- ECF-HANFORD-18-0035, *Central Plateau Vadose Zone Geoframework*, describes the updates to the hydrostratigraphy surfaces defined in CP-60925, and defines the hydrostratigraphy surfaces used by this modeling effort.
- ECF-HANFORD-19-0032, *Distribution of Infiltration in the 216-U-10, 216-B-3 Pond, and 216-T-4 Pond Systems 1944-1997*, estimates the routing of effluent and infiltration between ditches and ponds of the 216-U-10 Pond system, between the main pond and expansion lobes of the 216-B-3 Pond system, and between the two ponds and two influent ditches of the 216-T-4 Pond system.

- ECF-HANFORD-19-0094, *Calculation of Moisture-Dependent, Anisotropic Parameters Supporting the Hanford Site's Composite Analysis, Cumulative Impact Evaluation, and Performance Assessments*, describes calculations of moisture-dependent, anisotropy of hydraulic conductivity for the HSUs.
- 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*, describes the physical and chemical properties used for these models.

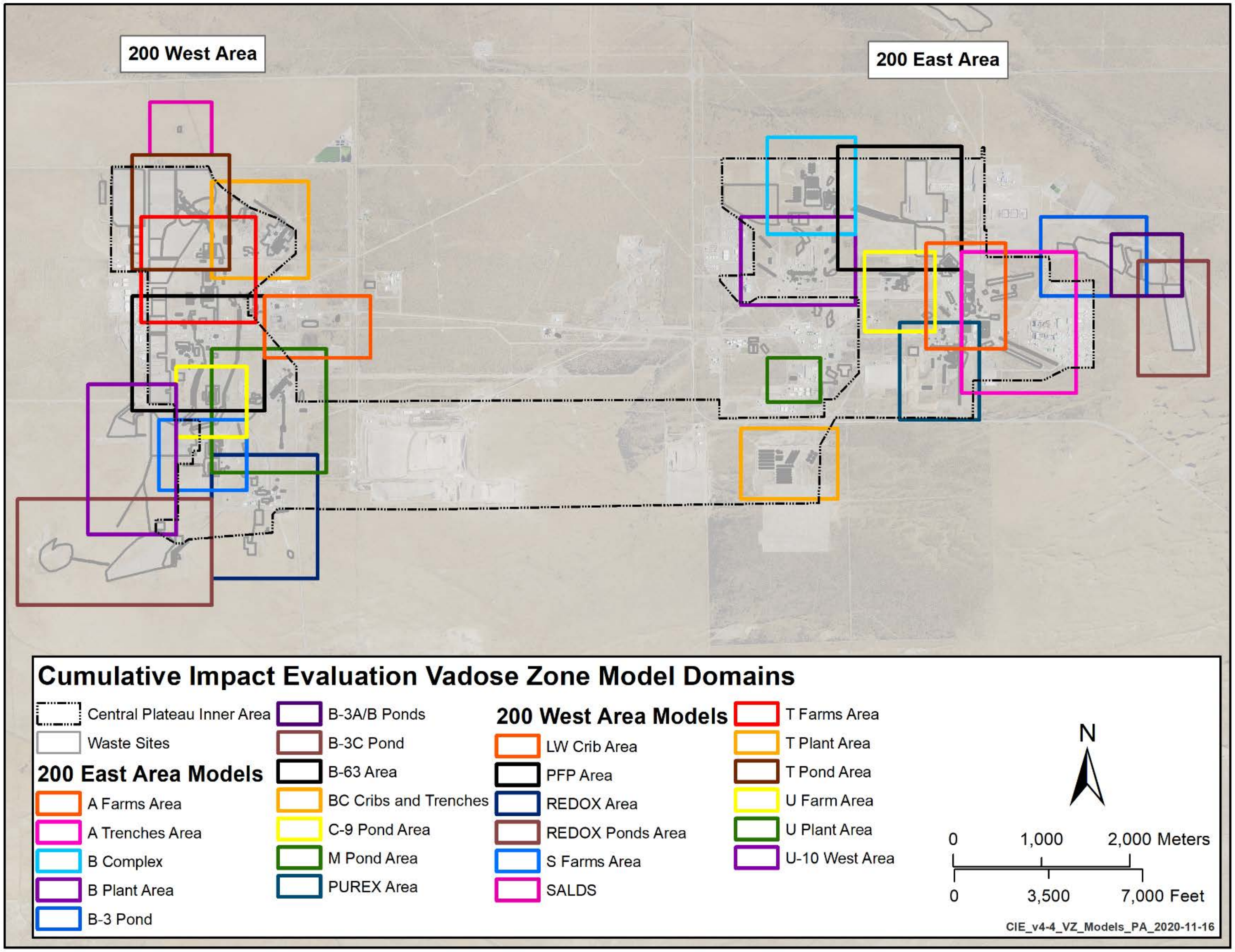

Figure 1-1. CIE Vadose Zone Model Domains

2 Background

The U-10 West Area model covers the vicinity of the 216-U-10 Pond in the southwestern part of the 200 West Area (Figure 2-1). There are two liquid waste sites within the source zone of the model: the 216-U-10 and 216-U-11 Ponds. The 216-U-11 Pond, an overflow pond for 216-U-10, is entirely within the model domain, but only the western part of the 216-U-10 Pond is within the model. The southeastern part of the pond is within the source zone of the S Farms Area model (ECF-HANFORD-20-0126, *Cumulative Impact Evaluation Vadose Zone Model for the S Farms Area, No Further Action Scenario*), and the northeastern part is within the U Farm Area model (ECF-HANFORD-20-0131, *Cumulative Impact Evaluation Vadose Zone Model for the U Farm Area, No Further Action Scenario*).

The 216-U-10 Pond System operated from 1944 to 1984 and consisted of the main pond, influent ditches, and overflow facilities (DOE/RL-91-52, *U Plant Source Aggregate Area Management Study Report*; RHO-HS-SR-84-3 4QLIQ, *Radioactive Liquid Wastes Discharged to Ground in the 200 Areas during 1984*). Originally, the 216-Z-1D Ditch conveyed water to the pond from the Plutonium Finishing Plant (PFP), and the 216-U-14 Ditch conveyed water from other sources mostly on the east side of the 200 West Area. Replacement ditches 216-Z-11 and 216-Z-19 were constructed to convey water from PFP, but the 216-U-14 Ditch was used the entire time 216-U-10 Pond was in operation (and continued as a standalone disposal facility until 1994). Sources of effluents to the 216-U-10 Pond System included the following (DOE/RL-91-52):

- Steam condensate and laboratory waste from PFP
- 284-W Powerhouse process cooling water
- Wastewater from the mask cleaning and laundry facilities
- Chemical sewer and cooling water from U Plant
- 241-U-110 Tank condenser water
- 242-S Evaporator steam condensate

The 216-U-11 Pond is located west of 216-U-10. It received overflow from 216-U-10 during years when discharge to the pond system was highest. It is estimated to have received water only from 1953 to 1958 (ECF-HANFORD-19-0032). Overflow water also entered the 216-U-9 Ditch which extended from the southwestern corner of the 216-U-10 Pond, but only for <1 year so it was not included as a source in the U-10 West Area model (ECF-HANFORD-19-0032).

The 216-U-10 Pond System received 165 million m^3 of effluents (DOE-RL, 2020, *Waste Information Data System General Summary Report*). Wastewater volumes and radionuclide inventories assigned to the 216-U-10 Pond System in CP-61786 did not take into account the movement of water between components of the pond system. To better estimate infiltration from each component, effluents assigned in CP-61786 were rerouted for this modeling effort, as described in Section 4.5.1.1 of this ECF and ECF-HANFORD-19-0032. Releases of radionuclides to the pond system were relatively low with the exception of uranium. An estimated 1,150 kg of uranium was released to the part of the pond system within the U-10 West Area model. The 216-U-10 Pond may be the source of elevated uranium concentrations in groundwater near the pond (DOE/RL-2009-122, *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit*).

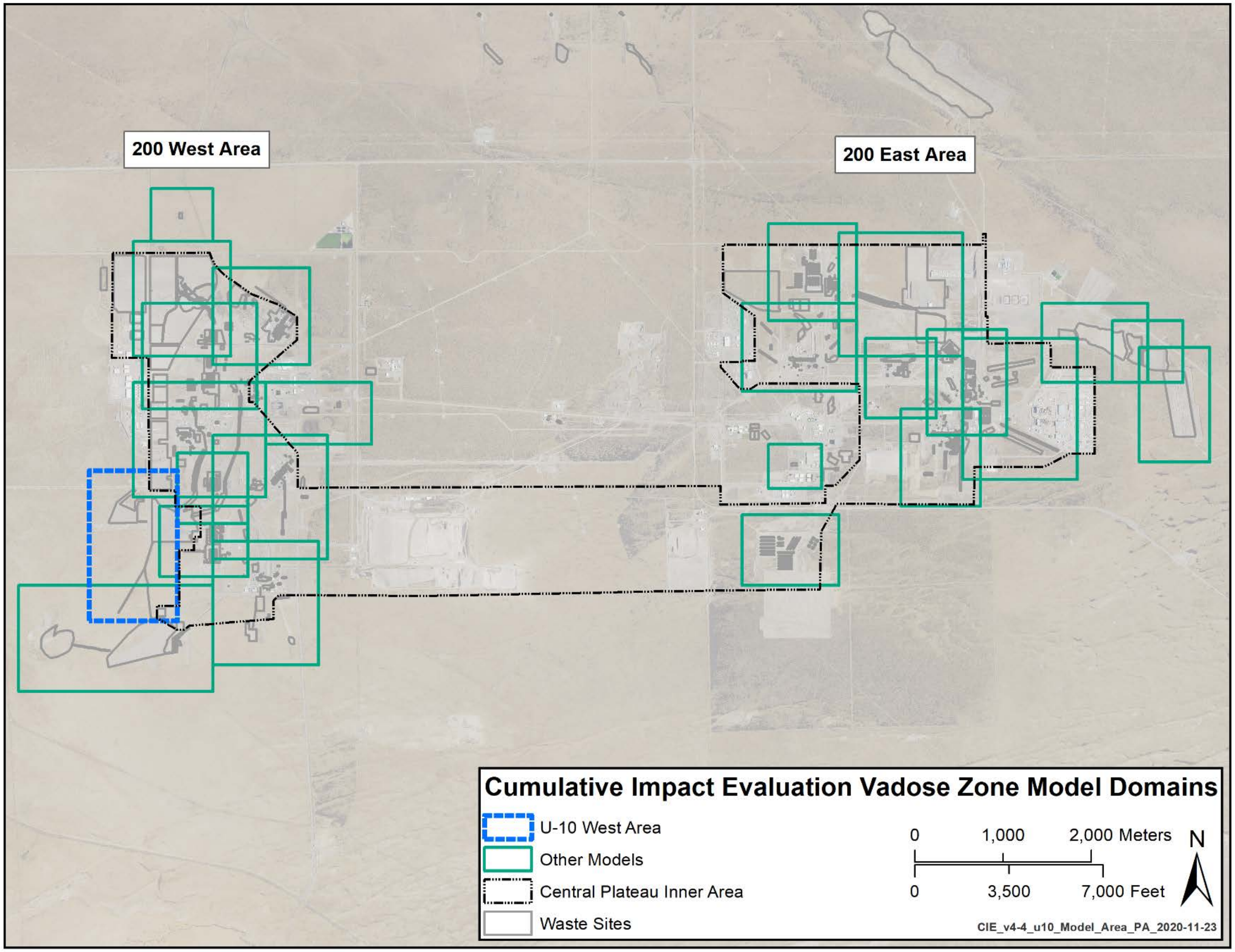

Figure 2-1. Location of the U-10 West Area Model

3 Methodology

This chapter contains a discussion of configuration control, a brief overview of the methodology for creating the U-10 West Area model, and a list of modifications specific to this model.

3.1 Configuration Control

A configuration control system was developed so that all vadose zone models generated for the CIE would follow a consistent set of conventions and use only approved input data (e.g., geoframework, hydraulic and contaminant properties, source releases, etc.). This system was manifested as sets of qualified input data, scripts used to construct the models and post-process the results, and sets of instructions for building and executing the models. Each script was reviewed, tested, and documented to qualify it for use. A list of scripts developed for the vadose zone modeling effort is found in Section 5.3 of this ECF. Each CIE model used the same directory structure. A discussion of the configuration control system is found in CP-63515.

A data configuration quality-control system (hereinafter called 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 to support the file management system.

The ICF houses all data produced by and in support of the CIE modeling effort. The ICF file management system ensures that no data can be modified, deleted, or used in a model application without being checked into the ICF, reviewed, and accepted by the ICF administrator. Separating the data flow from the modeling helps prevent accidental modification and guarantees a data review prior to acceptance of any data product into the ICF.

The utility scripts establish a pedigree for any data product stored in the ICF. The ICF allows users to ascertain all the ancestor and derivative products related to any ICF data product. By combining the file structure and software utilities, the ICF provides confidence that the CIE output data are associated with a set of versioned input data.

The CIE models were constructed on a central computer system, and many of the models contained over one million nodes. Along with the long time period simulated and the release of large volumes of water from liquid waste disposal sites in many of the model domains, the size of the models caused long run times. Thus, the model files were transferred to a high-power computer system, GAIA, for execution. Following completion of model runs, the input and output files were returned to the original computer system for post-processing. File fingerprinting was used to verify this transfer process and to verify that the correct input files were used for each model simulation.

3.2 Model Construction and Execution

This ECF is one of 24 similar ECFs, one for each CIE vadose zone model, each of which followed the same general methodology. A detailed description of the general model construction is found in CP-63515. Adjustments are made to the methodology as needed to tailor model development to best represent the area being simulated. The steps were developed to include mass balance checks to verify model performance. All model inputs were checked during production. Checking documentation is found in Appendix A. This model uses the same grid and HSU structure as the model in ECF-HANFORD-19-0062. Hydraulic and transport properties are retrieved from ECF-HANFORD-19-0121. A brief outline for the construction and execution of the U-10 West Area model is as follows:

1. Construct the model grid.

2. Assign HSUs and material properties to the model grid nodes.
3. Generate the temporal-spatial recharge distributions for the model using the RET.
4. Execute the steady-state flow simulation to establish the initial conditions for the transient simulations.
5. Conduct post-processing of the steady-state simulation, including calculating the liquid volume balance.
6. Incorporate the transient RET results, contaminant waste release, and liquid waste release data into the model input file. Generate input files for a historical simulation from 1943–2018, a forecast simulation from 2018–3070, and a simulation from 1943–3070 with no radionuclide decay which is used to check the mass and activity balances of the contaminants and liquid.
7. Modify liquid waste releases as necessary, for example, averaging of releases over time to improve model convergence.
8. Execute the contaminant mass/activity balance simulation.
9. Conduct post-processing of the contaminant mass/activity balance simulation, including calculating the mass balance.
10. Execute the historical (1943–2018) contaminant transport simulations.
11. Execute the forecast contaminant transport simulation from 2018–3070.
12. Conduct post-processing of the contaminant transport simulations to generate contaminant fluxes to groundwater for the saturated zone model.

3.3 Model-Specific Modifications

Model-specific changes were required for some models. This model required model-specific modifications. These modifications are as follows: averaged aqueous sources]over a number of years. This is discussed in Section 4.5.2.1.

4 Assumptions and Inputs

The domain and structure of the U-10 West Area model, hydraulic properties, boundary and initial conditions, source releases, the types of simulations performed, and assumptions are described in this chapter.

4.1 Model Domain and Grid

The U-10 West Area model was constructed to simulate contaminant transport through the vadose zone from the waste sites at and around the U-10 West Area in the 200 West Area. The extents and grid spacing of this model are shown in Figure 4-1. The grid used for this model was constructed in ECF-HANFORD-19-0062. A general approach to grid spacing for the CIE vadose zone models, both horizontal and vertical, is discussed in CP-63515. The U-10 West Area model grid is aligned with the saturated zone model grid (as defined by the P2R model, CP-57037) as shown in Figure 4-2. The U-10 West Area model has 93 columns from west to east (X-nodes), 156 rows from south to north (Y-nodes), and 152 layers in the vertical dimension (Z-nodes), for a total of 2,205,216 nodes. The total extent of the model is 1,000 m in the east-west direction and 1,700 m in the north-south direction. The southwest corner of the domain has coordinates of 565,400 m east and 133,500 m north (Washington State Plane, South Zone [4602]). The model extends vertically from the approximate water table elevation to the ground surface. Grid spacing was determined based on geologic layer thickness, plume extent, waste site alignment, and mass balance considerations. Preliminary model runs were used to evaluate spatial discretization, and refinements were made as necessary (e.g., to better represent source zone geometry and plume migration). Vertical spacing is 0.5 m.

This model has a source zone and a buffer zone. The dashed blue line in Figure 4-1 indicates the separation between the source and buffer zones. These regions are distinguished by how the contaminant inventory from waste sites is distributed. Water and contaminant releases are simulated for waste sites in the source zone, whereas only water volume releases are simulated for waste sites in the buffer zone. Water volume releases in the buffer zone were included so that their hydraulic effect on flow beneath the source area is accounted for. A waste site with contaminant releases located in the buffer zone is included in the source zone of another model.

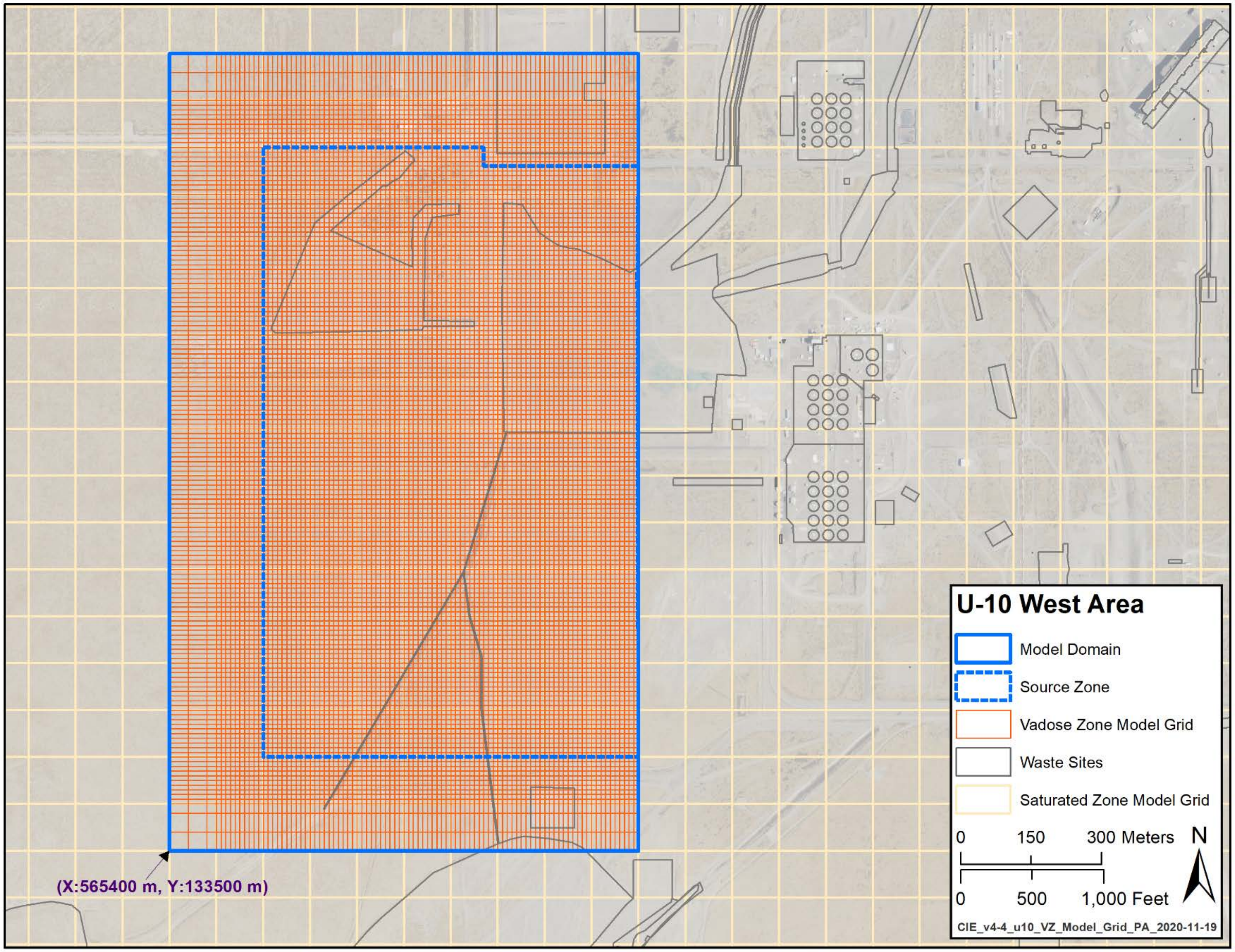

Figure 4-1. Plan View of the U-10 West Area Model Grid Overlain on the Saturated Zone Model Grid Cells

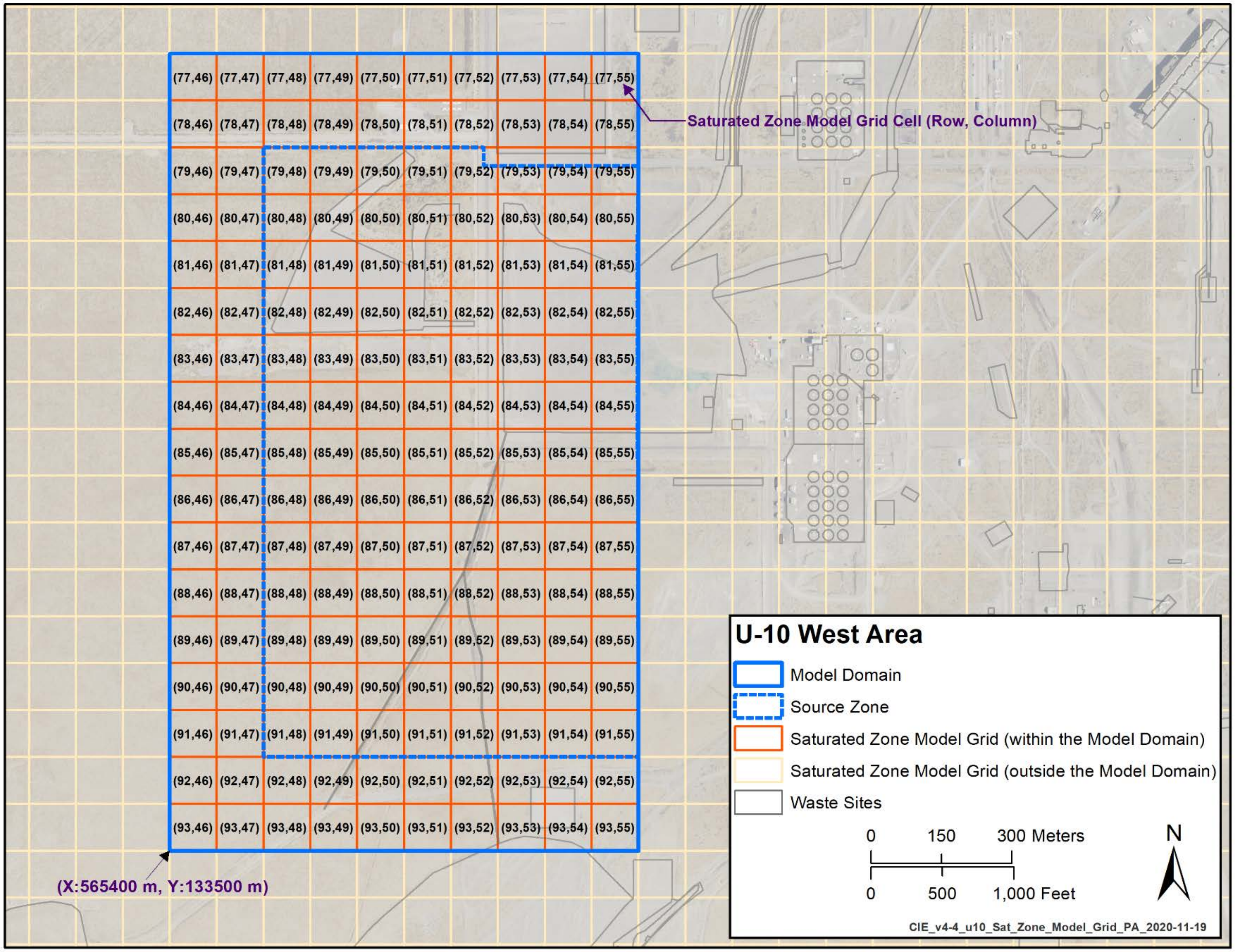

Figure 4-2. Plan View of the Saturated Zone Model Grid Cells beneath the U-10 West Area Model

4.2 Model Hydrostratigraphy

The U-10 West Area model includes seven HSUs: Backfill, Hanford formation unit 1 (Hf1), Hanford formation unit 2 (Hf2), Cold Creek unit upper silt and sand (CCUsilt), Cold Creek unit caliche (CCUc), Ringold Formation Member of Taylor Flat (Rtf), and Ringold Formation Member of Wooded Island – unit E (Rwie), in descending sequence. HSU designations were assigned to each grid node based on the surfaces in the geoframework model (ECF-HANFORD-18-0035). Standard Hanford Site nomenclature for the CCUsilt is CCUz, but this modeling effort refers to it as CCUsilt. Properties assigned to each HSU are presented in ECF-HANFORD-19-0121 and are described in Section 4.3. Figure 4-3 through Figure 4-6 show the hydrostratigraphic framework for the U-10 West Area model from various orientations. A progression of cross-sections from west to east and south to north through the model are shown in Appendix B of this ECF.

The topography is generally flat, although the northeast corner of the model has a higher elevation than elsewhere. The units in the model are relatively flat lying and have little variation in thickness, with some minor local undulations. The thickest units are the Hf1, Hf2, and Rwie. Hf2 and Rwie are separated by the relatively thin CCUsilt, CCUc, and Rtf units. The Rwie occurs at the bottom of the model and is the oldest layer.

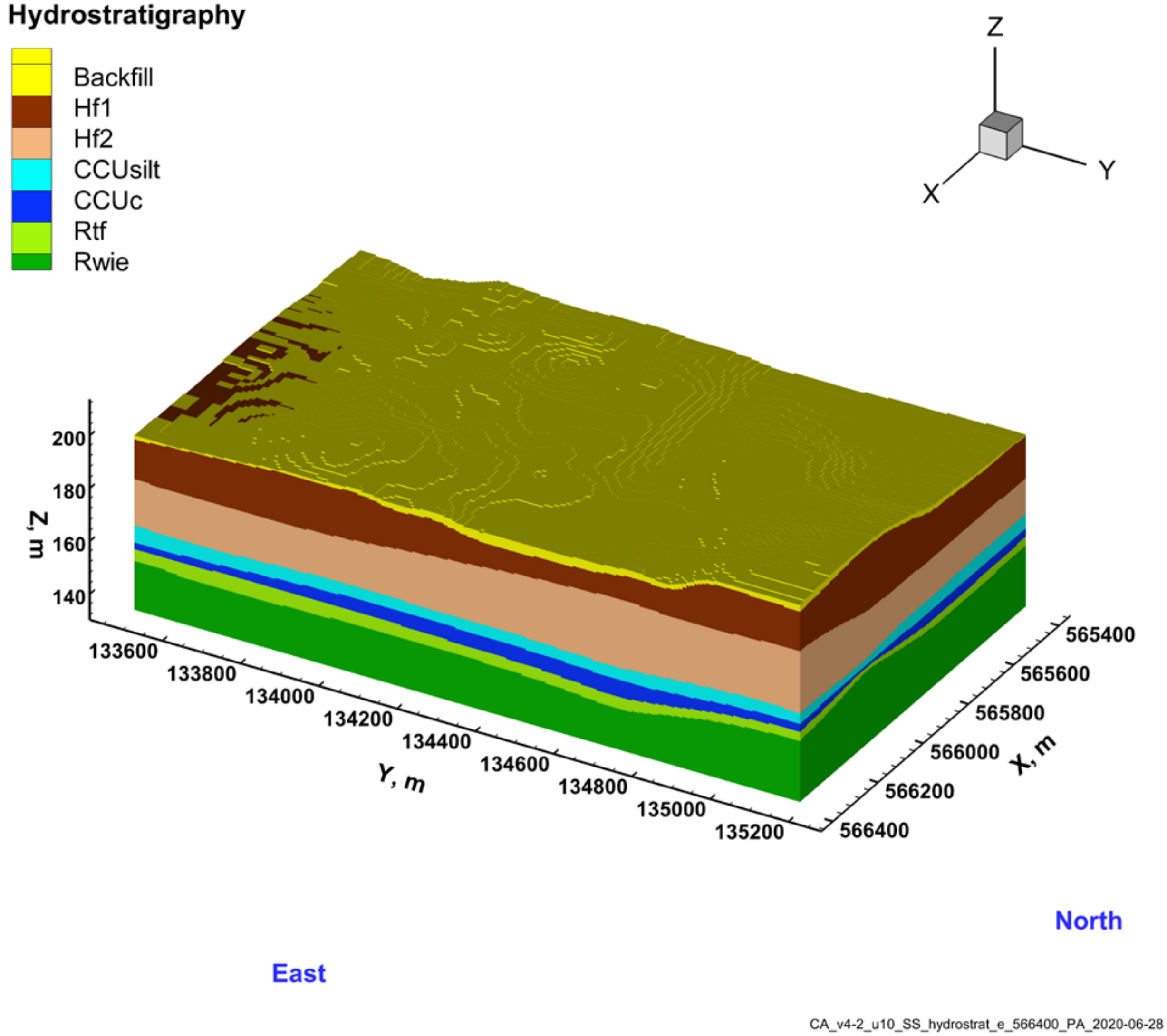

Figure 4-3. Model Hydrostratigraphy Three-Dimensional View Showing the North and East Faces

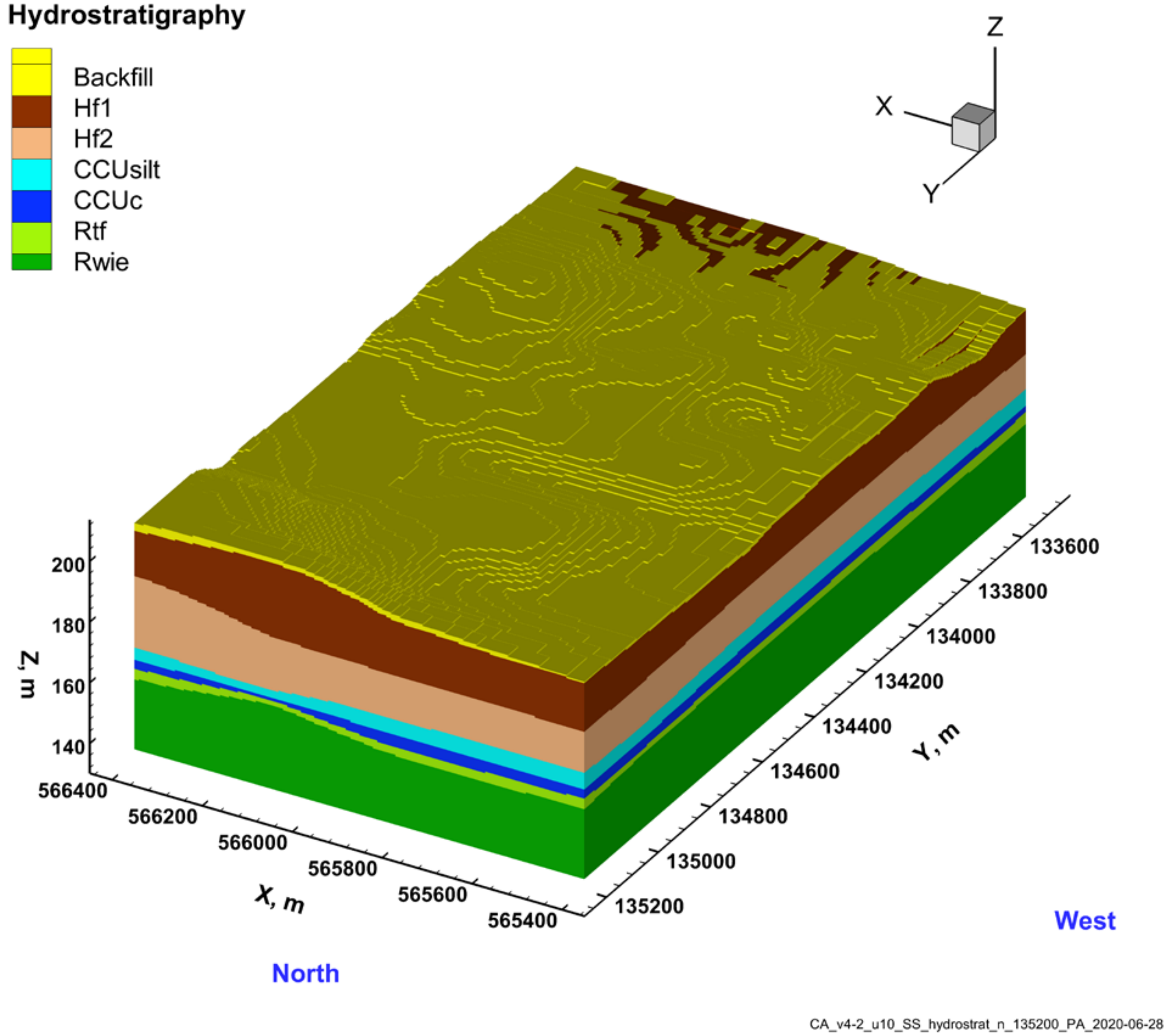

Figure 4-4. Model Hydrostratigraphy Three-Dimensional View Showing the North and West Faces

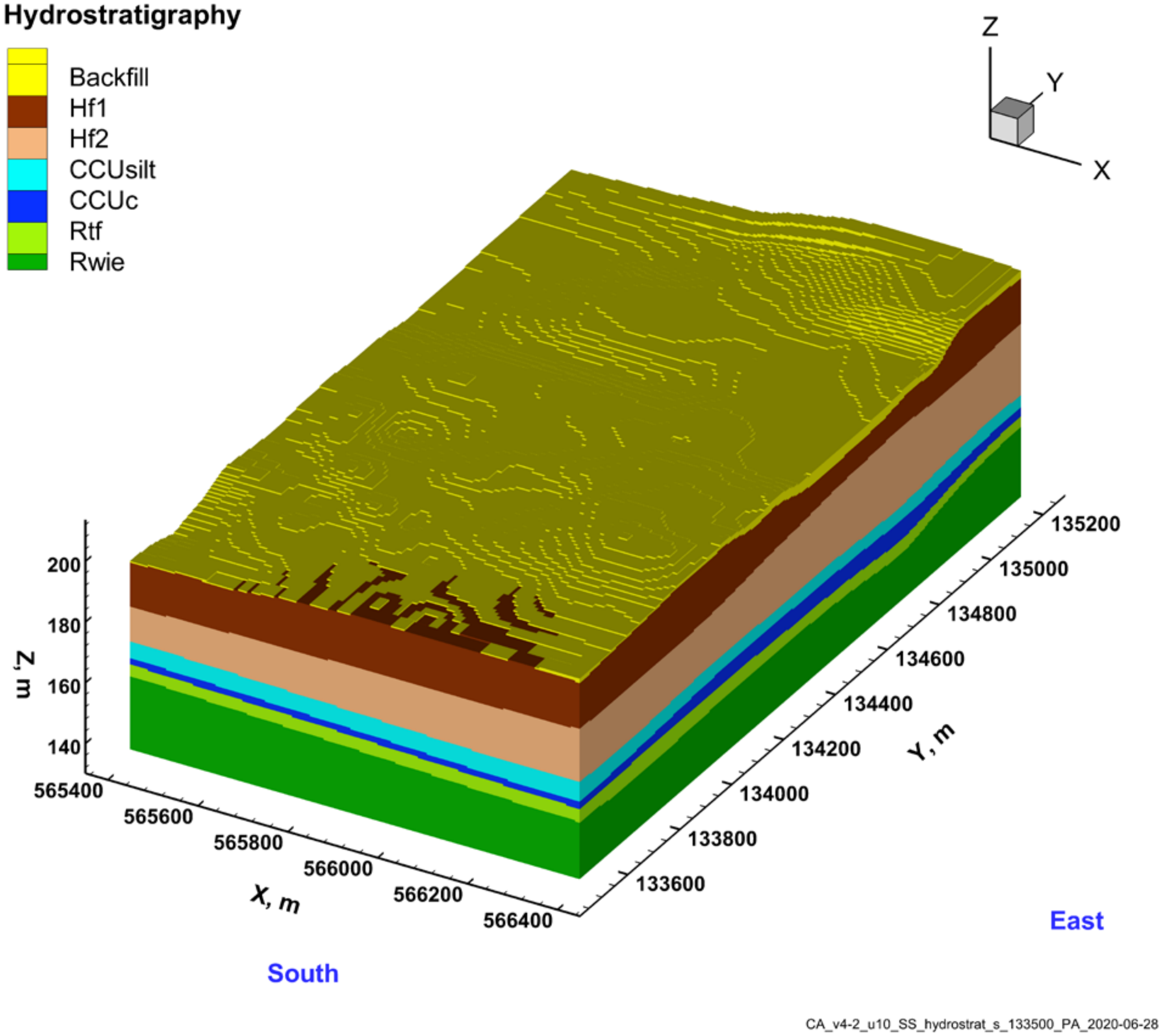

Figure 4-5. Model Hydrostratigraphy Three-Dimensional View Showing the South and East Faces

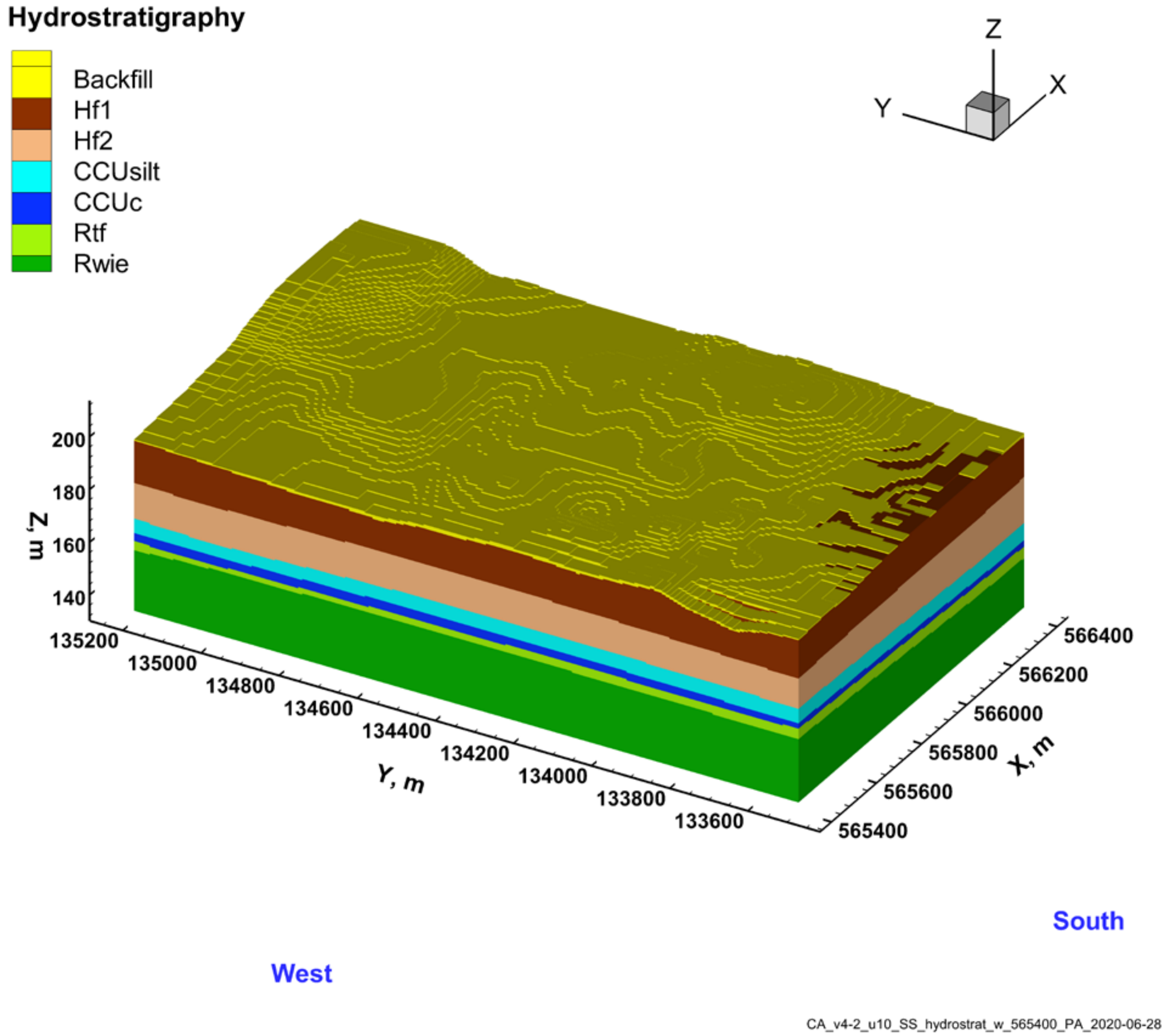

Figure 4-6. Model Hydrostratigraphy Three-Dimensional View Showing the South and West Faces

4.3 Hydraulic Properties

Hydraulic properties for the U-10 West Area HSUs are shown in Tables 3, 4, 6, and 7 of ECF-HANFORD-19-0121. For most of the HSUs, hydraulic property estimates in ECF-HANFORD-19-0121 were obtained from CP-63883, which contains a detailed description of the development of these parameters for the unconsolidated sediments overlying the basalt HSU in the Central Plateau. Properties for the basalt HSU were obtained from other sources.

HSUs were assumed to follow the van Genuchten moisture-retention constitutive relation (van Genuchten, 1980, “A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils”) and the Mualem-van Genuchten relative-permeability constitutive relation (Mualem, 1976, “A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media”), requiring values to be specified in STOMP for the following items:

- Saturated hydraulic conductivity.

- Saturated moisture content.
- Residual saturation, equal to the residual moisture content divided by the saturated moisture content.
- van Genuchten α, proportional to the inverse of the air entry matric potential.
- The dimensionless van Genuchten *n* fitting parameter.
- The tensorial connectivity-tortuosity (TCT) parameters for moisture dependent anisotropy (the TCT parameters are discussed in CP-63515 and ECF-HANFORD-19-0094).

4.4 Transport Parameters

In addition to the hydraulic properties discussed in Section 4.3, the transport simulations also require particle density, molecular diffusion rate, longitudinal and transverse dispersivity, solid-aqueous partition coefficient (K_d), and radionuclide half-life. Tables 5, 8, 9, 10, 13, 15, and 16 of ECF-HANFORD-19-0121 list the transport properties for the HSUs present in the modeled area. A detailed description of the transport properties used for the CIE vadose zone models can be found in ECF-HANFORD-19-0121.

4.5 Source Releases

As discussed in Section 4.1, waste sites in the source zone release both water and contaminants, while waste sites within the buffer zone are simulated as water-only releases (i.e., the contaminant inventory is not included). Some sites within a model's source zone lack a contaminant inventory and are also simulated as water-only releases (e.g., septic systems). The CIE vadose zone models currently only consider liquid waste releases and not releases from solid wastes (DOE/RL-2018-69). An index of waste sites contributing releases to the model is shown in Table 4-1. A map of waste sites contributing releases to this model is shown in Figure 4-7. Section 4.5.1 contains a discussion of the contaminant inventory released from waste sites in the model, and Section 4.5.2 addresses liquid (volume) releases from waste sites, including water-only release sites.

Table 4-1. Waste Sites Included in the U-10 West Area Model

Source Zone – Waste Sites with Liquid Contaminant Releases (2)	
216-U-10	216-U-11
Source Zone – Sites with No Contaminant Releases (Liquid Only) (0)	
None	
Buffer Zone – Sites (Liquid Only) (2)	
216-S-17	216-S-6

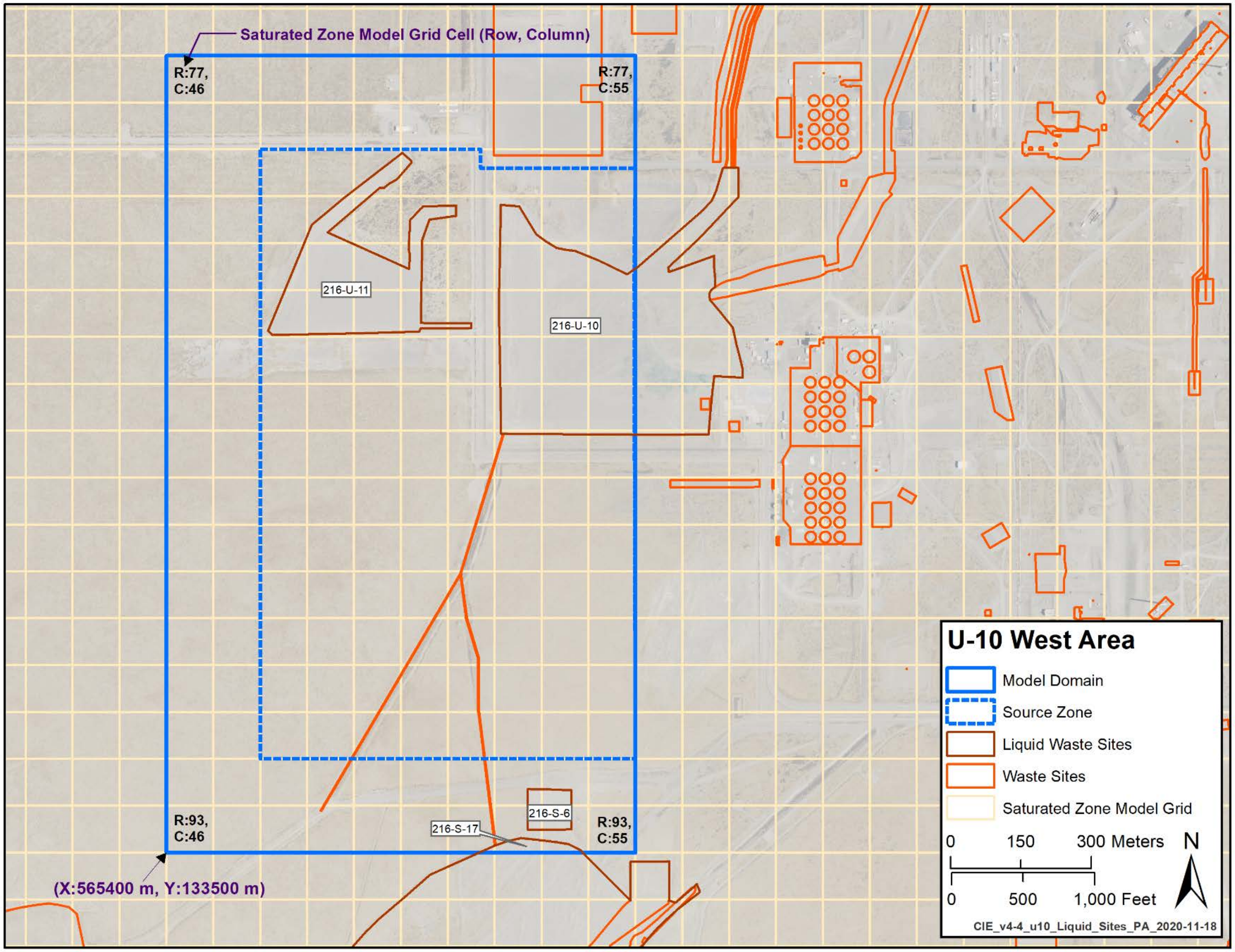

Figure 4-7. Waste Sites in the U-10 West Area Model with Liquid Source Inventory

The contaminants selected for the CIE vadose zone modeling effort were determined through a screening process based on prior modeling studies. DOE/RL-2018-69 identified eight contaminants for simulation. Not all eight contaminants are present in every model. No inventory is present at the waste sites in this model domain for CN; therefore, it was not simulated. Chemical contaminant masses and radionuclide activities released in the model are shown in Table 4-2. Radionuclide inventory is decayed to the year of release (CP-61786). All contaminated liquid releases end prior to 2018.

Table 4-2. Released Contaminant Inventory in the U-10 West Area Model, 1943–2018

Contaminant	Total Mass or Activity Released*
H-3	6.934E+02
I-129	1.113E-01
Sr-90	2.025E+00
Tc-99	8.859E-03
Total U	1.154E+03
Cr	5.586E+03
NO_3	1.364E+06
CN	0.000E+00

*Units are in kilograms for Cr, CN, NO_3, and total U, units are in Curies for tritium, I-129, Sr-90, and Tc-99.

The waste site inventory was compiled from multiple sources. The main sources of data for the inventory are Appendix B of CP-64710 and Appendix F of CP-61786. Water-only (e.g., non-contaminated wastes) waste disposals not otherwise included in CP-64710 and CP-61786 inventories were sourced from EMDT-IN-0046[4]. Certain waste sites required liquid waste rerouting; this calculation was carried out as pre-processing to this modeling effort and is discussed in ECF-HANFORD-19-0032 and in the following paragraphs.

The assignment of contaminant inventories to ditch/pond systems in CP-61786 and CP-64710 did not take into account the movement of water between components of these systems (e.g., between an influent ditch and the main pond, or between lobes of a pond system). Only a portion of the inventory assigned to a particular ditch or pond in CP-61786 and CP-64710 may have infiltrated from that site due to movement of the water into another segment of the system. For the U-10 West Area model, liquid wastes assigned to the 216-U-10 Pond System and the 216-U-14 Ditch were adjusted to better account for the partitioning of infiltration within this system (ECF-HANFORD-19-0032).

The 216-U-10 Pond received effluents via the 216-U-14 Ditch and the 216-Z Ditches, the latter from the PFP. In CP-61786 and CP-64710, all of the releases to the 216-Z Ditches were assigned to those ditches. However, only a small percentage of the discharged volume infiltrated from the ditches as most of the

[4] EMDT-IN-0046, *SAC Inventory Results File for Non-Contaminated Effluent Discharges*, Rev. 0, CH2M Hill Plateau Remediation Company, Richland, Washington. Electronic model data transmittals are stored in the Environmental Model Management Archive. A copy of the cover sheet for this EMDT is provided in Appendix E of this ECF.

water flowed into the 216-U-10 Pond. Infiltration of this water was partitioned between the ditches and the 216-U-10 Pond based on the ratio of the area of each ditch to the pond area. Infiltration from the 216-U-14 Ditch was partitioned between the ditch and the 216-U-10 Pond in CP-61786 and CP-64710, but this was recalculated using the same methodology as used for the 216-Z Ditches for consistency. During years of high total discharge to the 216-U-10 Pond, some of the water flowed into the 216-U-11 Pond, which was used for overflow. This was estimated also as part of the rerouting based on an estimated maximum infiltration volume for the 216-U-10 Pond. For more details, see ECF-HANFORD-19-0032.

The 216-Z and 216-U-14 Ditches are not in the U-10 West Area model, but occur to the east and north in the source zones of the U Farm Area model (ECF-HANFORD-20-0131) and the PFP Area model (ECF-HANFORD-20-0122, *Cumulative Impact Evaluation Vadose Zone Model for the PFP Area, No Further Action Scenario*). Portions of the 216-U-10 Pond occur also in several other models. The major portion (western) of the pond is within the U-10 West Area model; the remainder of the pond is in the U Farm Area model and the S Farms Area model. The U-10 West Area model also contains the entirety of the 216-U-11 Pond, and a small portion of this pond occurs in the buffer zone of the PFP Area model. The 216-U-10 Pond areal fractions are 0.1995, 0.1986, and 0.6019 for the S Farms Area, U Farm Area, and U-10 West Area models, respectively.

4.5.1 Contaminant Releases

This section describes the releases of contaminants to the subsurface from liquid waste sites included in the U-10 West Area model. Liquid waste sites are sites where liquid wastes, often containing contaminants, are released to the vadose zone. A map of liquid waste sites in the U-10 West Area model is shown in Figure 4-7. The contaminants discharged to this model from liquid waste sites are shown as site totals in Figure 4-8 through Figure 4-14, and by waste site by year in Figure 4-15 through Figure 4-21. Waste sites that contributed less than 0.1% of the total contaminant release were not included in the images for Figure 4-8 through Figure 4-14.

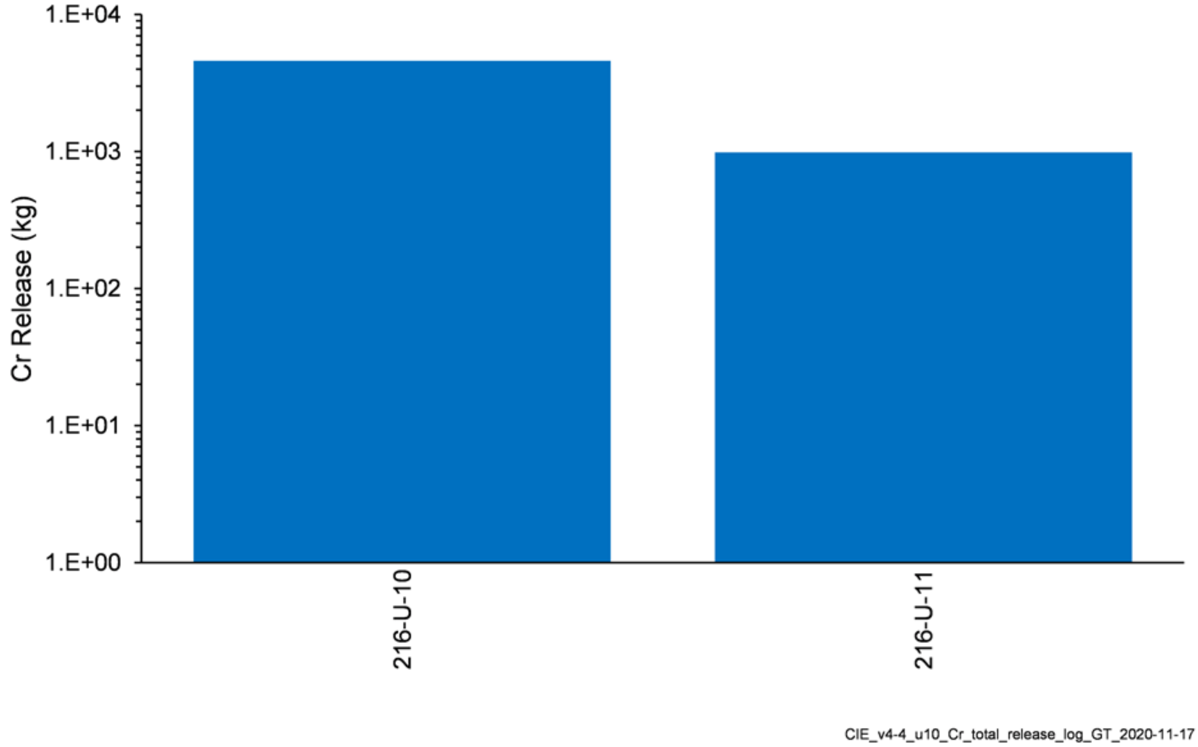

Figure 4-8. Chromium Mass Released from Liquid Waste Sites in the U-10 West Area Model

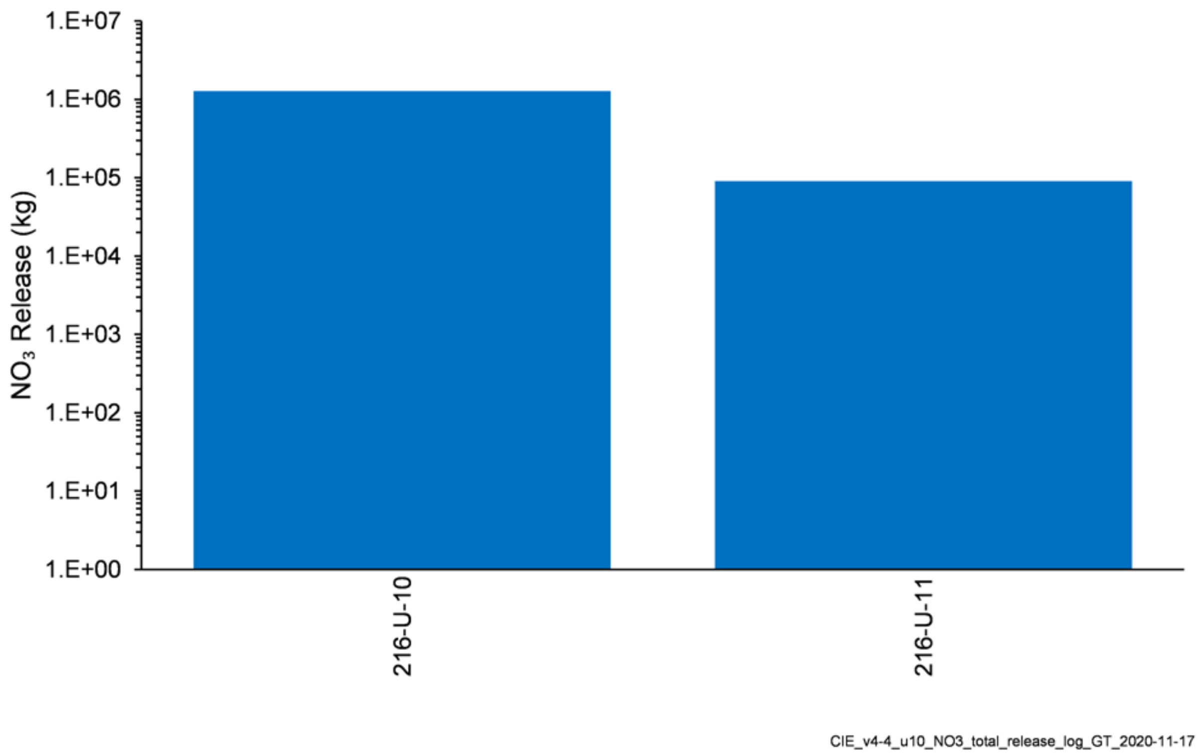

Figure 4-9. NO_3 Mass Released from Liquid Waste Sites in the U-10 West Area Model

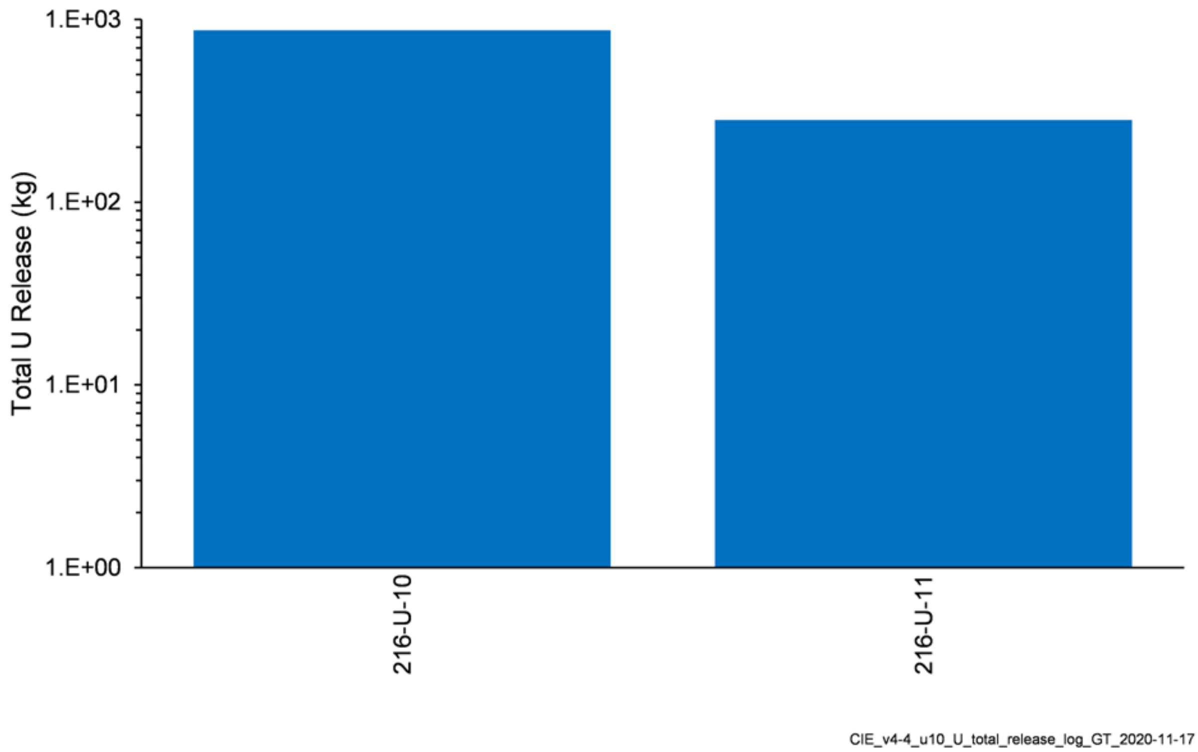

Figure 4-10. Total Uranium Mass Released from Liquid Waste Sites in the U-10 West Area Model

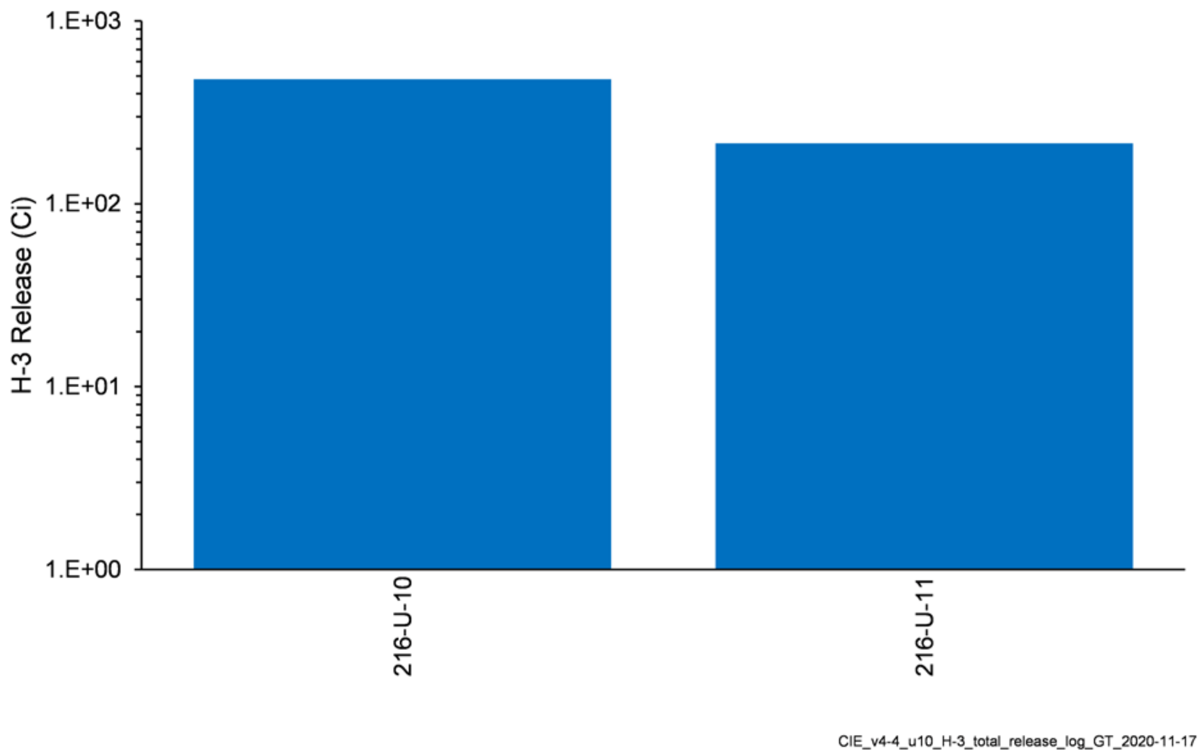

Figure 4-11. H-3 Activity Released from Liquid Waste Sites in the U-10 West Area Model

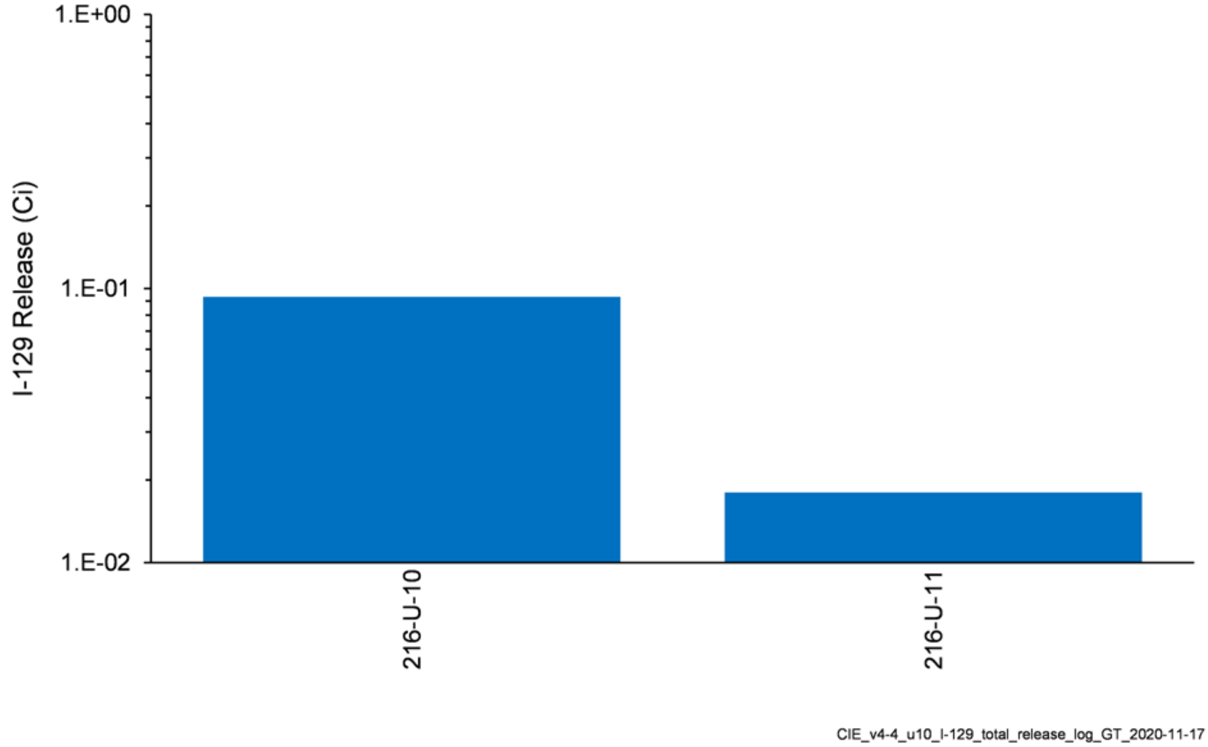

Figure 4-12. I-129 Activity Released from Liquid Waste Sites in the U-10 West Area Model

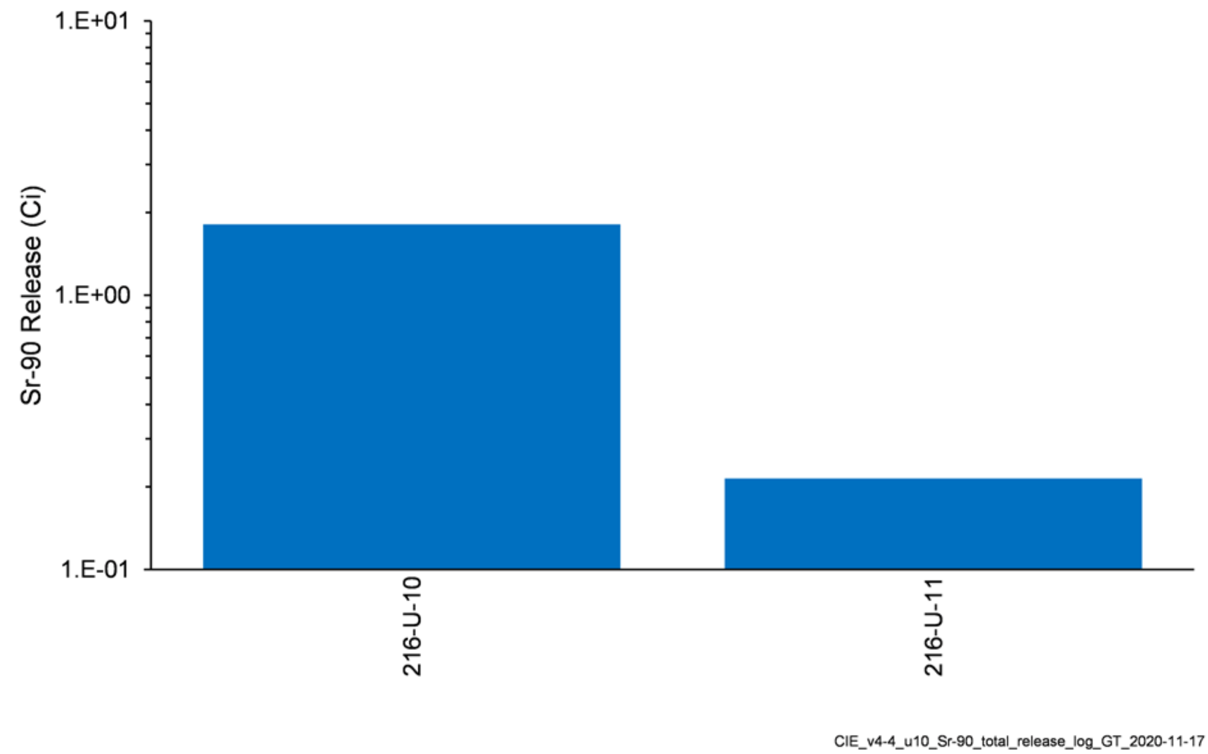

Figure 4-13. Sr-90 Activity Released from Liquid Waste Sites in the U-10 West Area Model

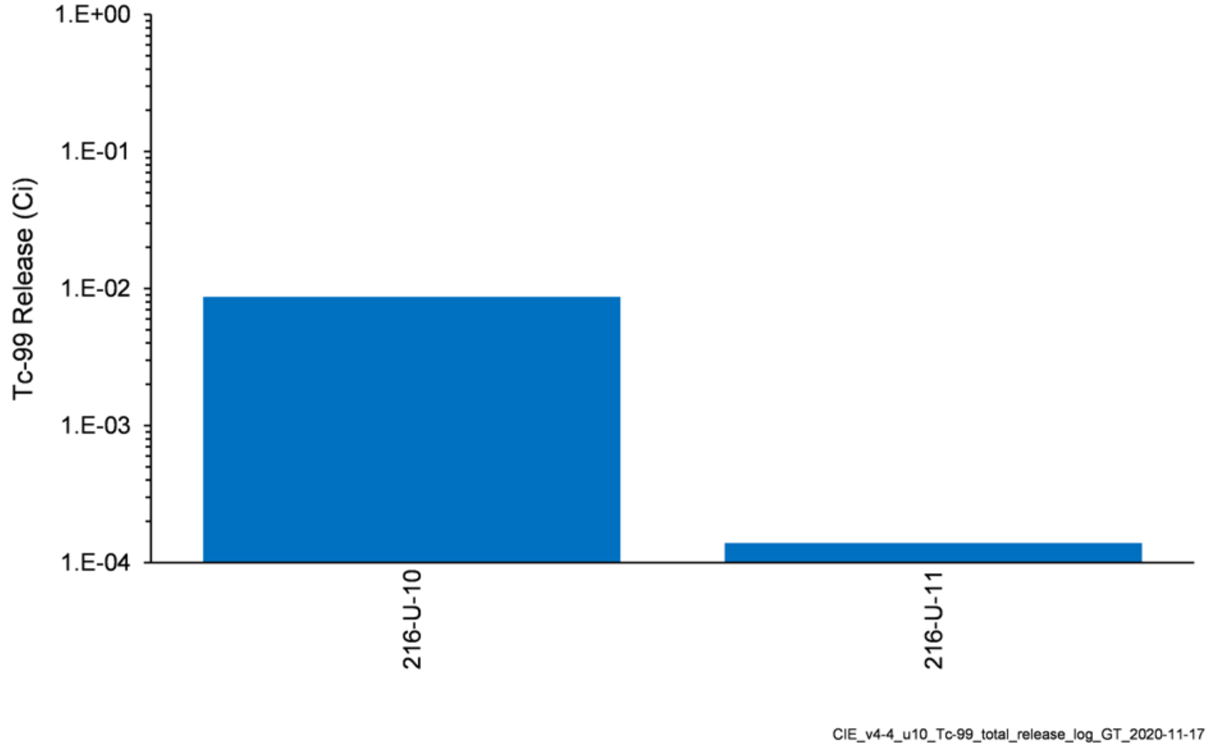

Figure 4-14. Tc-99 Activity Released from Liquid Waste Sites in the U-10 West Area Model

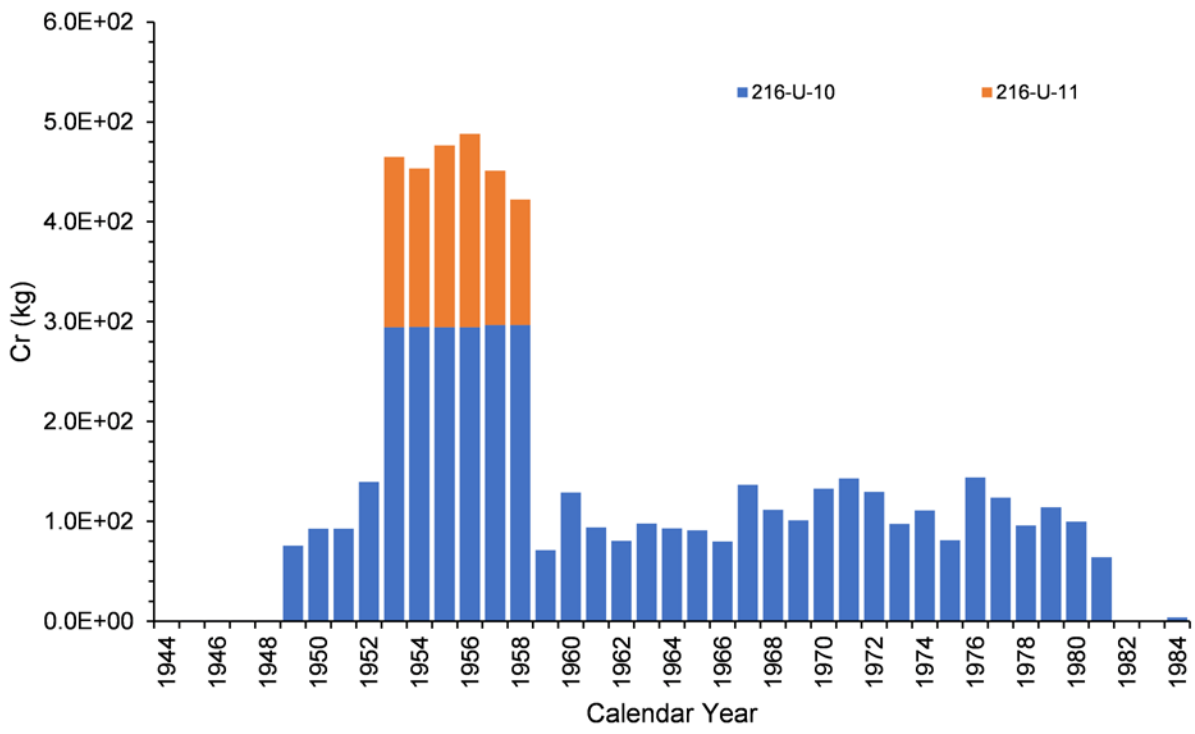

Figure 4-15. Annual Chromium Mass Released from Liquid Waste Sites in the U-10 West Area Model

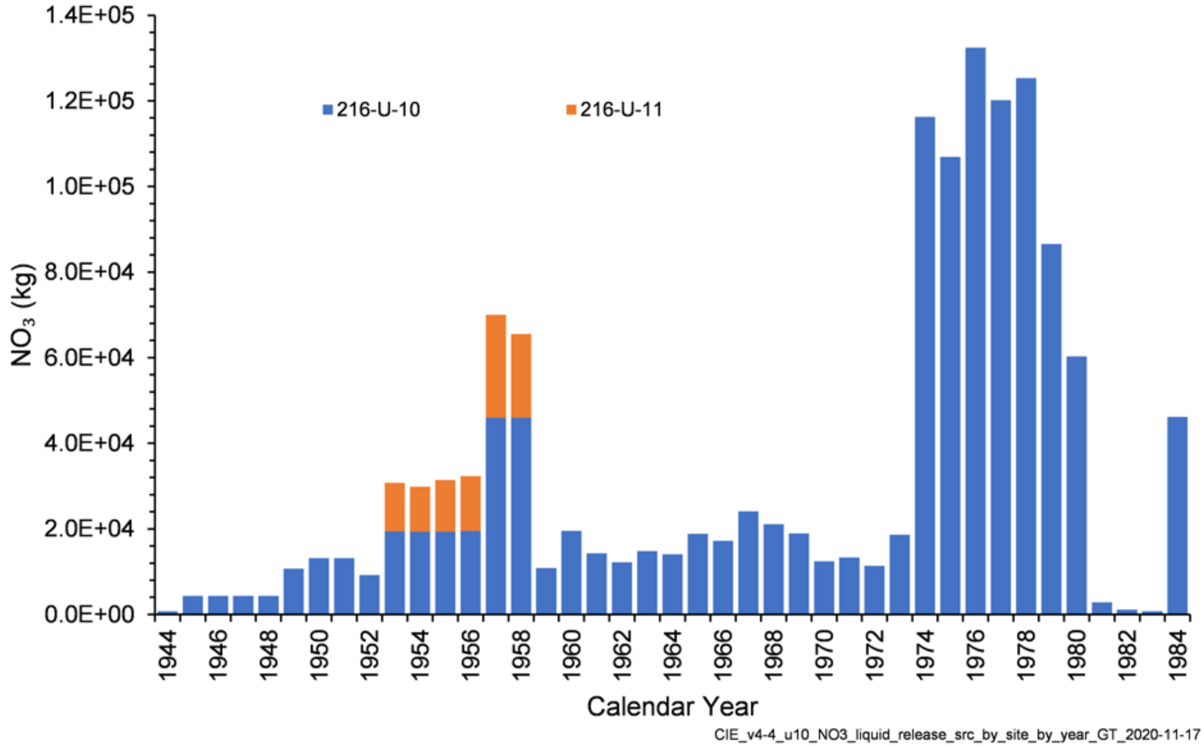

Figure 4-16. Annual NO_3 Mass Released from Liquid Waste Sites in the U-10 West Area Model

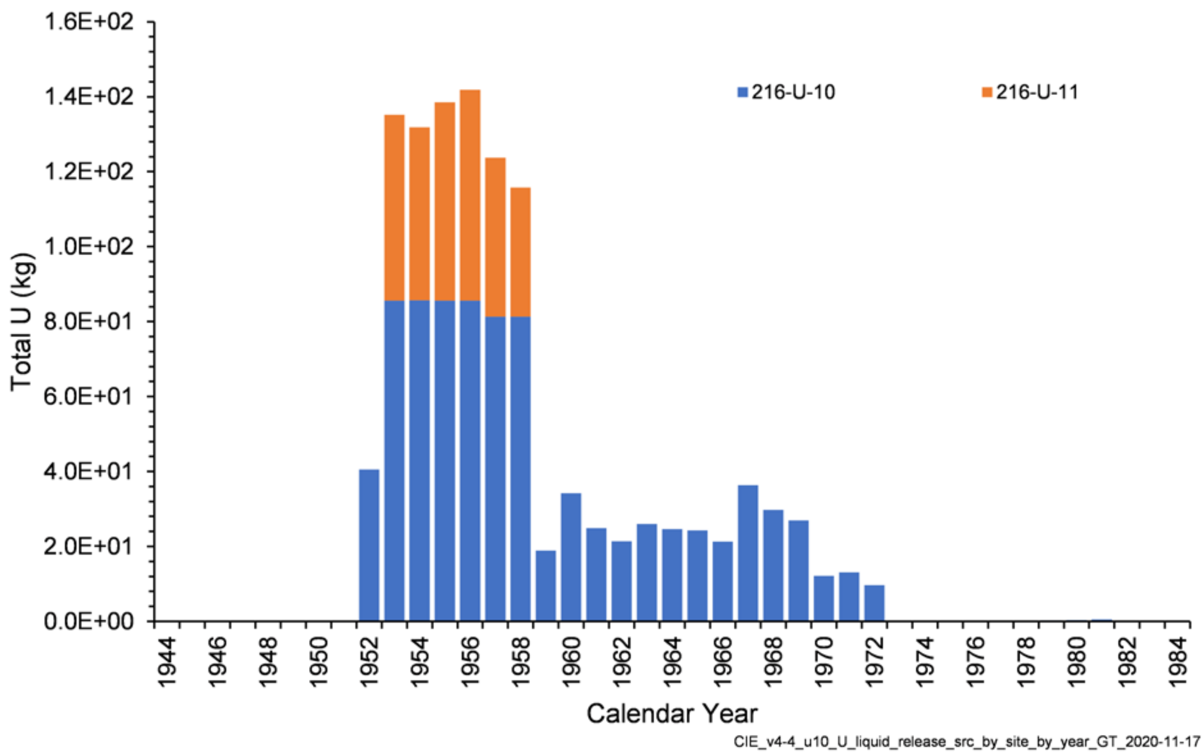

Figure 4-17. Annual Total Uranium Mass Released from Liquid Waste Sites in the U-10 West Area Model

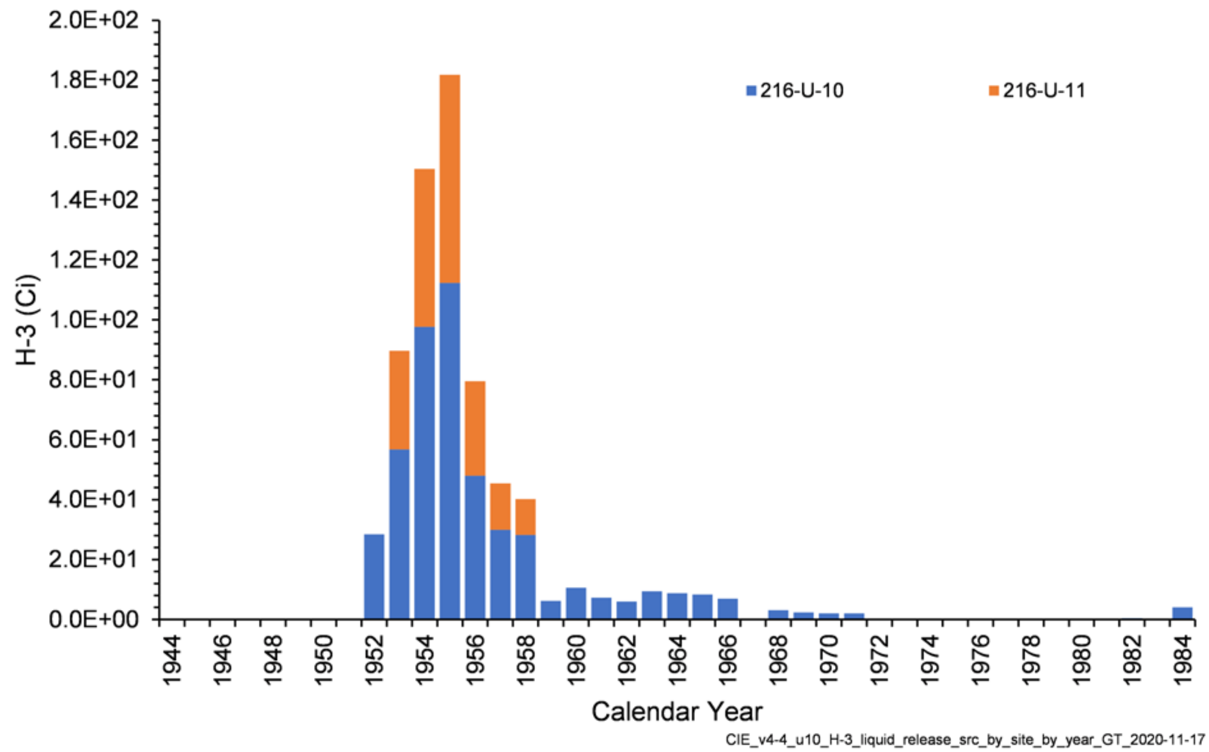

Figure 4-18. Annual H-3 Activity Released from Liquid Waste Sites in the U-10 West Area Model

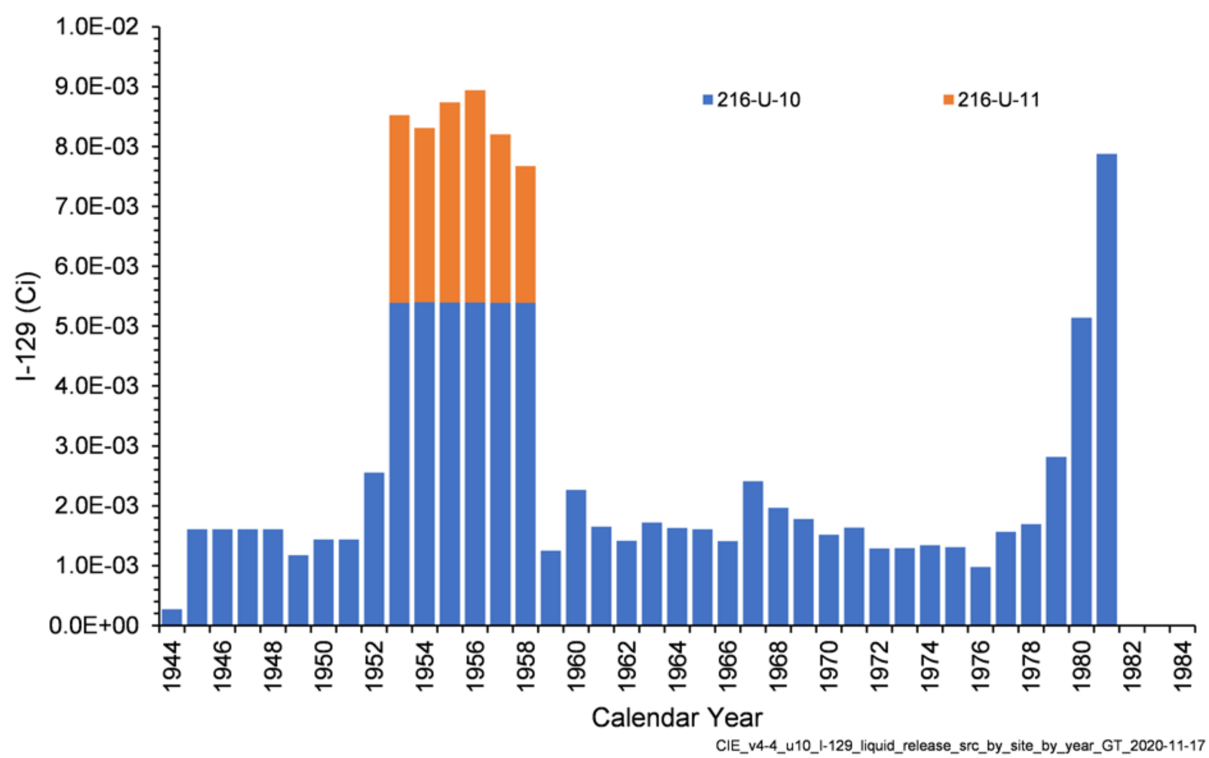

Figure 4-19. Annual I-129 Activity Released from Liquid Waste Sites in the U-10 West Area Model

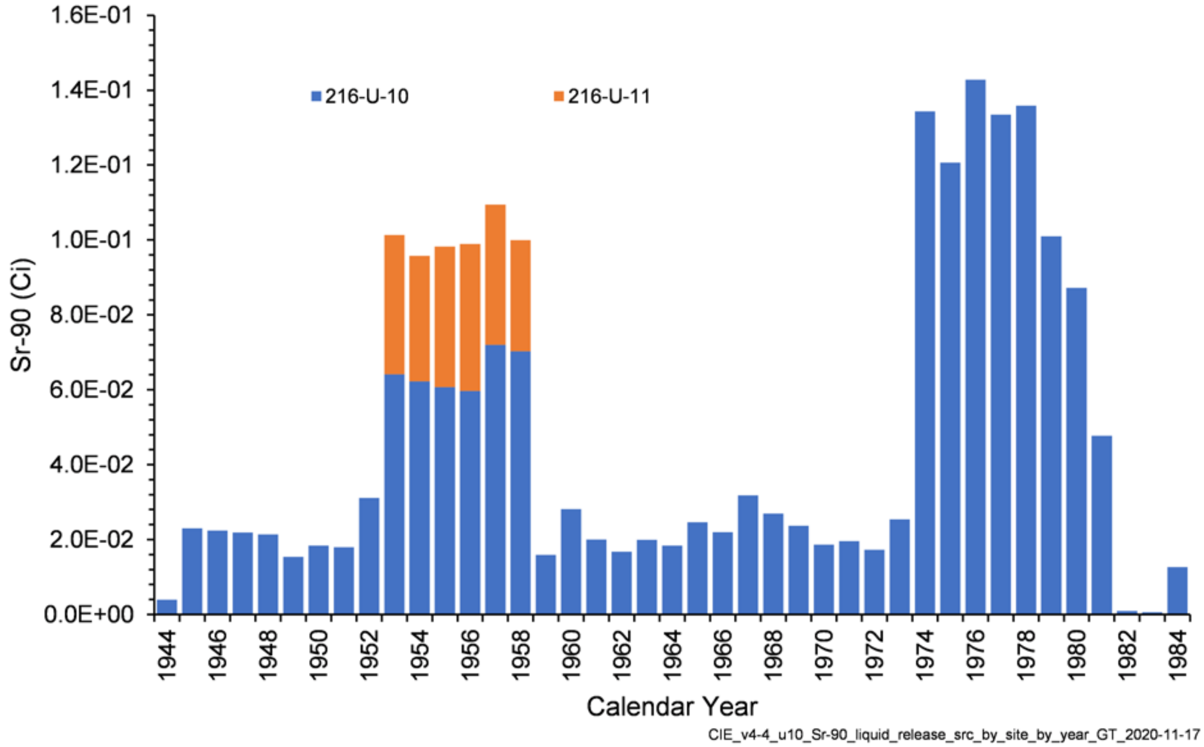

Figure 4-20. Annual Sr-90 Activity Released from Liquid Waste Sites in the U-10 West Area Model

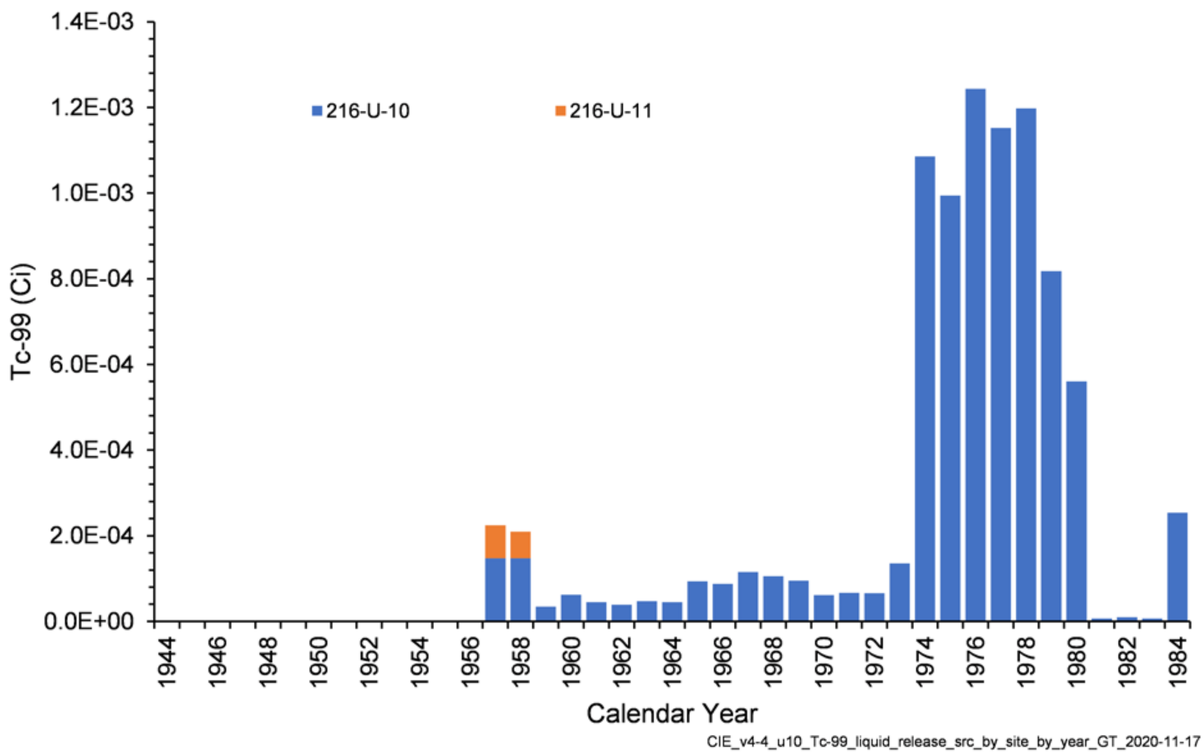

Figure 4-21. Annual Tc-99 Activity Released from Liquid Waste Sites in the U-10 West Area Model

4.5.2 Liquid (Volume) Releases

This section provides information on liquid volumes released within the domain of the U-10 West Area model. These liquids can act as a driving force for the movement of contaminants deeper into the subsurface. Table 4-3 shows an overview of the total liquids released in the model. Figure 4-22 shows the volume of water released within the model domain by waste site, and Figure 4-23 shows the total volume of water released by year.

Table 4-3. Released Liquid Volumes in the U-10 West Area Model

Modeled Time Period	Total	Source Zone	Buffer Zone
1943–2018	9.006E+07	8.552E+07	4.545E+06
2018–3070	0.000E+00	0.000E+00	0.000E+00

Note: All values reported in m^3.

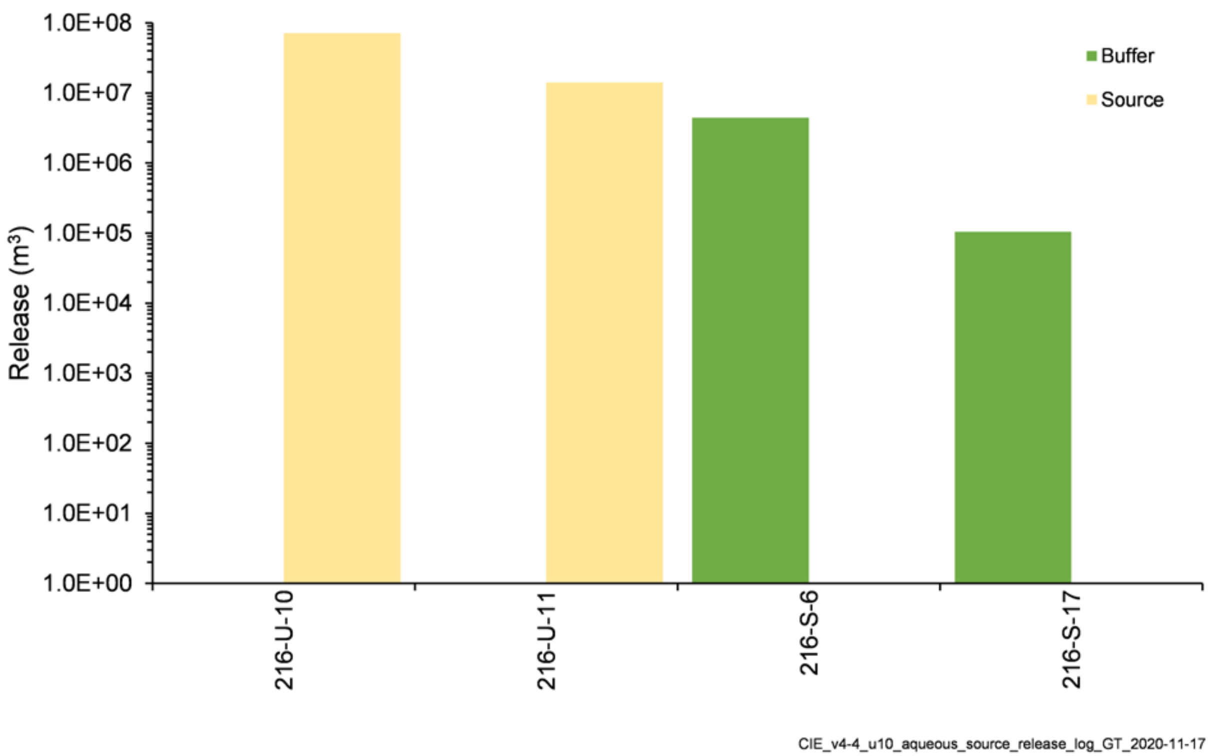

Figure 4-22. Total Volume of Water Released from Liquid Waste Sites in the U-10 West Area Model

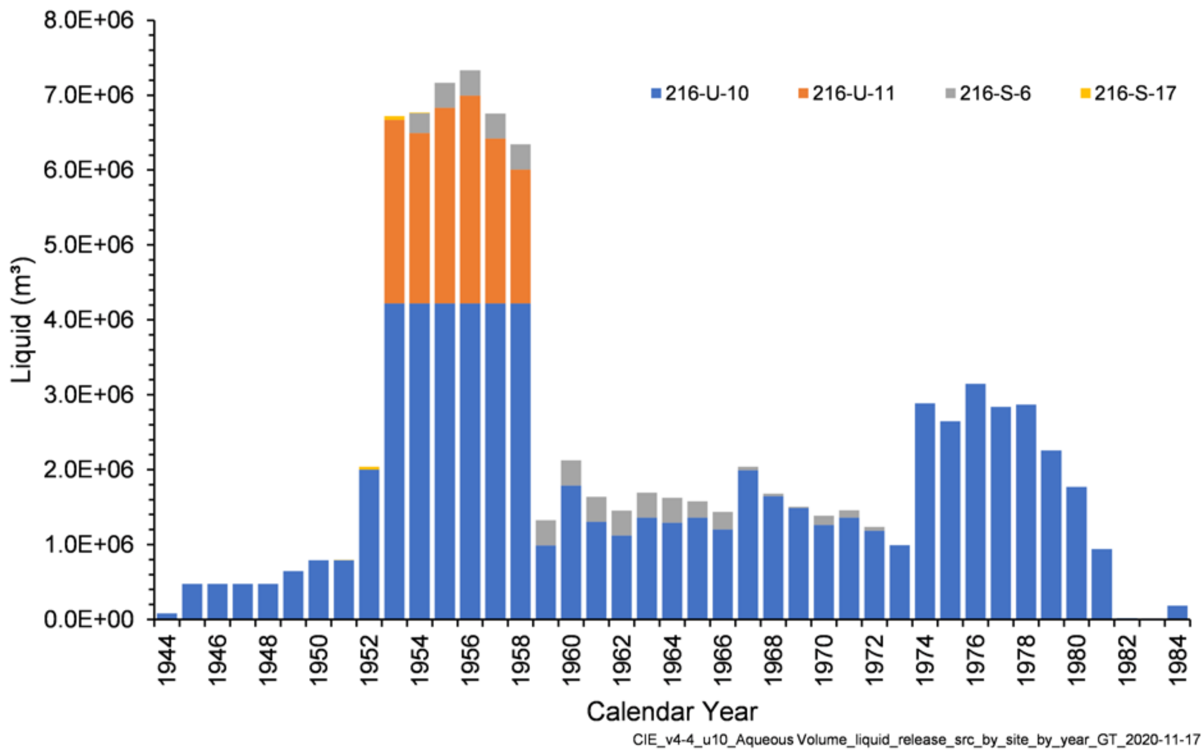

Figure 4-23. Total Volume of Water Released by Year from Liquid Waste Sites in the U-10 West Area Model

4.5.2.1 Liquid Release Modifications

For some models, modifications to liquid release volumes were needed to help with convergence of the numerical solution or to provide for more representative transport through the vadose zone.

Model Convergence Resolution

This model required that the water at 216-S-6 be averaged so the numerical solution of the model governing equation may converge. For each waste site, the water discharged over a specified time period was summed, averaged, and evenly distributed throughout the same time period. The time period over which the discharge was averaged for the waste site is shown in Table 4-4.

Table 4-4. Liquid Release Modifications for the U-10 West Area Model

Site Name	Model Zone	Original Start Year	Original End Year	Modified Start Year	Modified End Year	Averaged Release Rate (m^3/yr)
216-S-6	Buffer	1955	1964	1955	1964	335,305

4.6 Simulations

Three different types of simulations were performed. Constant recharge conditions were used in a flow-only simulation to set the initial aqueous pressure conditions in the model, a mass balance simulation was conducted to evaluate model performance, and transport simulations were performed to estimate annual contaminant mass or activity entering the saturated zone. These three types of simulations are discussed in the following sections.

4.6.1 Flow-Only (Steady-State) Simulation

The flow-only simulation was performed using recharge estimated for 1943, the year prior to the start of Hanford Site operations. These recharge conditions are assumed to represent pre-Hanford Site conditions, as disturbances in recharge values due to Hanford Site operations had not yet occurred. The flow-only simulation is a transient simulation, but it is referred to hereinafter as the steady-state simulation because recharge was held constant at the 1943 values and the simulation was run for 10,000 years to ensure steady-state conditions were achieved within the model domain. The results were used as the initial aqueous pressure conditions for the contaminant transport simulations starting in 1943.

4.6.2 Mass/Activity Balance Simulation

A mass/activity balance simulation was conducted to evaluate model performance. This simulation was run from 1943–3070, 1,000 years after assumed Hanford Site closure in 2070, using the source releases described in Section 4.5 and the initial aqueous pressure conditions from the steady-state simulation described in Section 4.6.1. Radionuclide half-lives were set to 1.0E+20 years to eliminate radiological decay and allow for the activity balance to be evaluated directly. The mass or activity of each constituent leaving the model and the mass or activity present in the model at the end of the simulation were summed, and the results were compared to the mass or activity released from the sources. The liquid volume balance was also calculated.

4.6.3 Transport Simulations

Transport simulations were performed to estimate the contaminant activity/mass entering the saturated zone. These were done in stages. The time period for the CIE evaluation is 2018–3070. To set the initial contaminant concentrations in the model domain for simulations of the forecast period, a historical simulation of contaminant releases was performed from 1943 up to but not including 2018. The contaminant distributions in the model domain at the end of this simulation are used as the starting concentrations for the forecast runs.

The forecast simulation was performed from 2018–3070. The forecast simulation was performed in a single stage because this model contains no waste sites with a disposition of remove, treat, and dispose (RTD; CP-64711). If it had contained such sites, the forecast period would have been simulated in two stages. After starting in 2018, execution of the model would have been stopped at the year RTD was planned to reset concentrations in the model to zero at the RTD locations, and then the model would have been restarted from that year.

4.7 Initial Conditions

The simulations performed for the U-10 West Area model require that initial aqueous pressure conditions and contaminant concentrations in the model domain be specified, depending on the simulation. Initial aqueous pressure conditions for the steady-state, flow-only simulation are based on hydrostatic conditions assuming that the base of the model is at the water table. This is input to STOMP as an aqueous pressure of 101,325 Pa at the water table and a z-direction gradient of -9,793.52 Pa/m. The ending aqueous pressure conditions from the steady-state simulation are used as initial aqueous pressure conditions for the historical (i.e., 1943–2018) transient simulation and the mass/activity balance simulation.

The CIE vadose zone models use a “forward” modeling approach. This approach starts with an uncontaminated model area and simulates the release of contaminants as they are understood to have occurred in space and time. The contaminants are transported through the vadose zone by advection and hydrodynamic dispersion, with potential retardation due to sorption. Radionuclide decay is also modeled in this time period. The resulting distribution of the contaminants and aqueous pressure are used as initial conditions for the evaluation period (i.e., 2018–3070). Therefore, the initial contaminant concentrations of the historical model are zero in all model domains, and the initial contaminant concentrations of the forecast model are the concentrations taken from the final timestep of the historical model. The initial aqueous pressure conditions for the forecast model are also taken from the final timestep of the historical model.

This model does not contain any RTD sites, so the forecast simulation was performed as a single run. If this model did have an RTD site, this would have been simulated by stopping model execution at the year designated for the RTD action, concentrations in the model where RTD would have occurred would have been set to zero, and then model execution resumed.

4.8 Boundary Conditions

Boundary conditions for the U-10 West Area model include recharge to the top of the model, water table conditions at the base of the model, and no-flow conditions along the sides of the model. The boundary conditions are described in further detail in the rest of this section.

4.8.1 Natural Recharge – Top Boundary Condition

The vadose zone model natural recharge was estimated using the RET (ECF-HANFORD-15-0019). The RET assigns soil infiltration rates for the CIE vadose zone models based on land use, surface cover information from multiple sources (including existing buildings and structures, waste site footprints, and natural vegetative cover), and soil survey information. Planned future actions for waste site closure are used to develop future recharge estimates through the end of the modeling period. The RET generates spatial representations of recharge estimates for each year from 1943 until recharge reaches a final post-closure condition. These yearly recharge estimates for the model domain are then post-processed to generate the STOMP boundary condition input. The steady-state simulation uses the 1943 RET recharge values for the entire simulation under the assumption that the 1943 recharge is representative of pre-Hanford Site conditions. Recharge rates from every output year from the RET are used as the transient boundary conditions. The spatially-averaged annual RET recharge in the U-10 West Area model through time is shown in Figure 4-24.

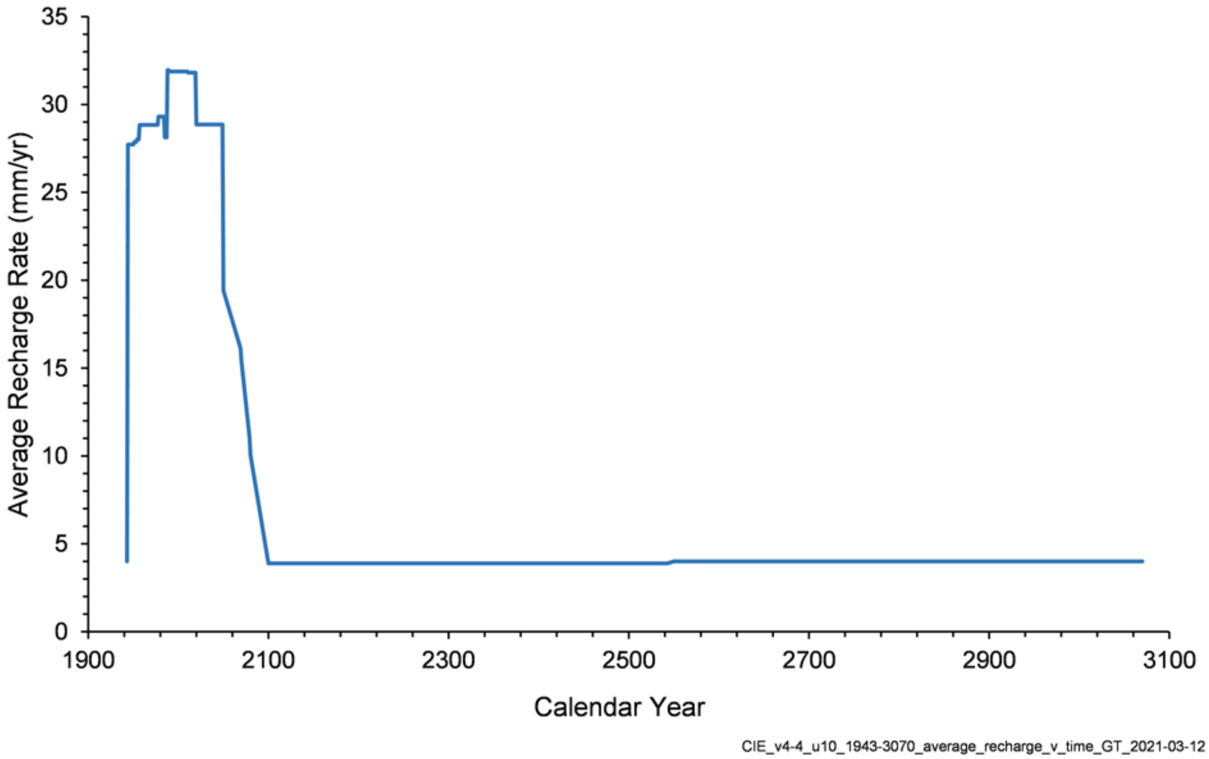

Figure 4-24. Spatially-Averaged Annual Recharge in the U-10 West Area Model, 1943–3070

Natural recharge within the model domain is spatially variable. Figures of the spatial distribution of RET recharge estimates for the U-10 West Area model for every year there is a change in recharge estimate within the model domain are shown in Appendix C. Figure 4-25 to Figure 4-28 show the RET recharge estimates for the U-10 West Area model for 1943, 1988, 2050, and 2550. Additional figures that show the changes in recharge rate as calculated by the RET are shown in Appendix C of this document. The pre-Hanford recharge rate distribution is determined by Rupert Sand, covered with mature shrub-steppe plant communities (Figure 4-25). The recharge rate for this soil with mature vegetation is 4.0 mm/yr. As shown in Figure 4-7, several ponds and waste sites were constructed after 1943, resulting in variable recharge rates over time. Construction, including excavation, caused surface disturbances resulting in increased recharge rates. The maximum average recharge rate for the model domain is reached in 1988 (Figure 4-26) with estimated recharge rates of 63 mm/yr for waste sites with major disturbances. The construction of a surface infiltration barrier in the buffer zone of the model, with an assumed recharge rate of 0.5 mm/yr, is scheduled to be completed by 2050 (Figure 4-27). Post remediation, the surface barrier is assumed to have a design life of 500 years, after which the affected areas will have an assigned recharge rate of 4.0 mm/yr (Figure 4-28).

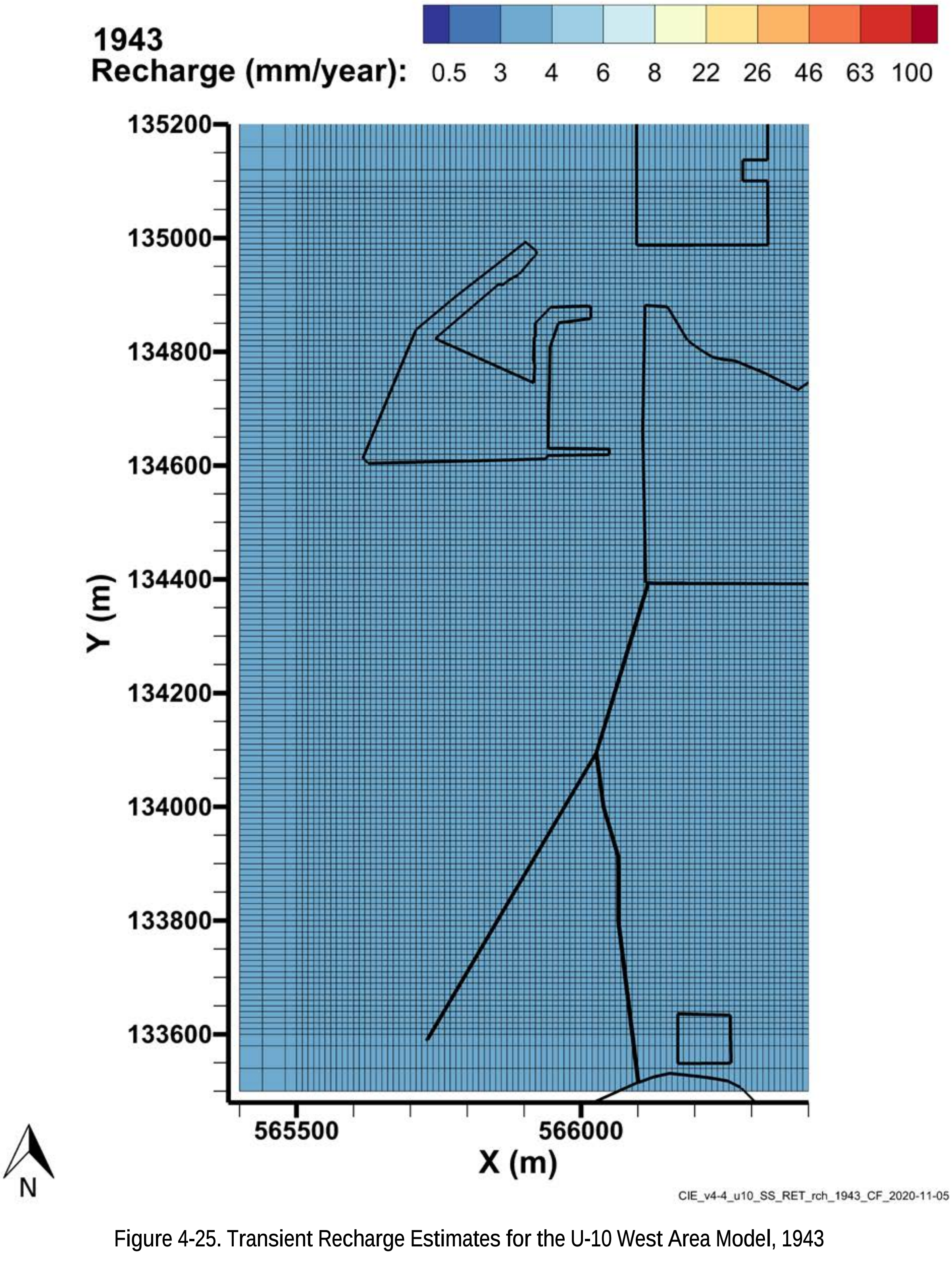

Figure 4-25. Transient Recharge Estimates for the U-10 West Area Model, 1943

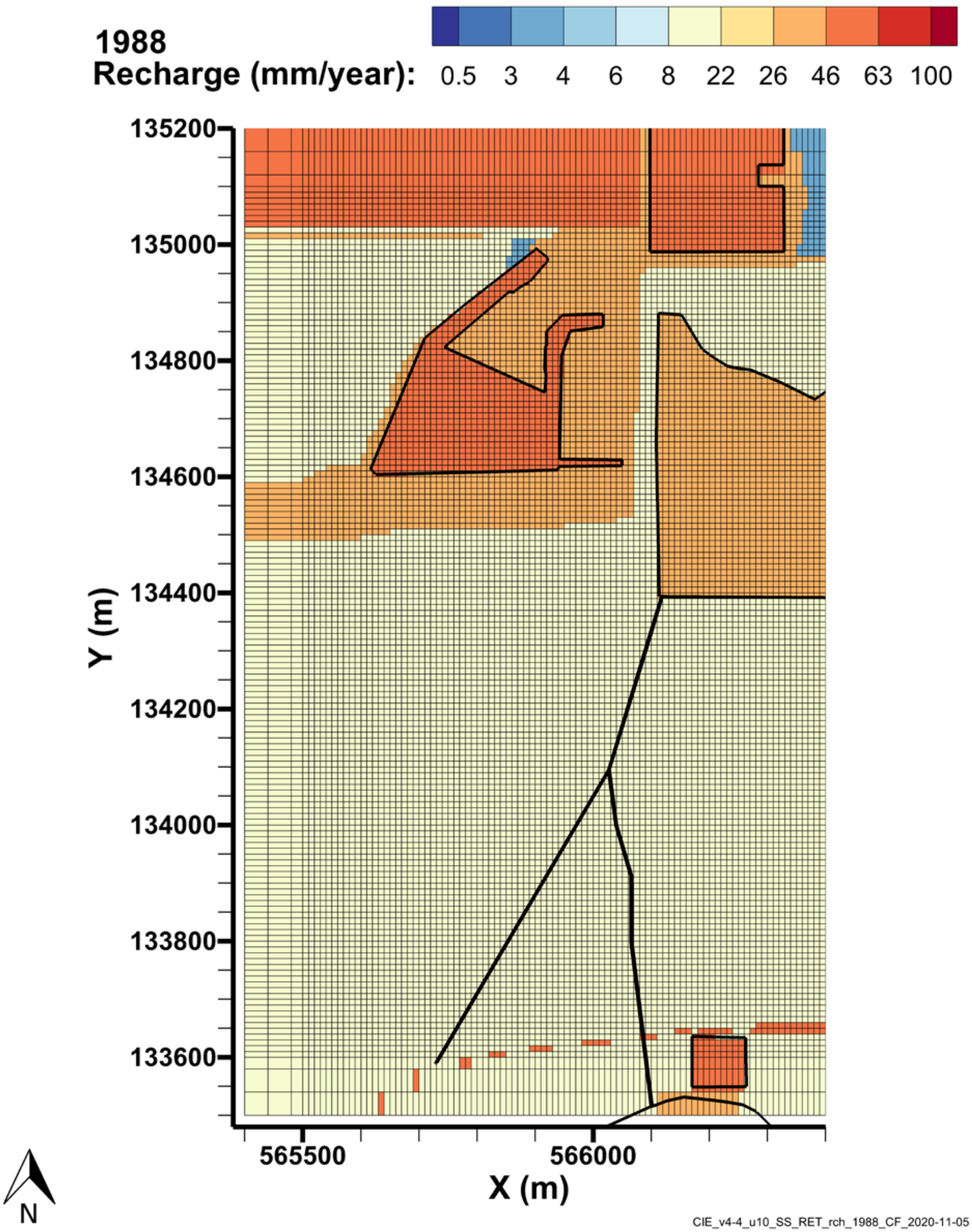

Figure 4-26. Transient Recharge Estimates for the U-10 West Area Model, 1988

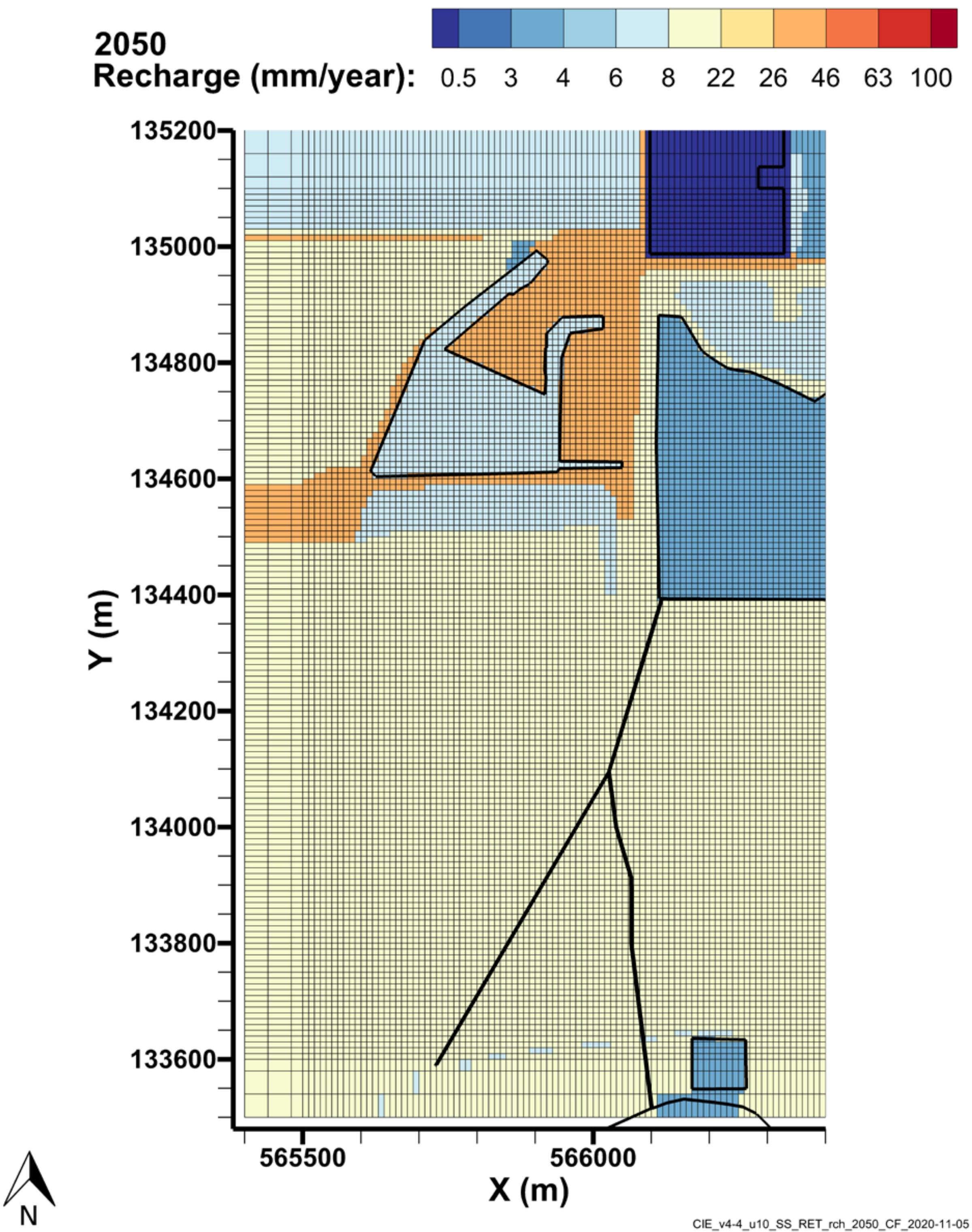

Figure 4-27. Transient Recharge Estimates for the U-10 West Area Model, 2050

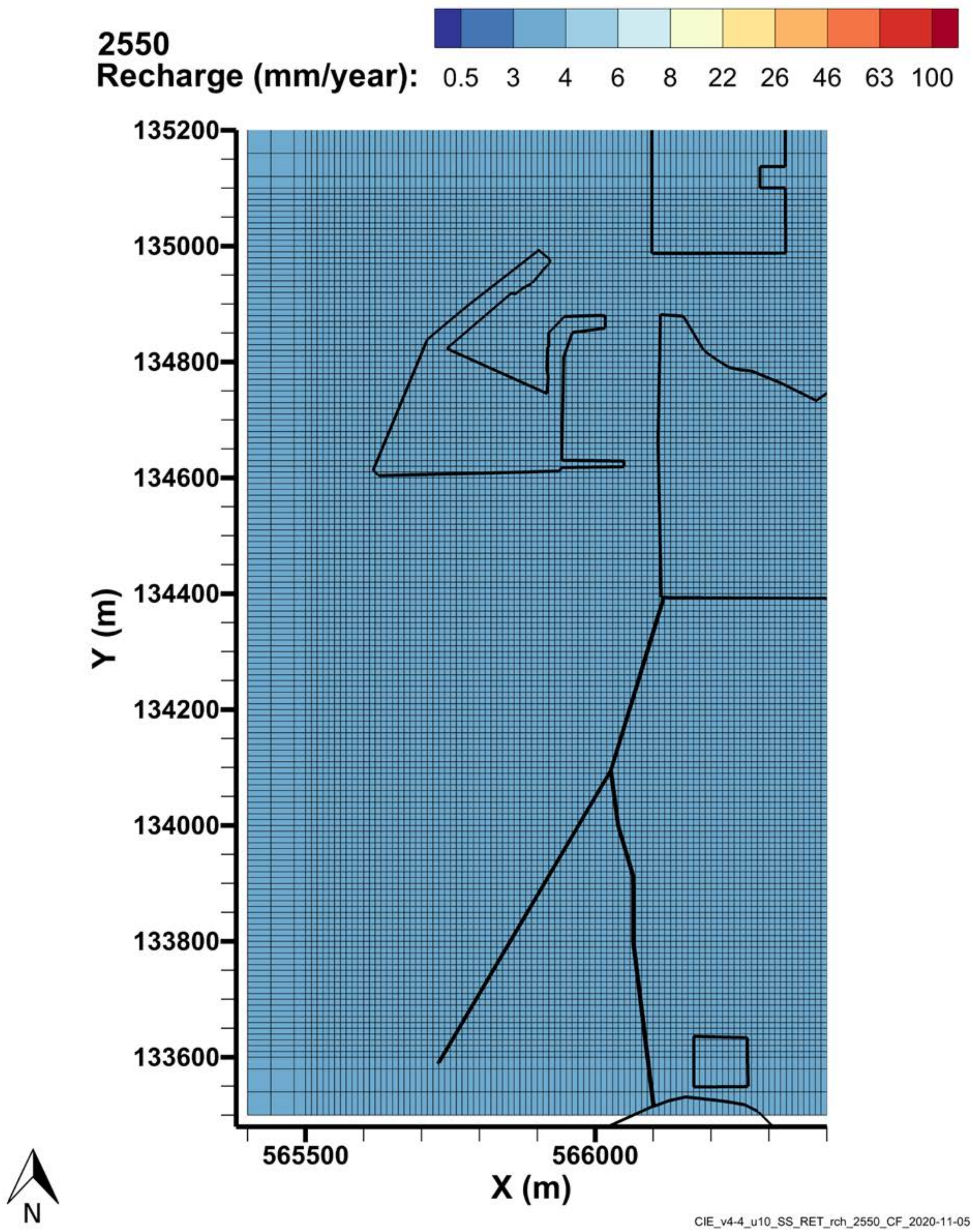

Figure 4-28. Transient Recharge Estimates for the U-10 West Area Model, 2550

Example time series charts of natural recharge rates for selected locations within the model domain (locations shown in Figure 4-29) are shown in Figure 4-30 through Figure 4-34. All locations on Figure 4-39, except for location A, represent waste sites (location B, Figure 4-31; location C, Figure 4-32;

location D, Figure 4-33; location E, Figure 4-34). The pre-Hanford recharge rate at these sites is 4.0 mm/yr, determined by Rupert Sand covered with mature shrub-steppe plant communities. After Hanford construction began in 1943, an initial increase in recharge occurred depending on the activities that took place within the waste site boundaries. At all the selected waste site locations, a disposition of “disturbed sand” due to excavation activities and other disturbances is reached at some time, with an assigned recharge rate of 63 mm/yr. This value is consistent with rates measured in unvegetated sands (see Table 4-15 in PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*). Before reaching a value of 63 mm/yr, locations C and D are affected by cheatgrass development, with an assigned recharge rate of 22 mm/yr. Locations B and E do not have this phase and the recharge rate goes from the mature soil cover rate directly to 63 mm/yr. After the period with the 63 mm/yr recharge rate, locations C, D, and E go through a phase of partial revegetation (cheatgrass over gravel), with an assigned recharge rate of 46 mm/yr. All of the waste site locations go through a revegetation phase where the recharge rate decreases stepwise to 8.0 mm/yr in 2020 (2050 for location B) and a final recharge rate of 4.0 mm/yr in 2050 (2080 for location B).

Location A (Figure 4-30) is not located on a waste site. The recharge rate initially increases to 22 mm/yr due to cheatgrass development. A revegetation cycle with a 30-year linear recharge rate decrease to 4.0 mm/yr is imposed in 2070. After 2100, the recharge rate remains at 4.0 mm/yr.

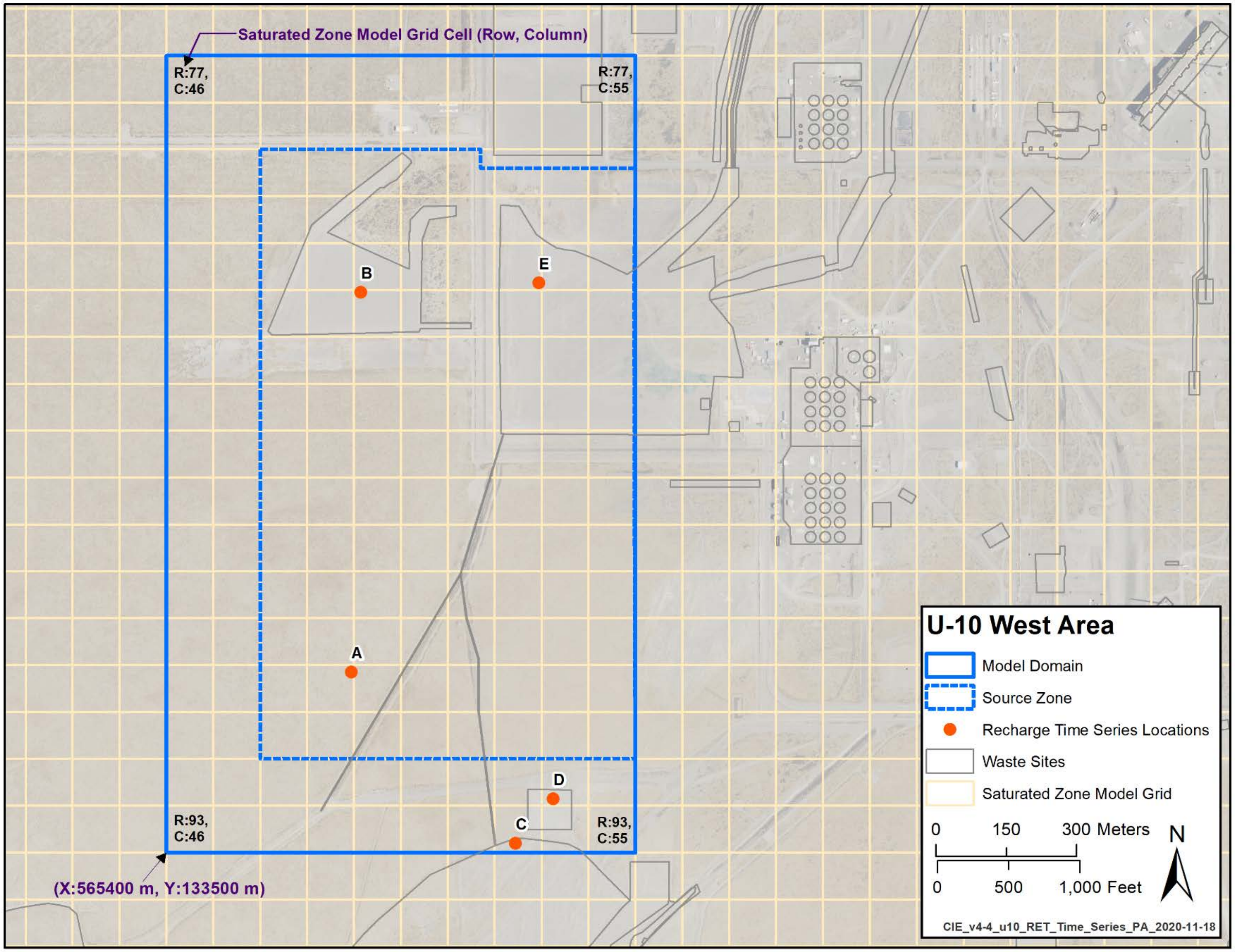

Figure 4-29. Locations of Recharge Rate Time Series Examples

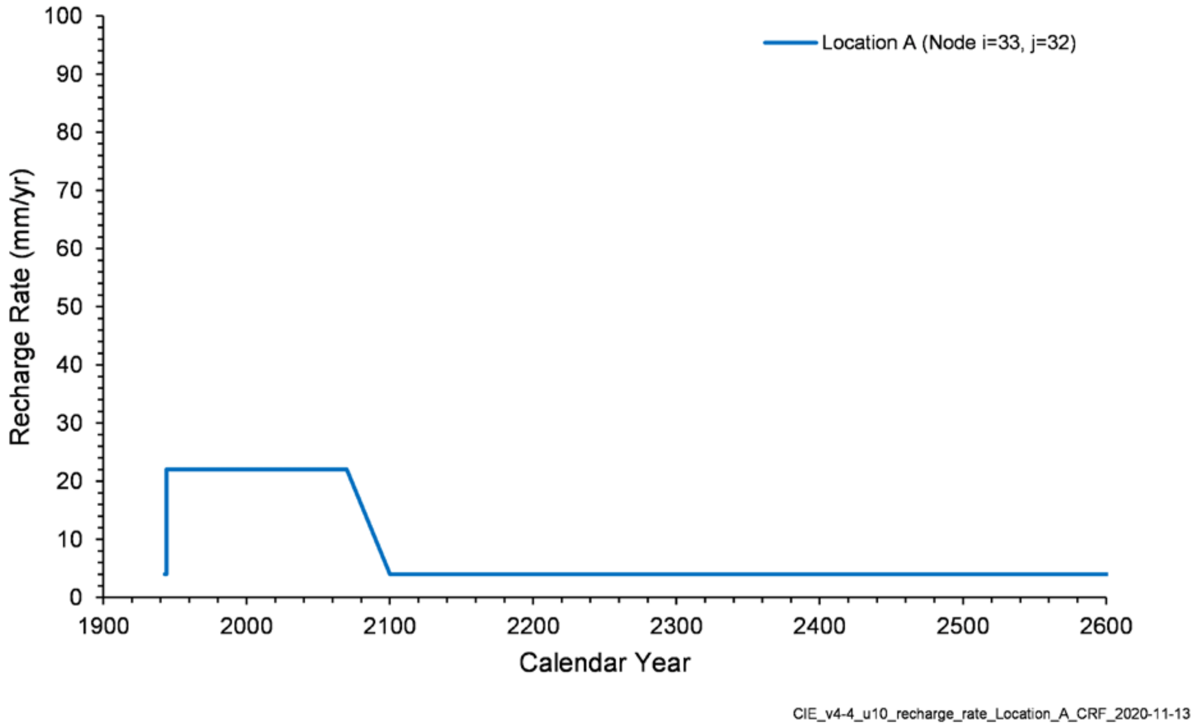

Figure 4-30. Time Series of Natural Recharge Rates, Location A

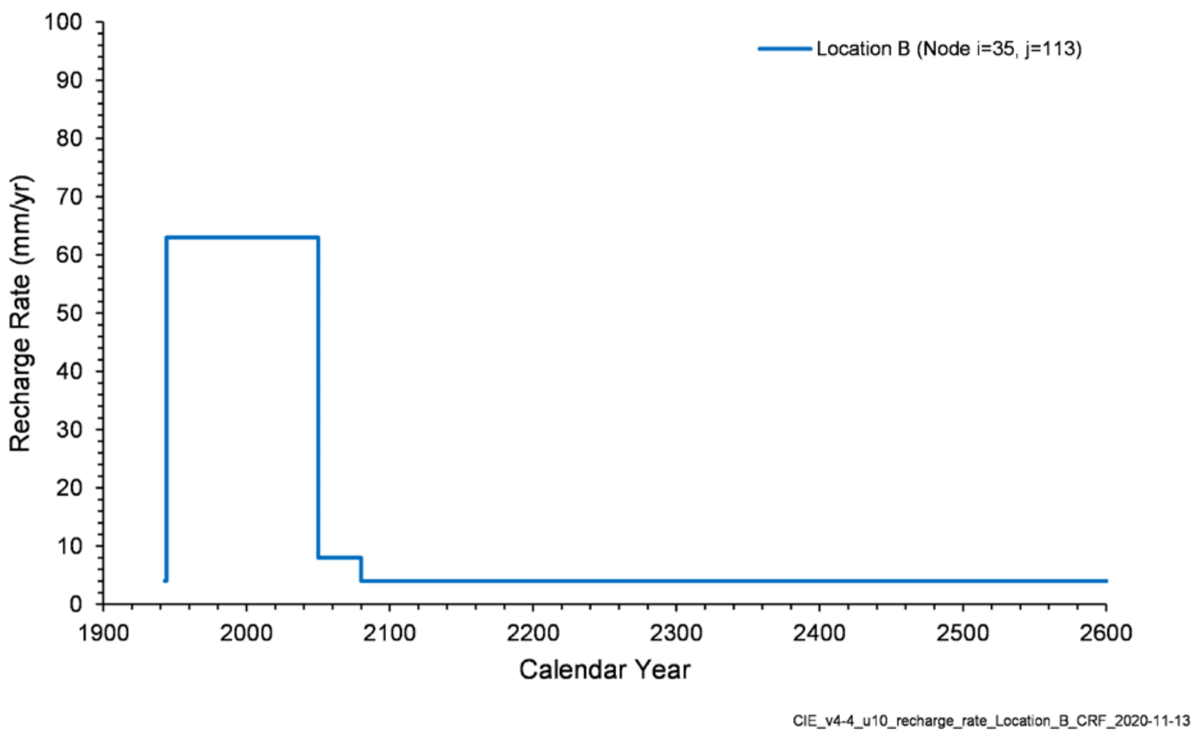

Figure 4-31. Time Series of Natural Recharge Rates, Location B

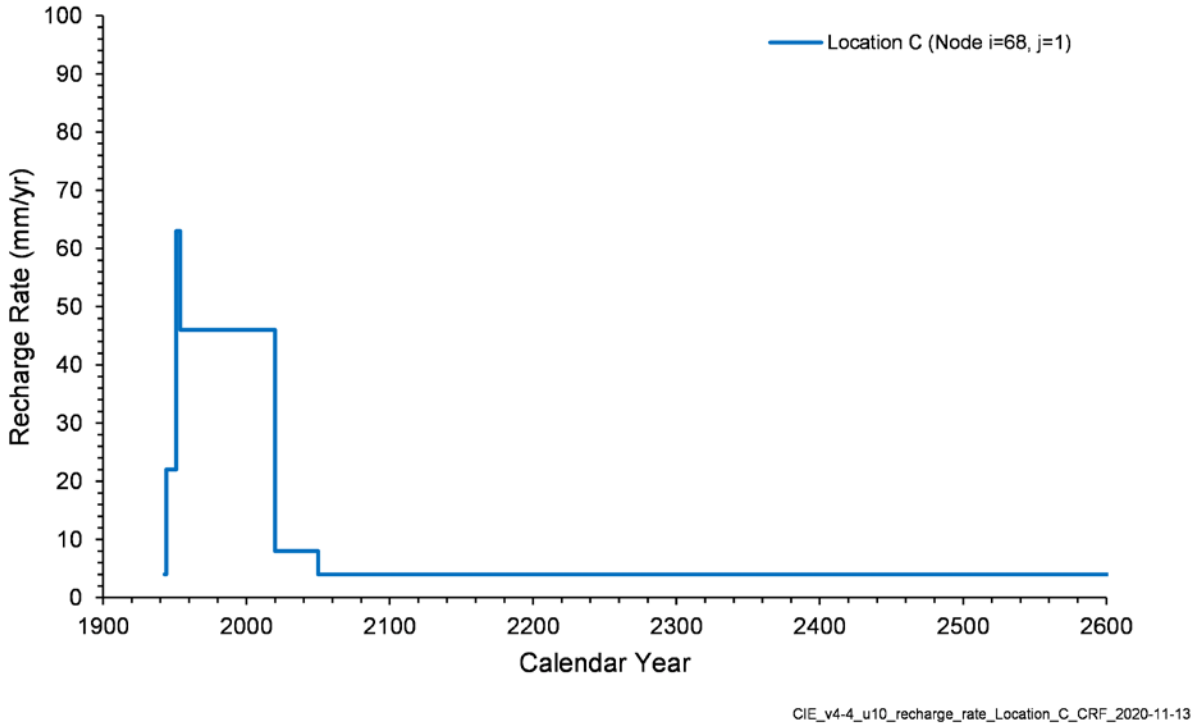

Figure 4-32. Time Series of Natural Recharge Rates, Location C

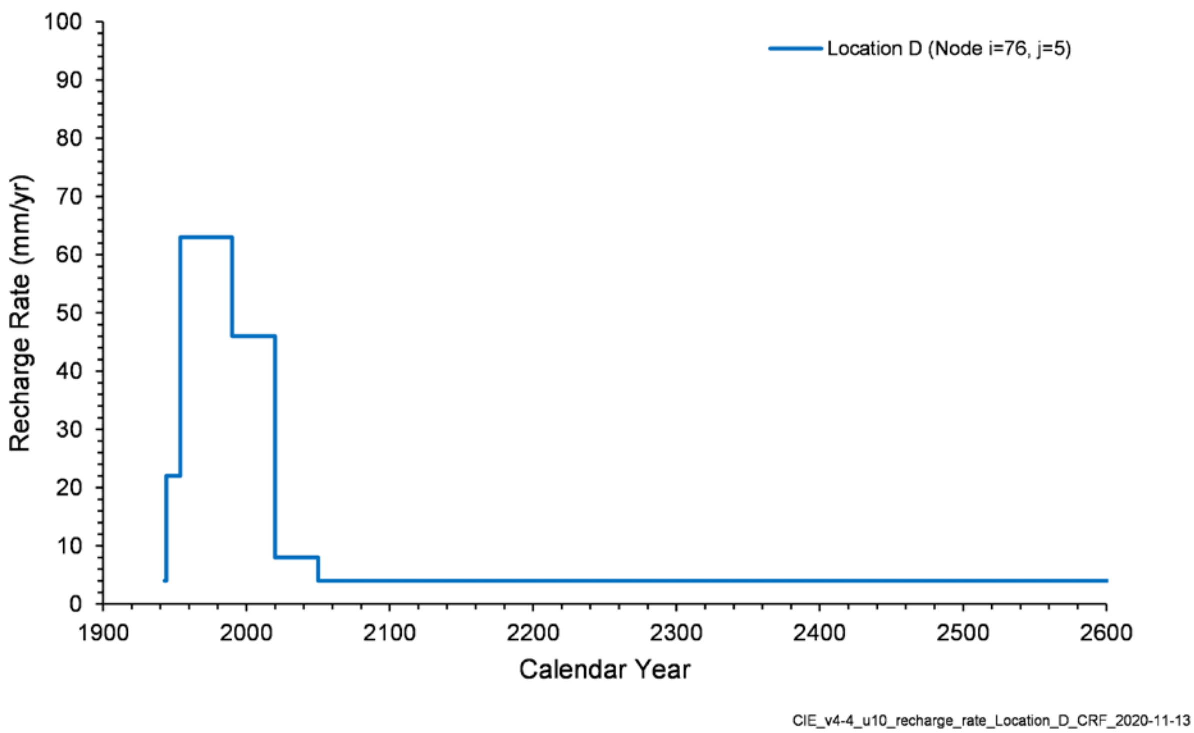

Figure 4-33. Time Series of Natural Recharge Rates, Location D

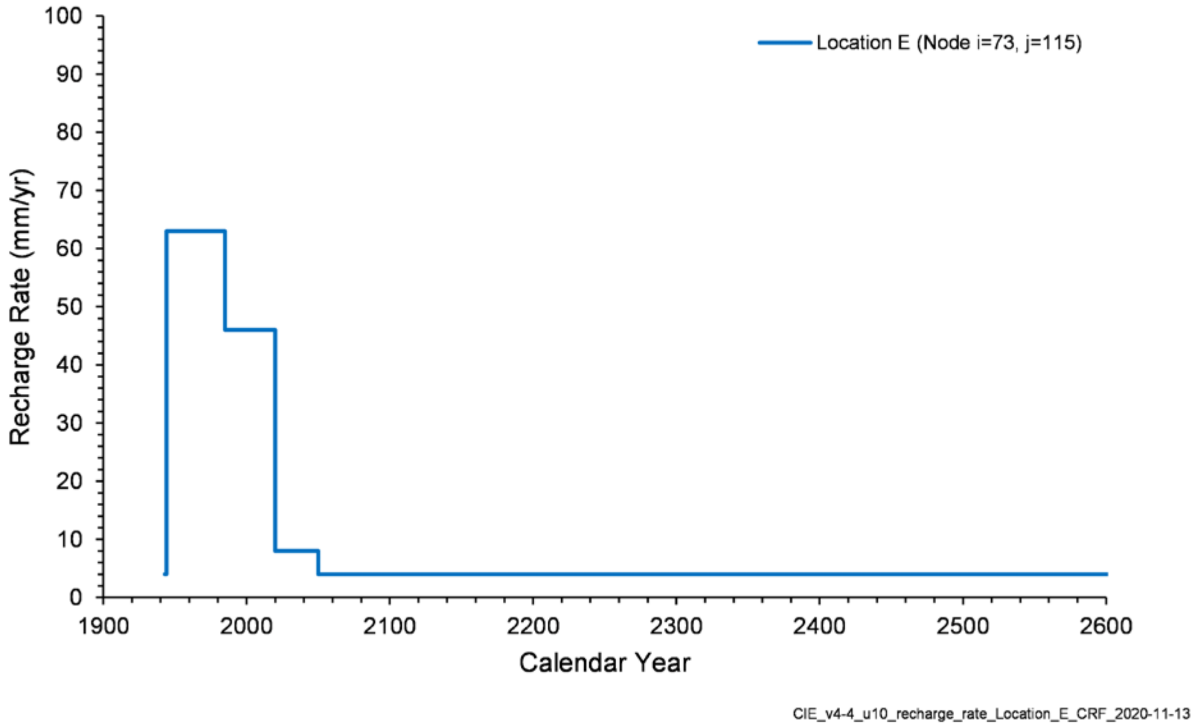

Figure 4-34. Time Series of Natural Recharge Rates, Location E

4.8.2 Lateral and Bottom Boundaries

Lateral boundaries for the model are assumed to be zero-flux boundaries for both contaminant transport and water flow. The locations of the lateral boundaries were selected in an iterative procedure to ensure that the contaminant plumes would not reach the model boundary. Model boundaries were generally selected to be at least 100 m away from source zone waste sites with contaminant and liquid releases so the releases would not affect soil moisture or contents at or near the boundary. For elongated waste sites extending into adjacent models, the assumption is that bifurcation of a waste site by a model boundary does not lead to soil moisture gradients across the boundary and that zero-flux boundaries are therefore appropriate for such waste sites. Further discussion of the model boundary selection process is included in CP-63515.

The bottom of the model was assumed to be coincident with the water table at the model location, as estimated from the 2017 water table elevation (ECF-HANFORD-17-0120, *Preparation of the March 2017 Hanford Site Water Table and Potentiometric Surface Maps*). This boundary was represented by a Dirichlet boundary condition with a pressure of 101,325 Pa.

4.9 Source Nodes

Contaminants and water discharged from waste sites are introduced to this model via source nodes. The distribution of these source nodes is shown in Figure 4-35. The STOMP Source Cards (i.e., source location and release data in the STOMP input file) were built using waste site footprints, source inventory, and the model grid. A discussion of the source node allocation process is found in CP-63515.

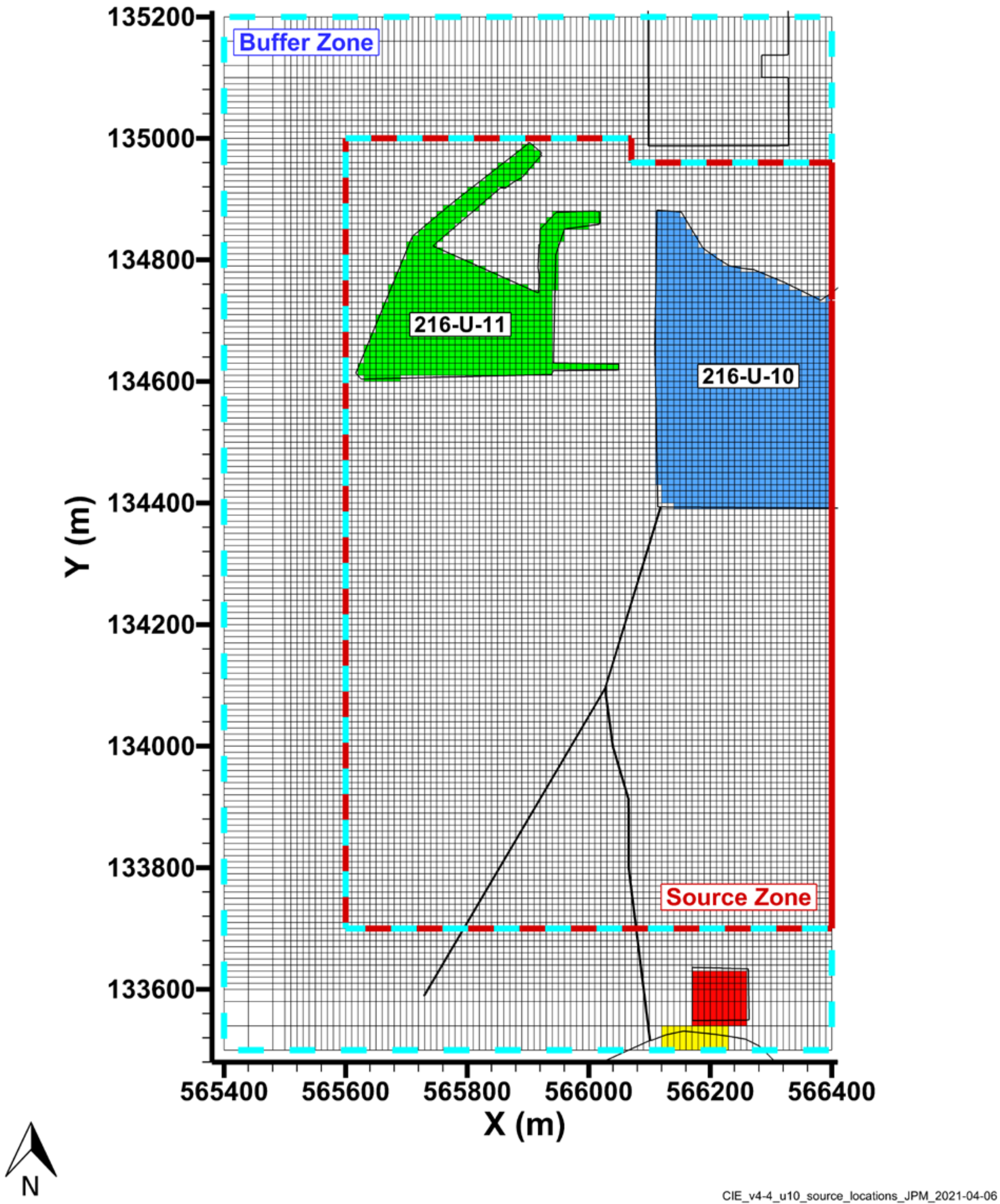

Figure 4-35. Distribution of Source Nodes in the U-10 West Area Model

4.10 Modeling Assumptions

The development of the U-10 West Area model required several conceptual and simulation assumptions. The major assumptions are as follows:

- The Central Plateau Vadose Zone Geoframework Model (CP-60925) is assumed to provide a three-dimensional representation of the subsurface beneath the Central Plateau at a scale appropriate to the model scope. The geoframework model is constructed using a combination of lithologic and sequence stratigraphic interpretations, leading to the definition of a series of HSUs. With this approach, correlated, hydraulically significant units are mapped while still representing the interpretations of lithologically heterogeneous features. This approach is assumed to adequately represent the hydrostratigraphy for this model. The HSU surfaces used in generating the U-10 West Area model are from an update to CP-60925, ECF-HANFORD-18-0035.

- The modeling approach assumes that the HSUs can be represented as anisotropic Equivalent Homogeneous Media (EHM) to simulate flow and transport in the heterogeneous Central Plateau. The EHM representation is recommended by Yeh et al., 2015, *Flow Through Heterogeneous Geologic Media*, for systems with large-scale HSUs. An EHM has two main characteristics: (1) representative hydraulic property and parameter values are applied that are equivalently homogeneous (i.e., constant) in space, and (2) the effects of heterogeneity on flow are described using an anisotropic unsaturated hydraulic conductivity. An important feature of an anisotropic EHM model representation is that it captures the mean or the bulk flow characteristics of the vadose zone moisture plumes, as demonstrated by Zhang and Khaleel, 2010, “Simulating Field-Scale Moisture Flow Using a Combined Power-Averaging and Tensorial Connectivity-Tortuosity Approach.” Therefore, the contaminant peak arrival time under recharge-dominated flow conditions is adequately captured by an anisotropic EHM model representation. Anisotropic EHMs are commonly used to model flow and transport at the Hanford Site. For instance, recent PA vadose modeling for WMA C (RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington*) used anisotropic EHMs to simulate subsurface flow and transport.

- For simulation of flow in unsaturated sediments, the soil water retention relation (i.e., the relation between soil moisture content and capillary pressure) and the unsaturated hydraulic conductivity relation (i.e., the relation between moisture content and unsaturated hydraulic conductivity) need to be provided. The unsaturated hydraulic conductivity is the product of the saturated hydraulic conductivity and the aqueous phase relative permeability. For the vadose zone simulations, it is assumed that the nonhysteretic van Genuchten equation (van Genuchten, 1980) describes the soil water retention relation. The Mualem relation (Mualem, 1976) coupled with the van Genuchten (1980) soil water retention relation, is assumed to represent the unsaturated hydraulic conductivity.

- The EHM assumption requires that each anisotropic EHM has representative hydraulic properties. The hydraulic properties used in the CIE model are on a grid-block scale that is much larger than the sediment cores typically analyzed in the laboratory. Thus, upscaled hydraulic properties based on small-scale laboratory measurements are needed to simulate the large, field-scale behavior. It is assumed that parameter values for the water retention and relative permeability relations can be upscaled to the grid-block scale by applying averaging procedures to core-scale data. For the soil water retention relation, the linear upscaling scheme (Green et al., 1996, “Upscaled Soil-Water Retention Using Van Genuchten’s Function”) is applied. For the unsaturated hydraulic conductivity, the power-averaging tensorial connectivity-tortuosity (PA-TCT) method (Zhang et al., 2003, “A Tensorial Connectivity–Tortuosity Concept to Describe the Unsaturated Hydraulic Properties of Anisotropic Soils”; Zhang and Khaleel, 2010) is used to determine directionally-dependent saturated hydraulic conductivity and relative permeability tortuosity parameters that are functions of the soil moisture content. The PA-TCT upscaling method leads to a soil-moisture-dependent anisotropic unsaturated hydraulic conductivity. Applying the PA-TCT method allows for an assessment of the effects of heterogeneity on lateral flow and contaminant spreading, including plume commingling at the HSU scale. The method has been successfully applied to evaluate various water infiltration tests performed at the Sisson and Lu field experiment site in the 200 East Area (Ye et al., 2005, "Stochastic Analysis of Moisture Plume Dynamics of a Field Injection Experiment"; Zhang and Khaleel, 2010). The field applications of the upscaled vadose zone property values based on the PA-TCT method suggests that it provides a reasonable framework for upscaling core-scale measurements, as well as an accurate simulation of moisture flow in the heterogeneous vadose zone under the Central Plateau.

- A "forward" modeling approach is used to simulate contaminant transport in the vadose zone: model transport simulations initiate at a time when contamination is not present in the subsurface, and the contaminant activity is introduced in the models as sources over time. It is assumed that this approach will adequately represent the spatial and temporal contamination distribution for the CIE vadose zone models. This approach has been used to simulate Hanford Site contaminant transport resulting from liquid waste disposal (e.g., Oostrom et al., 2017, "Deep Vadose Zone Contaminant Flux Evaluation at the Hanford BY-Cribs Site Using Forward and Imposed Concentration Modeling Approaches") and past leaks (RPP-RPT-59197).

- Contaminants are assumed to be transported in the vadose zone by advection and hydrodynamic dispersion, the latter of which is the sum of molecular diffusion and mechanical dispersion. The two components of hydrodynamic dispersion are described by a single hydrodynamic dispersion coefficient and treated as a diffusive flux proportional to the concentration gradient. Advective transport and mechanical dispersion are computed using the flow field obtained when solving the water conservation equation. The contaminants are considered to be solutes, without affecting fluid properties like density and viscosity.

- Mechanical dispersion is assumed to be directionally dependent with a constant macroscopic dispersivity value for each HSU. The use of a constant (asymptotic) macrodispersivity for large-scale vadose zone CIE modeling is considered appropriate (NUREG/CR-5965, *Modeling Field Scale Unsaturated Flow and Transport Processes*). Macrodispersivity values for the HSUs in the longitudinal direction, are obtained from Hanford Site field-scale numerical simulations and field experiments. Hanford Site-specific datasets include Khaleel et al., 2002, "Upscaled Flow and Transport Properties for Heterogeneous Unsaturated Media"; and PNNL-25146, *Scale-Dependent Solute Dispersion in Variably Saturated Porous Media*. In the absence of unsaturated media experimental data, the CIE transport models used a transverse macrodispersivity value that is 1/10th of the obtained longitudinal value.

- The linear sorption model approach is assumed to be adequate for modeling large-scale transport at the Hanford Site (PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*). Contaminant sorption is simulated using a reversible linear sorption isotherm with a constant distribution coefficient (K_d) for each HSU. An important benefit of the linear adsorption assumption is that an extensive database of K_d values applicable to Hanford Site sediments is over a broad range of conditions (e.g., PNNL-17154, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site*). Use of reversible linear K_d isotherms is computationally efficient and appropriate for the scale of the CIE problem. Recognizing that experimental K_d values are mostly determined using sediment grain sizes <2 mm, corrections for gravel content using equations provided in PNNL-17154 are used to adjust measured values for the finer fraction applicable to HSUs with considerable gravel content.

- The spatially and temporally variable natural recharge rate is assumed to define the upper boundary conditions for the water conservation equation. The natural recharge rate is a term applied to define the net infiltration that migrates through the vadose zone to reach the water table. At the Hanford Site, this rate is primarily a function of the surface soil type and type/density of vegetative cover. Effects of climate change on natural recharge during the forecast model time period are not accounted for in the simulations.

- Zero flux boundary conditions are assumed at the lateral boundaries of the model domain. It is assumed that water and contaminants do not cross the model boundaries: in the cases where a waste site may be split by a model boundary, that boundary was selected along an axis where it was assumed there would be no net flow across the boundary. During development of the model domain, the proper locations of the zero flux lateral boundaries were determined in an iterative procedure.
- The 2018 water table is assumed to describe the lower boundary conditions of the model domain. Instead of a transient water table, the simulations use a fixed water table representing 2018 conditions to increase efficiency and reduce complexity during implementation of the vadose zone models. The effects of a transient water table on contaminant transfer after 2018 to the aquifer were evaluated to validate this approach in Farrow et al., 2019, "Prediction of Long-Term Contaminant Flux from the Vadose Zone to Groundwater for Fluctuating Water Table Conditions at the Hanford Site." Simulations for selected vadose zone models with continuing sources demonstrated that a simplification of the water table boundary condition (i.e., a static water table), could be adequately used to compute long-term predictions of contaminant flux to groundwater.
- The liquid volumes and waste site inventories from Appendix B of CP-64710 and Appendix F of CP-61786 are assumed to provide the representative contaminant sources in the model domain. Uncontaminated site liquid volumes not otherwise reported in other inventory sources reported in EMDT-IN-0046 are assumed to provide representative aqueous volumetric sources from waste sites. Using geometry information, contaminated and water-only waste site shapes were assigned to vadose zone model grid surfaces, according to EMDT-GR-0035[5], *Waste Site and Structure Footprint Shapefiles for Inclusion in Updated Composite Analysis*. Water volumes and contaminant inventories were assigned to the model grid cells at the lowest topographic location within the site footprints.

Chromium commonly occurs in two oxidation states: hexavalent and trivalent. The oxidation state chromium is in affects its mobility in the subsurface. Hexavalent chromium is generally mobile in the subsurface and is readily reduced to the trivalent form under reducing conditions. Conversely, trivalent chromium is considered to be essentially immobile in the subsurface with little tendency to re-oxidize to the mobile hexavalent form (PNNL-24705, *Assessment of Hexavalent Chromium Natural Attenuation for the Hanford Site 100 Area*). Both hexavalent and trivalent chromium were present in waste streams from Hanford Site processes. Inventories used in this modeling effort are for total chromium only, without a distinction between the hexavalent and trivalent oxidation states. Furthermore, tank waste releases result in complex and variable geochemical interactions with vadose zone sediments, causing changes to chromium speciation and subsequent migration that are difficult to predict and quantify (Zachara et al. 2004, "Chromium Speciation and Mobility in a High Level Nuclear Waste Vadose Zone Plume").

The complexity and variability of subsurface geochemical interactions for tank waste releases, and the lack of inventory distinction between the two major chromium forms for all waste sites, indicate that the estimation of hexavalent and trivalent chromium fractions in the subsurface is a highly detailed and extensive task, beyond the scope of the Central Plateau CIE. The complexity of the chromium speciation leads to the identification of two bounding cases, one where all the inventory is hexavalent and mobile,

[5] EMDT-GR-0035, *Waste Site and Structure Footprint Shapefiles for Inclusion in Updated Composite Analysis*, Rev. 0, CH2M Hill Plateau Remediation Company, Richland, Washington. Electronic model data transmittals are stored in the Environmental Model Management Archive. A copy of the cover sheet for this EMDT is provided in Appendix E of this ECF.

and one where all the inventory is trivalent and immobile. Neither case is realistic. The former results in an overly conservative result in that more chromium enters the aquifer than has been observed, while the latter will underpredict future chromium releases to the saturated zone. For the vadose zone model simulation documented in this ECF, it has been assumed that all the chromium inventory consists of the mobile hexavalent form with an assigned K_d = 0 ml/g. However, for the CIE NFA scenario, no chromium mass is passed on to the saturated zone model, thus not modeling the overly conservative bounding case in the saturated zone. The saturated zone simulation for the CIE NFA scenario considers only the chromium present in groundwater as of 2017, the initial conditions for the saturated zone modeling. An in-depth discussion of chromium speciation at the Hanford Site, and recommendations on modeling approaches for the CIE are found in CP-63515, Appendix C.

5 Software Applications

Three types of calculation software are used in this modeling effort: the numerical modeling simulator eSTOMP, support software (spreadsheet and geographic information system [GIS] applications), and custom utility calculation software. Custom utility calculations software is documented under CHPRC-04032, *Composite Analysis / Cumulative Impact Evaluation (CACIE) Utility Codes Integrated Software Management Plan* and described in further detail in Section 5.3 of this ECF.

5.1 Approved Software

The eSTOMP numerical simulator has been used for the flow and transport calculations reported in this ECF. The application of the simulator is managed under the requirements of CHPRC-00176, *STOMP Software Management Plan*. Use of this software is consistent with the intended uses of STOMP at the Hanford Site as defined in CHPRC-00222, *STOMP Functional Requirements Document*. The STOMP software is actively managed by the Central Plateau Cleanup Company and approved for use at the Hanford Site as Level C software under a procedure that implements the requirements of DOE O 414.1D, *Quality Assurance*.

Build 6 of the STOMP software was used in the implementation of the model described in this document. This version was approved for use at the Hanford Site based on acceptance testing results reported in CHPRC-00515, *STOMP Acceptance Test Report*. The status of requirements for this software are maintained in CHPRC-00269, *STOMP Software Requirements Traceability Matrix*. All acceptance testing was performed to the requirements of CHPRC-00211, *STOMP Software Test Plan*. Installation testing is also required for any computer system on which STOMP is run. The installation test is specified in CHPRC-00211.

The STOMP simulator was developed by Pacific Northwest National Laboratory to simulate flow and transport over multiple phases in a subsurface environment. The water mode of the simulator uses numerical approximation techniques to solve partial differential equations that describe the conservation of aqueous mass and radionuclide activity in variably saturated porous media. These governing conservation equations, along with a corresponding set of constitutive relations that relate variables within the conservation equations, are solved numerically by using integrated-volume, finite-difference discretization to the physical domain and first- or second-order Euler discretization to the time domain. The resulting equations are nonlinear, coupled algebraic equations that are solved using the Newton-Raphson iteration.

The theoretical and numerical approaches applied in the STOMP simulator are documented in a published theory guide (PNNL-12030). The simulator has undergone a rigorous verification procedure against analytical solutions, laboratory-scale experiments, and field-scale demonstrations. The application guide (PNNL-11216) provides instructive examples in the application of the code to classical groundwater and vadose zone flow and transport problems. The user's guide (PNNL-15782) describes the general use, input file formatting, compilation, and execution of the code.

- Software Title: STOMP, parallel implementation (eSTOMP), executable eSTOMP1-chprc06-20200204-g.x
- Software Version: CHPRC[6] Build 6

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

- Hanford Information System Inventory Identification Number: 2471
- Workstation type and property number (from which software is run): GAIA Subsurface Flow and Transport Modeling Platform, Nodes compute-0-0 through compute-0-8 inclusive, property tags: WF32991, WF32992, WF32993, WF32994, WF32995, WF32996, WF32997, WF32998, WF32999

5.1.1 Software Installation and Checkout

The software installation and checkout form for STOMP simulation software is provided as Appendix D to this ECF.

5.1.2 Statement of Valid Software Application

Use of the eSTOMP software to simulate vadose zone flow and transport for the CIE is a valid application of the software. The software has been used within the limits discussed in the simulator's theory guide (PNNL-12030) and user's guide (PNNL-15782). The water mode of the STOMP simulator is designed to simulate flow and transport over multiple phases in a subsurface environment, including unsaturated systems like the Hanford Site vadose zone. The simulator solves partial differential equations describing conservation of aqueous mass and radionuclide activity in variably saturated porous media, consistent with aqueous flow and contaminant transport in Hanford Site sediments. The STOMP code has been executed at research institutions and universities to address vadose zone flow and contaminant transport problems comparable to the CIE unsaturated systems.

The STOMP code, including the eSTOMP parallel implementation, was developed and tested by Pacific Northwest National Laboratory to NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications*, "by option" wherein testing was conducted option by option. Therefore, an "NQA-1 Options Analysis" is provided for the model application documented in this ECF (as well as other related model applications) in CP-63515 to demonstrate that all eSTOMP code options used in this model are NQA-1 qualified.

5.2 Support Software

The following programs are classified as Support Software:

- **Microsoft® Excel®** (version 2010): The tool was used to generate inventory plots and contaminant release and transfer timeseries.
- **ArcGIS®** (version 10.3.1): The tool was used to create of spatial model discretization and waste site location maps.
- **Tecplot® 360 EX** (version 2018R1): The tool was used to generate source location, recharge distribution, and mass transfer to groundwater plots.

5.3 Support Scripts

Generation of model input files and post-processing of model results was mostly performed with utility codes (scripts) that are managed, tested, and controlled in accordance with CHPRC-04032. CHPRC-04032 provides a common foundation for the management of custom-developed scripts to

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® Tecplot is a registered trademark or trademarks of Tecplot, Inc. in the United States and other countries.

manage pre- and post-processing operations and inter-facet information transfer between major software packages efficiently for the CIE. It also provides direction for electronic management of documentation requirements at the script level with respect to individual tool functional requirements, software requirements specification, software design description, requirements tracing, test plans and reporting, and user documentation. The utility scripts developed for this project, in alphabetical order by tool name, are as follows:

- The **Aqueous Source Averaging Tool** (*aq_mod_avg_linux-intel-64.exe*) averages aqueous source rates for user-specified waste sites and times.
- The **Build Surface Flux Tool** (*ca_build_surface_flux.py*) maps the STOMP grid into the MODFLOW grid.
- The **CA STOMP Tool** (CAST; *ModelSetupFY18.jar*) is a graphical user interface tool that produces STOMP input files based on user input model dimensions and material properties.
- The **CIE 2018 STOMP Input File Generator Tool** (*xprt_2018_input_gen_cie_linux-intel-64.exe*) generates the 1943–2018 STOMP transport input file.
- The **CIE 3070 STOMP Input File Generator Tool** (*xprt_3070_input_gen_cie_linux-intel-64.exe*) generates the 2018 (or RTD year if the model has RTD remediation sites)–3070 STOMP transport input file. This code reads and modifies the 1943–2018 STOMP input file created by the CIE 2018 STOMP Input File Generator Tool.
- The **CIE Mass Balance STOMP Input File Generator Tool** (*xprt_mb_input_gen_cie_linux-intel-64.exe*) generates the mass balance STOMP transport input file. This code reads and modifies the STOMP input file created by the CIE 2018 STOMP Input File Generator Tool.
- The **CIE RTD STOMP Input File Generator Tool** (*xprt_RTD_input_gen_cie_linux-intel-64.exe*) generates the 2018–RTD year STOMP transport input file. This code reads and modifies the 1943–2018 STOMP input file created by the CIE 2018 STOMP Input File Generator Tool.
- The **CIE Source Rerouting Tool** (*reroute_sources_cie_linux-intel-64.exe*) redistributes wastewater volumes and contaminant inventories for the 216-U-10 Pond System, the 216-B-3 Pond System, and the 216-T-4 Pond System.
- The **CIE Steady-State STOMP Input File Generator Tool** (*SS_input_gen_cie_linux-intel-64.exe*) generates the STOMP input file for the steady-state simulation.
- The **Duplicate Source Nodes Tool** (*ca-dups.pl*) identifies any source nodes that overlap spatially and writes information regarding the duplicate source node(s) to an output file.
- The **Inactive Nodes Tool** (*inactive_nodes_linux-intel-64.exe*) determines the number of active and inactive nodes in the uppermost five STOMP model layers.
- The **Inventory Pre-Processor Tool** (*cie-ipp.pl*) creates a comprehensive dataset consisting of contaminant and aqueous volume releases as a function of time for Central Plateau sites. The dataset is input for the SRC2STOMP Tool.
- The **Kingdom to ArcGIS Grid Tool** (*kingdom2arcgrid.py*) converts Kingdom point files (x, y, z) of surfaces (topographic surface and geologic structure tops) to ASCII raster files.

- The **Kingdom2STOMP Tool** (*K2S_ROCSAN.exe*) reads an input file representing each node in the model and generates an output file like the input file with the addition of which geologic formation each model node represents.
- The **Patchbowl Tool** (*ca-patchbowl.pl*) modifies STOMP soil zonation files to patch holes in the perching silt layer in the 200 East Area.
- The **RET2STOMP Tool** (*ca_RET2STOMP.py*) generates the natural recharge Boundary Condition Cards for the STOMP model input file using output generated by the RET. Development of this tool is documented in ECF-HANFORD-18-0074, *Application of the Recharge Estimation Tool (RET) to Prepare Spatially and Temporally Variable Recharge Boundary Conditions for Hanford Site Composite Analysis Vadose Zone Models*.
- The **RTD Initial Conditions Card Tool** (*ca-rtdic.pl*) generates Initial Conditions Cards at RTD years for models with RTD sites using an input source card file and a steady-state STOMP input file.
- The **Source Node Moving Tool** (*srcloc_modify_linux-intel-64.exe*) moves source nodes from the locations selected by the SRC2STOMP Tool.
- The **SplitKingdomLayer Tool** (*splitKingdomLayer.pl*) is used to split one geology surface layer file into two sub-unit surface layer files based on the information specified in the polygon file.
- The **SRC2STOMP Tool** (*ca-src2stomp.pl*) combines the site spatial information with the corresponding contaminant inventory and creates a STOMP-readable Source Card file containing grid cell definitions of solute and/or liquid sources.
- The **Steady-State Output Card Generator Tool** (*OC_SS_gen_linux-intel-64.exe*) reads files generated by CAST and generates a STOMP Output Control Card for the steady-state simulation.
- The **STOMP Surface Merge Tool** (*ca-merge_srf.pl*) merges STOMP surface file data from two consecutive STOMP simulations (e.g., surface files for the 2018 to RTD year simulation, and for the RTD year to 3070 simulation).
- The **Surface File to P2R Tool** (*ca-getmod_srf.pl*) aggregates solute flux and cumulative discharge data exiting the vadose zone model by saturated zone model grid cell.
- The **Transient Output Card Generator Tool** (*OC_TR_gen_cie_linux-intel-64.exe*): creates a STOMP Output Control Card used for mass balance and transport production simulations.

6 Calculation

The fate and transport calculations for the U-10 West Area model were performed using a suite of STOMP simulations: a steady-state simulation, a mass balance transport simulation, a historical transport simulation, and a forecast transport simulation, as discussed in Section 4.6. This chapter describes the mass balance calculations for the steady-state and transport simulations.

6.1 Steady-State Simulation

The purposes of the steady-state simulation are to verify model performance and to generate the initial primary variable (i.e., aqueous pressure) conditions within the model domain for the historical transport simulations, as discussed in Section 4.6.1. Contaminants are not simulated in the steady-state simulation, only flow. Pre-Hanford Site boundary conditions (i.e, natural recharge rates for 1943) are applied for a period of 10,000 years (from year zero to 10,000) to allow the simulation to reach steady-state conditions. Figure 6-1 compares the steady-state recharge flux into the top of the model to the flux leaving the base of the model, which represents discharge to groundwater from the model. Conditions reach equilibrium (i.e., flux in equals flux out) and remain unchanged through the end of the simulated time period, indicating that steady-state conditions have been achieved.

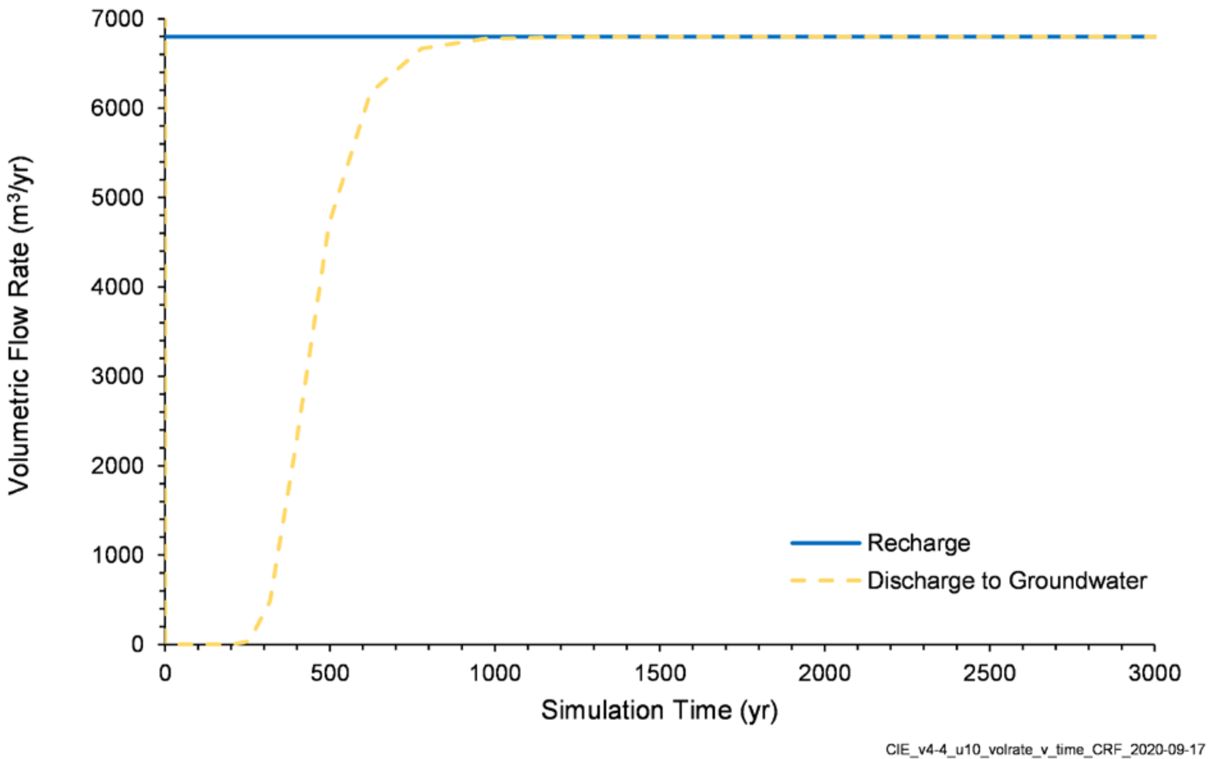

Figure 6-1. Steady-State Recharge Compared to Discharge to Groundwater Over Time

The steady-state liquid volume balance (also called mass balance) error (E) is calculated as shown in Equation 6-1 (all variables have units of m^3):

$$E = (S + O) - R_P \qquad \text{(Eq. 6-1)}$$

where:

E = liquid volume balance error

S	=	change in liquid storage within the model domain
O	=	total liquid outflow from the model domain
R_P	=	total pre-Hanford Site natural recharge.

The percent relative error (*%RE*) of the aqueous volume balance is calculated as shown in Equation 6-2:

$$\%RE = 100|E/R_P| \qquad \text{(Eq. 6-2)}$$

where:

%RE	=	liquid volume balance percent relative error.

Change in liquid storage (*S*) is the difference between liquid volume in the model at year 10,000 and year 0. Total liquid water outflow from the model (*O*) is the cumulative liquid volume that passed through the bottom of the model boundary at the end of 10,000 years. The pre-Hanford Site natural recharge (R_P) is the cumulative volume of recharge applied to the top layer of the model during the simulation. The flow-only steady-state liquid volume balance is shown in Table 6-1.

Table 6-1. Liquid Volume Balance for the U-10 West Area Model Steady-State Simulation

Natural Recharge (R_P) [a]	Change in Liquid Storage (*S*) [a,b]	Total Liquid Outflow (*O*) [a,b]	Error (*E*) [a]	Percent Relative Error (*%RE*)
68,000,000	2,807,086	65,193,630	716	1.052E-03

STOMP is a copyright of Battelle Memorial Institute, Columbus, Ohio, and used under the Limited Government License.

a. Volume units in m^3.

b. Calculated by STOMP.

%RE	=	liquid volume balance percent relative error
E	=	liquid volume balance error
O	=	total liquid outflow from the model domain
R_P	=	total pre-Hanford Site natural recharge
S	=	change in liquid storage within the model domain
STOMP	=	Subsurface Transport Over Multiple Phases

6.2 Radionuclide Transport Volume and Activity Simulations

A transient simulation was used to calculate the U-10 West Area model's liquid volume and contaminant mass or activity balances, hereinafter referred to collectively as mass balances. This simulation used the steady-state model final aqueous pressure distribution as initial aqueous pressure conditions, the transient natural recharge described in Section 4.8.1, and the waste site sources described in Section 4.5. The model execution time period is 1943–3070, and two sets of mass balance evaluations were performed: the first for the historical time period from 1943–2018, and the second for the entire transient model duration from 1943–3070. Radionuclide half-life values were set to 1.0E+20 years to virtually eliminate radioactive decay. Therefore, decay corrections were not necessary, and the radionuclide activity balances could be evaluated directly.

The liquid volume balance (also called mass balance) error (*E*) is calculated as shown in Equation 6-3 (all variables have units of m^3):

$$E = (S + O) - (I + R) \qquad \text{(Eq. 6-3)}$$

where:

E	=	liquid volume balance error
S	=	change in liquid storage within the model domain
O	=	total liquid outflow from the model domain
I	=	liquid inventory entering the model domain from liquid waste site releases
R	=	total natural recharge.

The percent relative error (*%RE*) of liquid volume balance is calculated as shown in Equation 6-4:

$$\%RE = 100|E/(I + R)| \quad \text{(Eq. 6-4)}$$

where:

%RE	=	liquid volume balance percent relative error.

The change in liquid storage within the model domain (*S*) is the difference between the volume of water in the model at the end of the mass balance analysis period (either 2018 or 3070) and the beginning of the simulation (1943). The total liquid outflow from the model domain (*O*) is the cumulative liquid volume that passed through the bottom of the model boundary by the end of the mass balance analysis period. The liquid inventory (*I*) is the cumulative volume of liquids released to the model from liquid waste sites in the source and buffer zones during the mass balance analysis period. The natural recharge (*R*) is the cumulative volume of liquid applied to the top of the model from natural recharge during the mass balance analysis period. The liquid volume balances for the U-10 West Area model are shown in Table 6-2.

Table 6-2. Transient Liquid Volume Balances for the U-10 West Area Model

Liquid Inventory (*I*) [a]	Natural Recharge (*R*) [a]	Change in Liquid Storage (*S*) [a,b]	Total Liquid Outflow (*O*) [a,b]	Error (*E*) [a]	Percent Relative Error (*%RE*)
1943–2018					
90,060,424	3,768,783	2,114,065	91,715,680	538	5.734E-04
1943–3070					
90,060,424	12,929,455	-1	102,989,500	-380	3.689E-04

a. Volume units in m^3.

b. Calculated by STOMP.

%RE	=	liquid volume balance percent relative error
E	=	liquid volume balance error
I	=	liquid inventory entering the model domain from liquid waste site releases
O	=	total liquid outflow from the model domain
R	=	total natural recharge
S	=	change in liquid storage within the model domain
STOMP	=	Subsurface Transport Over Multiple Phases

The contaminant mass balance error (E_C) is calculated as shown in Equation 6-5 (all variables have units of kg or Ci, depending upon if the contaminant is a chemical or a radionuclide):

$$E_C = (S_C + O_C) - I_C \quad \text{(Eq. 6-5)}$$

where:

E_C	=	contaminant mass or activity balance error
I_C	=	contaminant inventory entering the model domain from waste site releases
O_C	=	total contaminant mass or activity outflow from the model domain
S_C	=	contaminant storage within the model domain at the end of the simulation.

The percent relative error ($\%RE_C$) of the contaminant mass balance is calculated as shown in Equation 6-6:

$$\%RE_C = 100|E_C/I_C| \quad \text{(Eq. 6-6)}$$

where:

$\%RE_C$	=	the contaminant mass or activity balance percent relative error.

The total contaminant outflow (O_C) is the cumulative mass or activity of a particular contaminant that migrated through the bottom boundary of the vadose zone model from the beginning of the simulation (1943) to the end of the mass balance analysis period (either 2018 or 3070). The contaminant storage (S_C) is the difference in total mass or activity of a particular radionuclide in the model between the end of the mass balance analysis period and the beginning of the simulation. Because it is assumed there were no contaminants in the model in 1943, this can be understood as the change in total mass or activity of a contaminant in the model domain during the analysis period. The contaminant inventory (I_C) is the cumulative mass or activity of a contaminant released to the model from the liquid waste release sites in the source zone. Table 6-3 shows the mass and activity balances for the U-10 West Area model.

Table 6-3. Transient No-Decay Mass and Activity Balances for the U-10 West Area Model

Contaminant	Released Contaminant Inventory (I_C) [a]	Contaminant Storage (S_C) [a,b]	Contaminant Outflow (O_C) [a,b]	Error (E_C) [a]	Relative Error ($\%RE_C$)
1943–2018					
H-3	6.934E+02	9.867E+00	6.863E+02	2.689E+00	3.877E-01
I-129	1.113E-01	1.623E-02	9.529E-02	2.572E-04	2.312E-01
Sr-90	2.025E+00	2.025E+00	0.000E+00	3.137E-05	1.549E-03
Tc-99	8.859E-03	3.556E-04	8.547E-03	4.375E-05	4.939E-01
Total U	1.154E+03	1.361E+02	1.019E+03	1.687E+00	1.463E-01
Cr [d]	5.586E+03	9.752E+01	5.511E+03	2.279E+01	4.079E-01
NO_3	1.364E+06	6.275E+04	1.308E+06	6.484E+03	4.752E-01
CN	0.000E+00	0.000E+00	0.000E+00	See note c	See note c

Table 6-3. Transient No-Decay Mass and Activity Balances for the U-10 West Area Model

Contaminant	Released Contaminant Inventory (I_C)[a]	Contaminant Storage (S_C)[a,b]	Contaminant Outflow (O_C)[a,b]	Error (E_C)[a]	Relative Error ($\%RE_C$)
1943–3070					
H-3	6.934E+02	1.591E+00	6.945E+02	2.691E+00	3.881E-01
I-129	1.113E-01	1.308E-02	9.844E-02	2.574E-04	2.313E-01
Sr-90	2.025E+00	2.025E+00	0.000E+00	3.137E-05	1.549E-03
Tc-99	8.859E-03	1.008E-04	8.802E-03	4.395E-05	4.961E-01
Total U	1.154E+03	1.206E+02	1.035E+03	1.691E+00	1.465E-01
Cr[d]	5.586E+03	2.559E+00	5.606E+03	2.280E+01	4.081E-01
NO_3	1.364E+06	1.801E+04	1.353E+06	6.517E+03	4.777E-01
CN	0.000E+00	0.000E+00	0.000E+00	See note c	See note c

a. Units are in kilograms for CN, Cr, NO_3, and total U; units are in Curies for H-3, I-129, Sr-90, and Tc-99.

b. Calculated by STOMP.

c. The contaminant has no inventory.

d. All chromium was assumed to be in the mobile hexavalent form, with assumed K_d = 0 mL/g.

$\%RE_C$ = contaminant mass or activity balance percent relative error

E_C = contaminant mass or activity balance error

I_C = contaminant inventory entering the model domain from waste site releases

O_C = total contaminant mass or activity outflow from the model domain

S_C = contaminant storage within the model domain at the end of the simulation

STOMP = Subsurface Transport Over Multiple Phases

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7 Results

This chapter presents the results of the transport simulations. These results include the calculation of cumulative contaminant mass or activity transferred to the groundwater and the cumulative mass or activity remaining in the vadose zone at the end of the historical period (1943–2018) and the CIE evaluation (i.e., forecast) period (2018–3070).

For each of the eight contaminants, Table 7-1 and Table 7-2 list the total mass or activity discharged to the groundwater and the total mass or activity remaining in the vadose zone. Table 7-1 shows these data at the end of the historical simulation (1943–2018), and Table 7-2 shows these data at the end of the forecast simulation (2018–3070).

The data presented in Table 7-1 and Table 7-2 are presented graphically in Sections 7.1 through 7.8. These sections each present the data for one contaminant. The cumulative mass or activity of contaminants discharged to the groundwater presented in Table 7-1 and Table 7-2 are shown spatially, aggregated by saturated zone grid cell for 1943–2018 in Figure 7-1 and similar figures, and for 2018-3070 for Figure 7-2 and similar figures. The cumulative mass or activity discharged to groundwater and the cumulative inventory released to the model through time in Table 7-1 and Table 7-2 are shown in figures for 1943–2018 (like Figure 7-3) and for 1943–3070 (like Figure 7-4).

Table 7-1. U-10 West Area Model Contaminant Transfer to Groundwater from 1943–2018 and Remaining Mass or Activity in the Vadose Zone at 2018

Contaminant	1943–2018 Inventory Released to Vadose Zone [a]	1943–2018 Mass or Activity Transferred to Groundwater [a]	1943–2018 Percent Mass or Activity Transferred to Groundwater [b]	Mass or Activity Remaining in Vadose Zone at 2018 [a]	Percent Mass or Activity Remaining in Vadose Zone at 2018 [b]
H-3	6.934E+02	6.560E+02	94.6	8.809E-01	0.1
I-129	1.113E-01	9.529E-02	85.6	1.623E-02	14.6
Sr-90	2.025E+00	0.000E+00	0.0	6.121E-01	30.2
Tc-99	8.859E-03	8.547E-03	96.5	3.556E-04	4.0
Total U	1.154E+03	1.019E+03	88.4	1.361E+02	11.8
Cr [d]	5.586E+03	5.511E+03	98.7	9.752E+01	1.7
NO_3	1.364E+06	1.308E+06	95.9	6.275E+04	4.6
CN	0.000E+00	0.000E+00	See note c	0.000E+00	See note c

a. Units are in kilograms for CN, Cr, NO_3, and total U; units are in Curies for H-3, I-129, Sr-90, and Tc-99.

b. The percentage or sum of percentages could differ slightly from 100 due to numerical error.

c. The contaminant has no 1943-2018 inventory.

d. All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium releases were therefore not passed on to the saturated zone model.

Table 7-2. U-10 West Area Model Contaminant Transfer to Groundwater from 2018–3070 and Remaining Mass or Activity in the Vadose Zone at 3070

Contaminant	1943–3070 Inventory Released to Vadose Zone [a]	2018–3070 Mass or Activity Transferred to Groundwater [a]	2018–3070 Percent Mass or Activity Transferred to Groundwater [b]	Mass or Activity Remaining in Vadose Zone at 3070 [a]	Percent Mass or Activity Remaining in Vadose Zone at 3070 [b]
H-3	6.934E+02	3.475E-02	<0.1	0.000E+00	0.0
I-129	1.113E-01	3.154E-03	2.8	1.308E-02	11.8
Sr-90	2.025E+00	0.000E+00	0.0	4.568E-12	<0.1
Tc-99	8.859E-03	2.545E-04	2.9	1.004E-04	1.1
Total U	1.154E+03	1.542E+01	1.3	1.206E+02	10.5
Cr [d]	5.586E+03	9.497E+01	1.7	2.559E+00	<0.1
NO_3	1.364E+06	4.477E+04	3.3	1.801E+04	1.3
CN	0.000E+00	0.000E+00	See note c	0.000E+00	See note c

a. Units are in kilograms for CN, Cr, NO_3, and total U; units are in Curies for H-3, I-129, Sr-90, and Tc-99.

b. The percentage or sum of percentages could differ slightly from 100 due to numerical error.

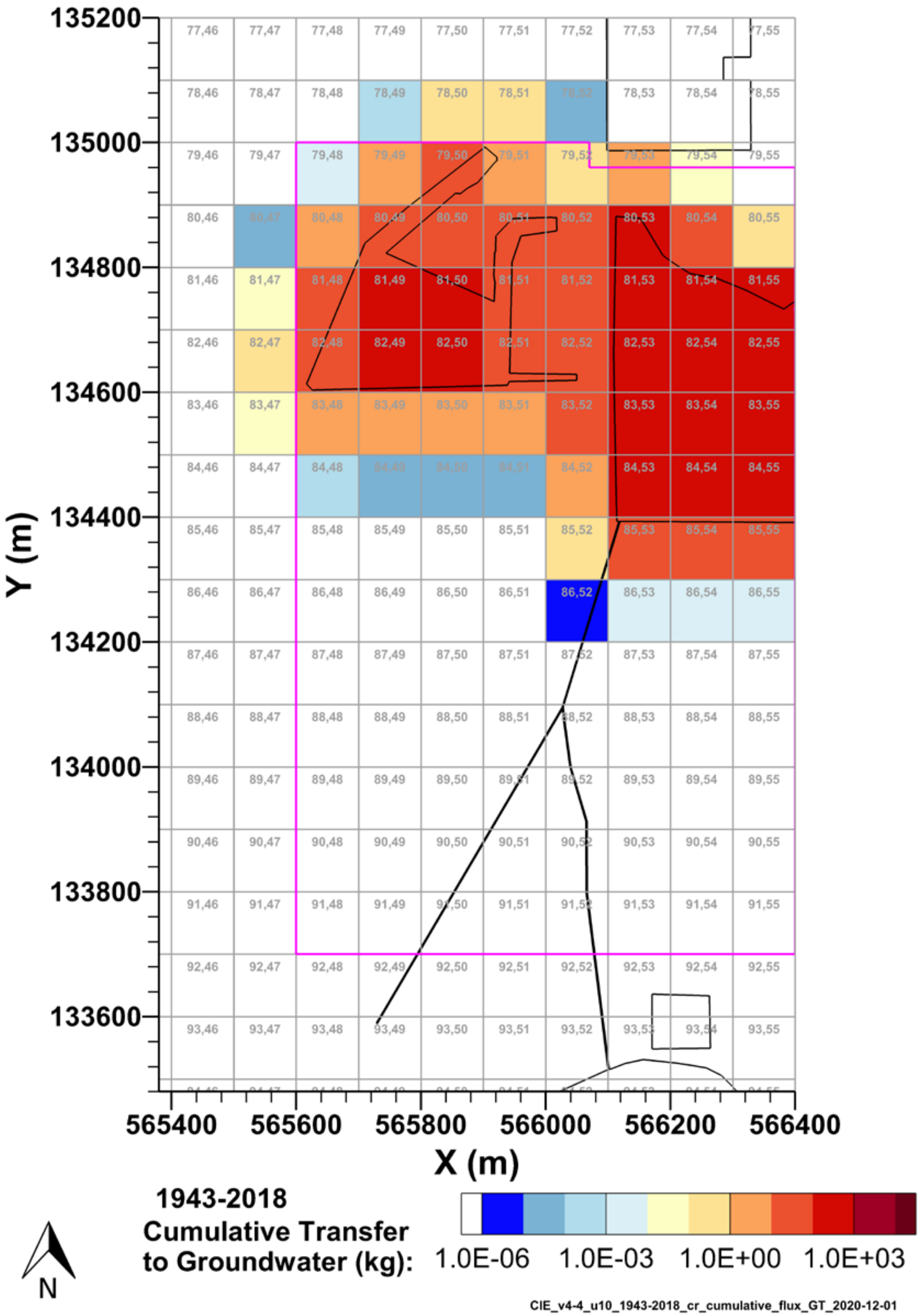
c. The contaminant has no 1943-3070 inventory.

d. All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium releases were therefore not passed on to the saturated zone model.

Further description of the fate and transport of each contaminant is outlined in Sections 7.1 through 7.8. Results presented in the sections show cumulative mass or activity of the contaminant discharged to groundwater over the historical (1943–2018) and forecast (2018–3070) simulations, and figures showing the cumulative mass or activity released from the sources compared to the transfer rate to groundwater for the historical (1943–2018) and entire (1943–3070) modeled periods. For chromium, I-129, NO_3, and total uranium, additional figures were included detailing the contaminant flux to groundwater.

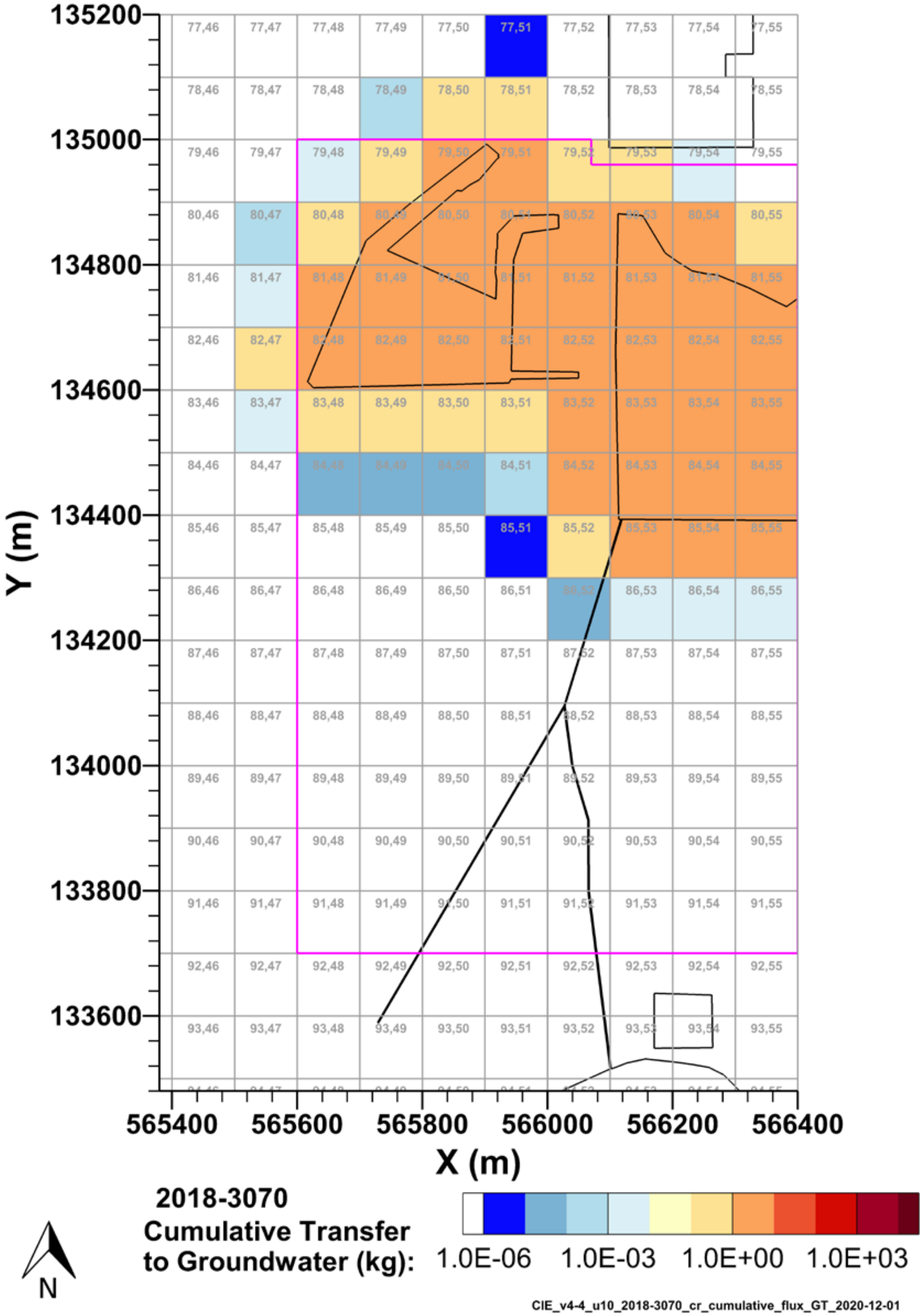
7.1 Chromium Fate and Transport Results

This model simulated the release and transport of chromium. The chromium released in this model represents a bounding case where all chromium released is assumed to be in mobile hexavalent form, where K_d = 0 mL/g. The figures presented here show contaminant transfer data which were not passed on to the saturated zone model. Further discussion of chromium modeling approach in these models can be found in CP-63515, Appendix C. The cumulative discharge of chromium into groundwater is shown aggregated by saturated zone model grid cell in Figure 7-1 and Figure 7-2 for 1943–2018 and 2018–3070, respectively. The inventory released to the U-10 West Area model and the transfer of chromium to groundwater are shown from 1943–2018 in Figure 7-3 and from 1943–3070 in Figure 7-4. Figure 7-5 through Figure 7-9 show the flux of chromium to groundwater in kg/m^2/yr. These figures are generated at times with peak fluxes (local maxima) and during periods with gradual decline, as shown in Figure 7-3 and Figure 7-4. A figure for 2018, Figure 7-7, is also included to demonstrate the flux conditions at the start of the 2018–3070 simulation.



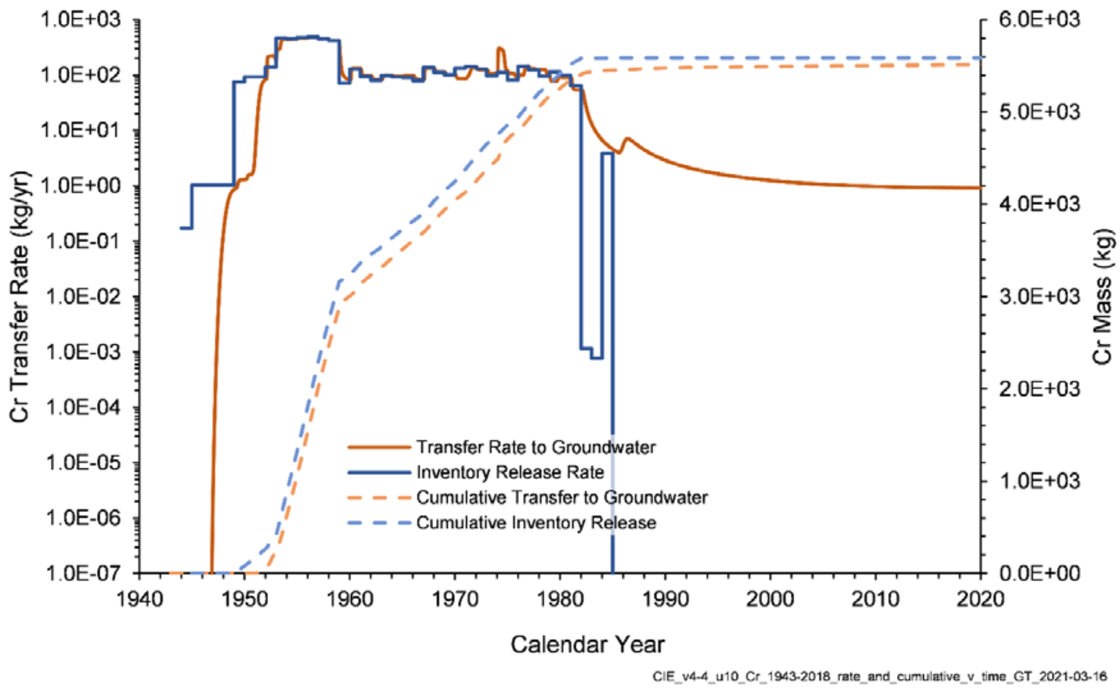
Note: source zone outlined in pink. All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium results were therefore not passed on to the saturated zone model.

Figure 7-1. Cumulative Chromium Mass Discharged to Groundwater from the U-10 West Area Model from 1943–2018 per Saturated Zone Model Grid Cell



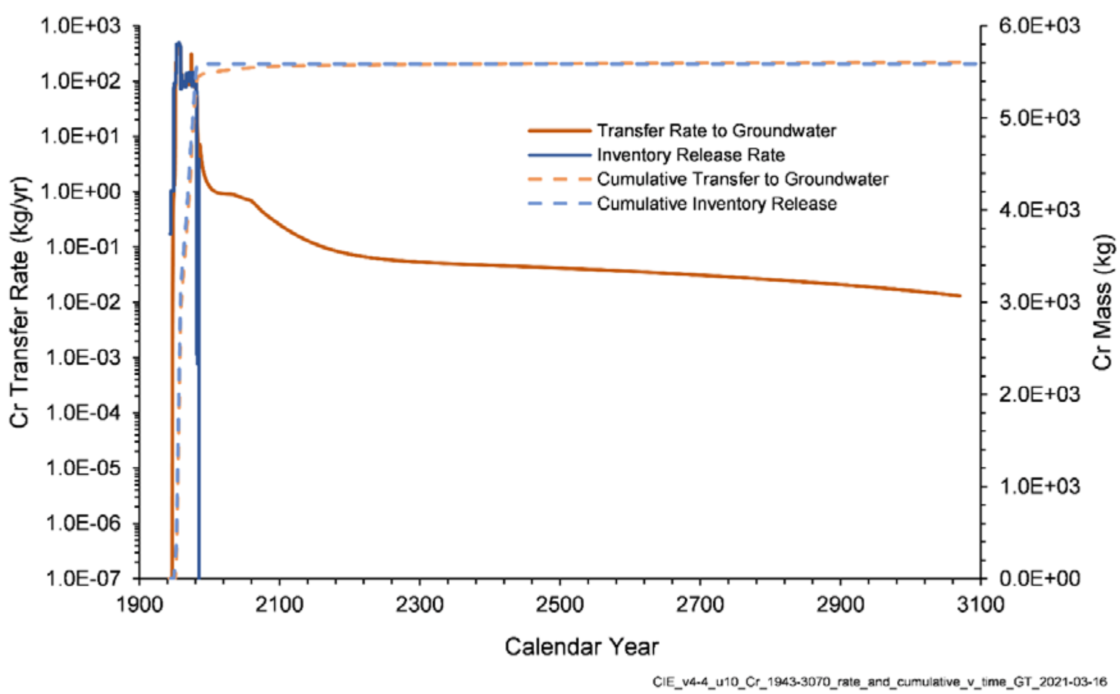
Note: source zone outlined in pink. All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium results were therefore not passed on to the saturated zone model.

Figure 7-2. Cumulative Chromium Mass Discharged to Groundwater from the U-10 West Area Model from 2018–3070 per Saturated Zone Model Grid Cell



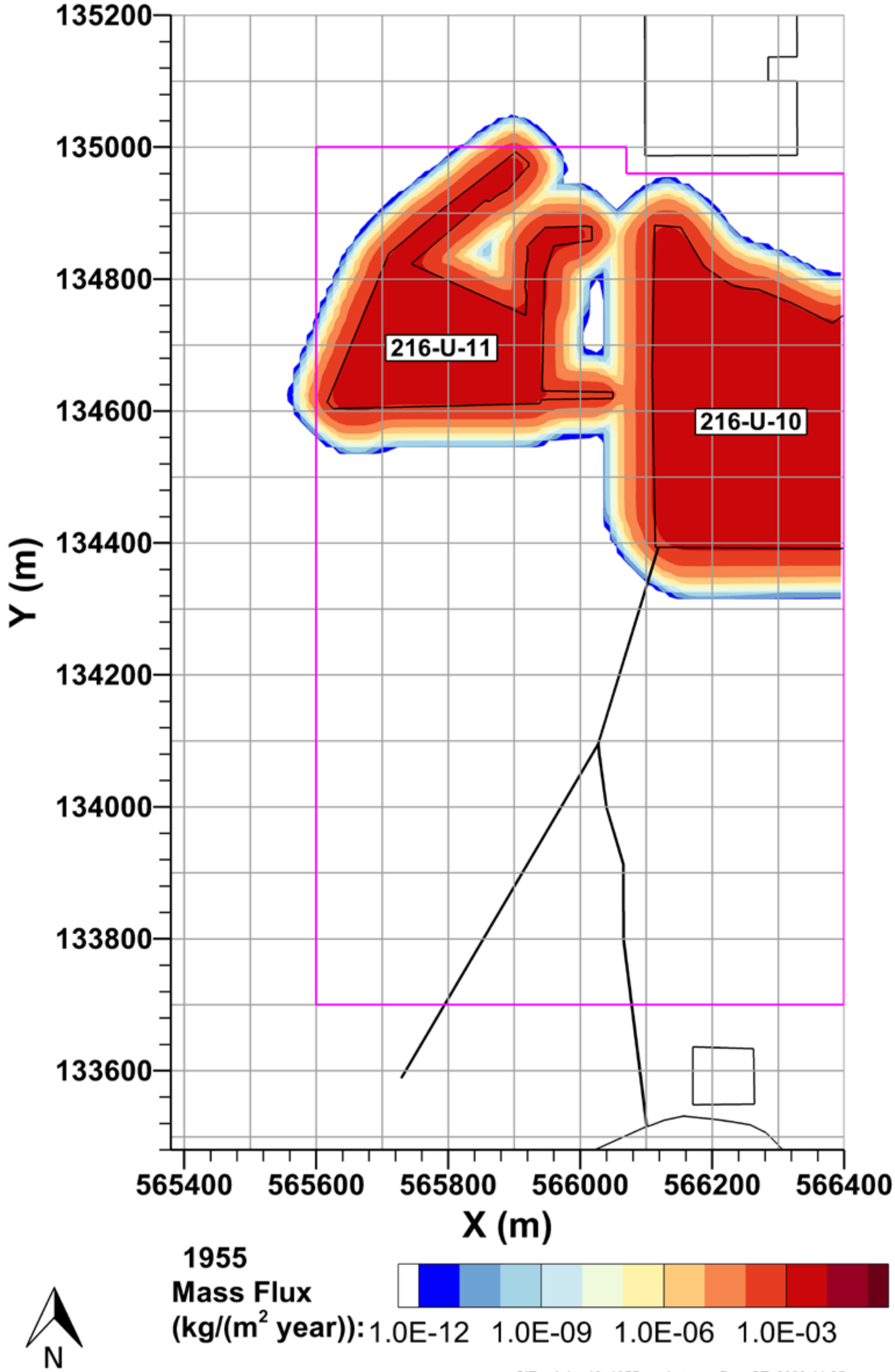
Note: All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium results were therefore not passed on to the saturated zone model.

Figure 7-3. Chromium Inventory Release from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–2018



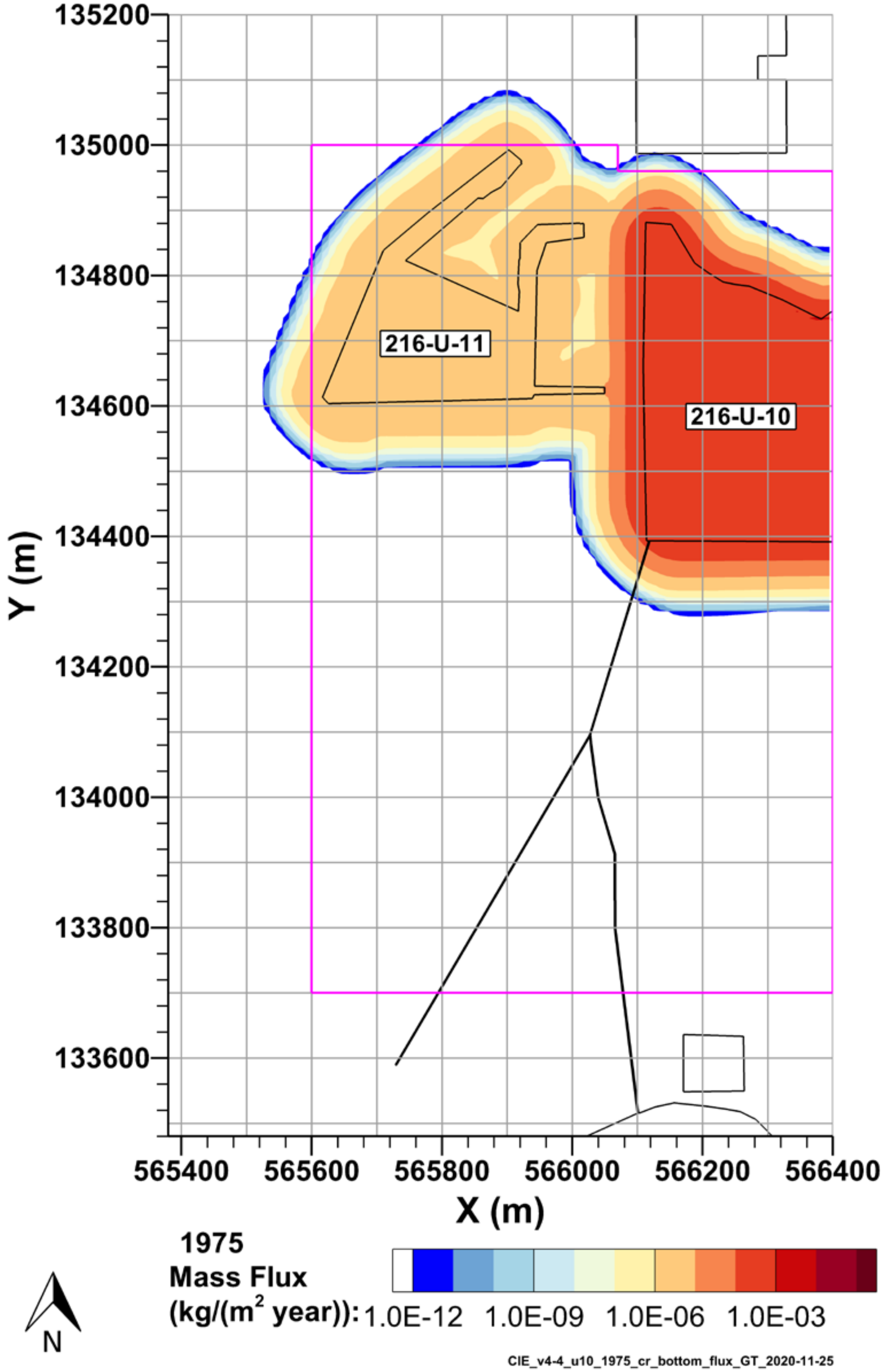
Note: All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium results were therefore not passed on to the saturated zone model.

Figure 7-4. Chromium Inventory Release from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–3070



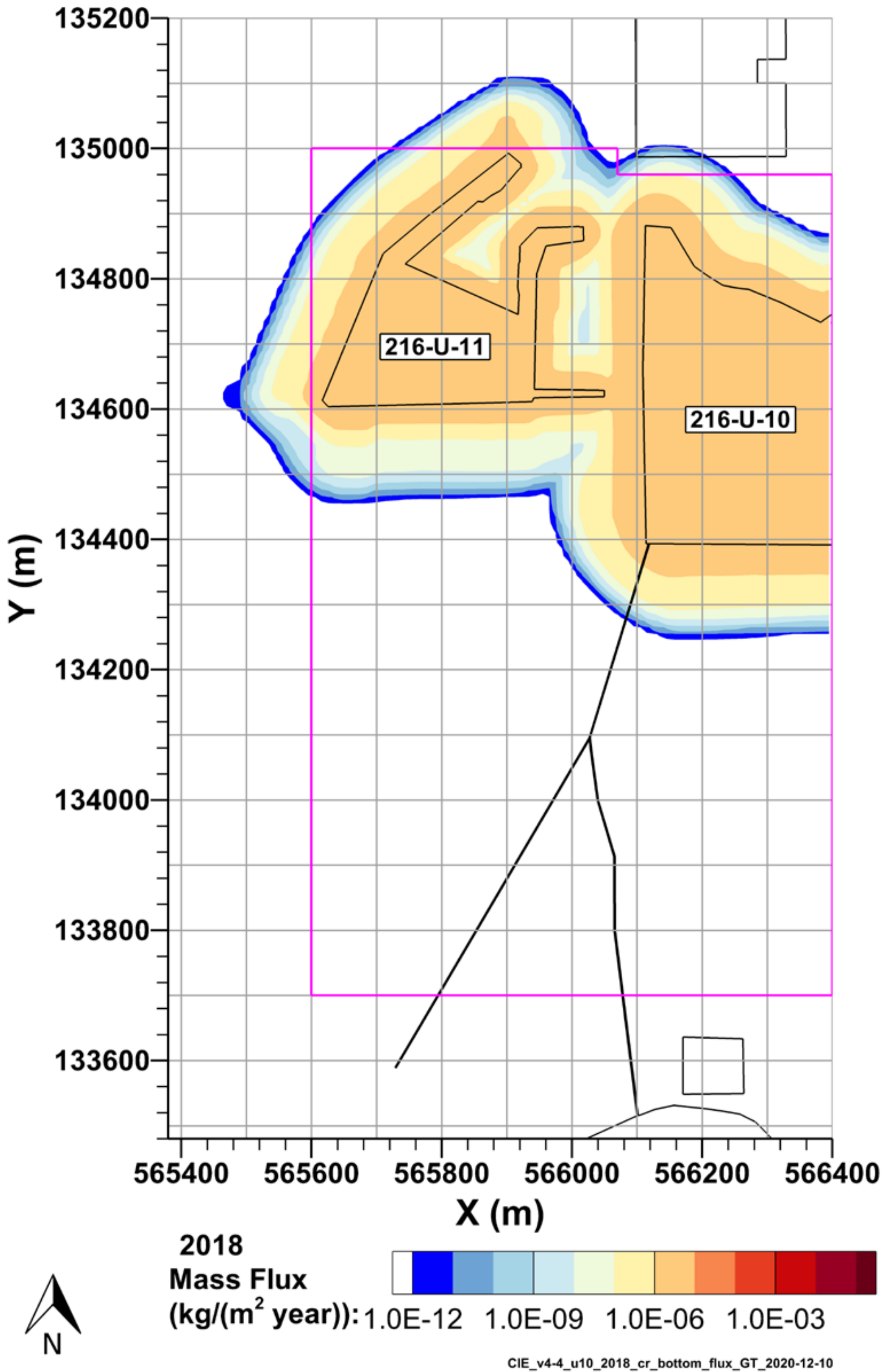
Note: source zone outlined in pink. All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium results were therefore not passed on to the saturated zone model.

Figure 7-5. Chromium Flux to Groundwater, 1955



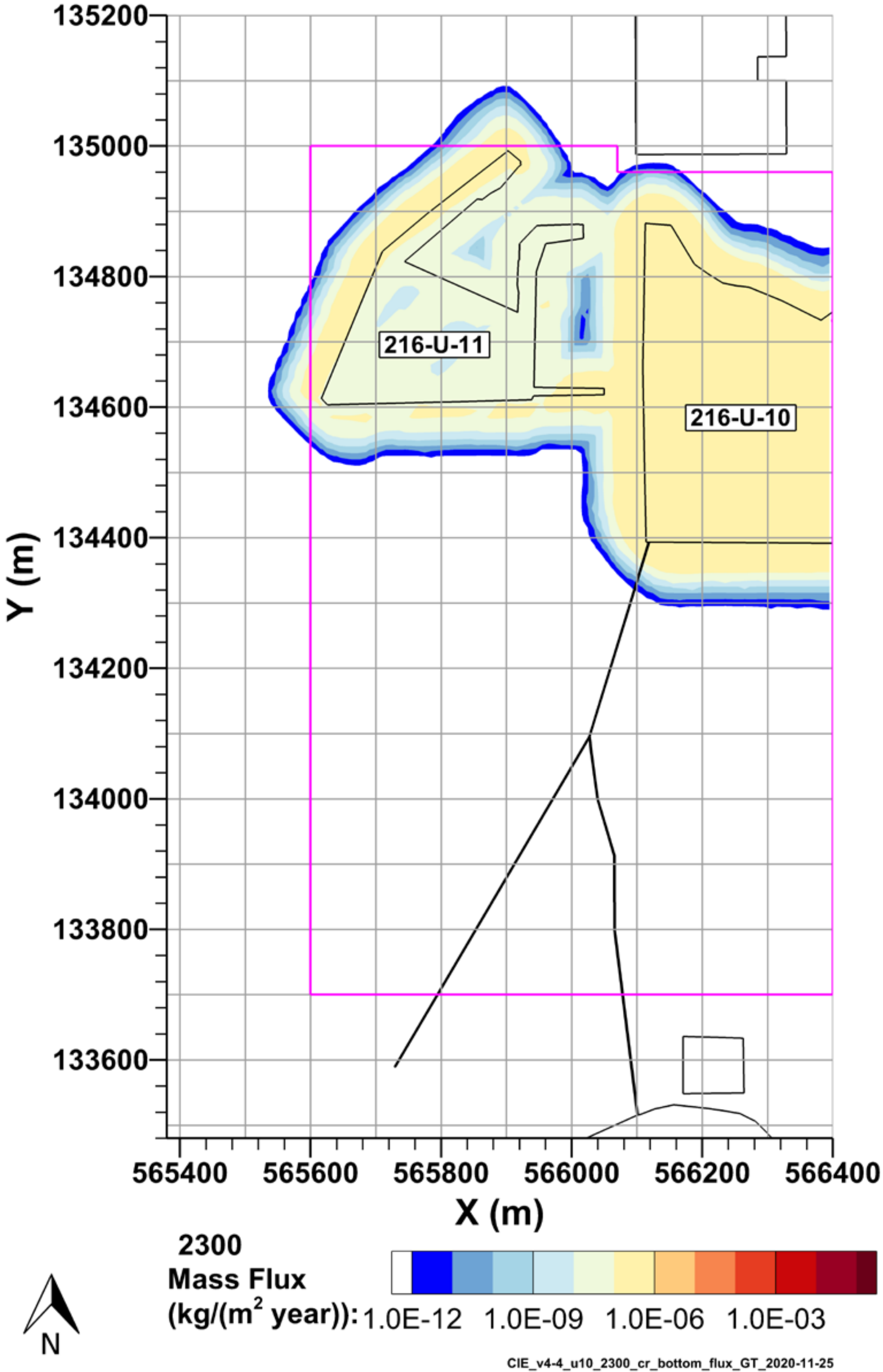
Note: source zone outlined in pink. All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium results were therefore not passed on to the saturated zone model.

Figure 7-6. Chromium Flux to Groundwater, 1975



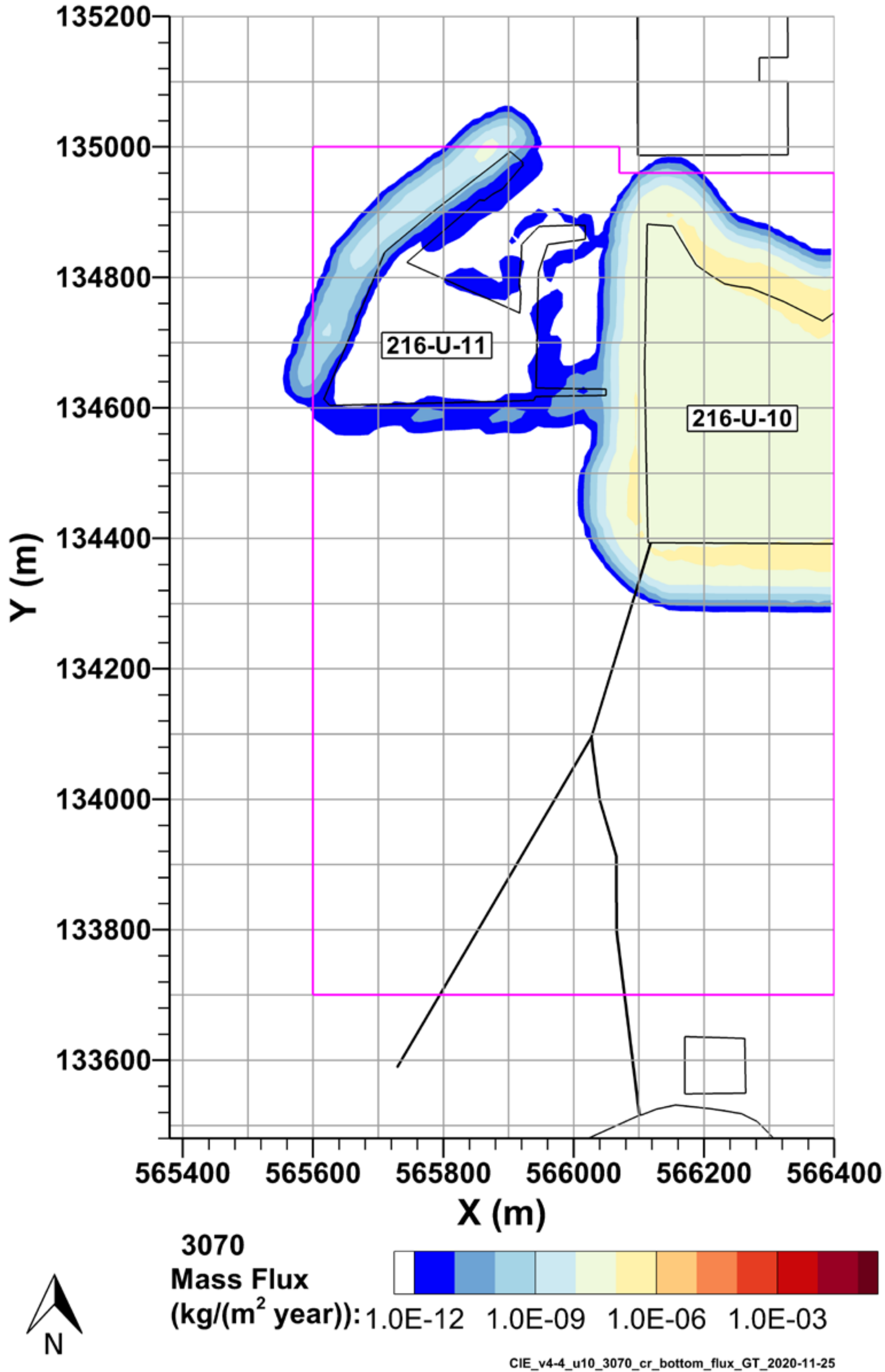
Note: source zone outlined in pink. All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium results were therefore not passed on to the saturated zone model.

Figure 7-7. Chromium Flux to Groundwater, 2018



Note: source zone outlined in pink. All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium results were therefore not passed on to the saturated zone model.

Figure 7-8. Chromium Flux to Groundwater, 2300



Note: source zone outlined in pink. All chromium was assumed to be in the mobile hexavalent form, where K_d = 0 mL/g. This assumption may over-estimate release to groundwater. Chromium results were therefore not passed on to the saturated zone model.

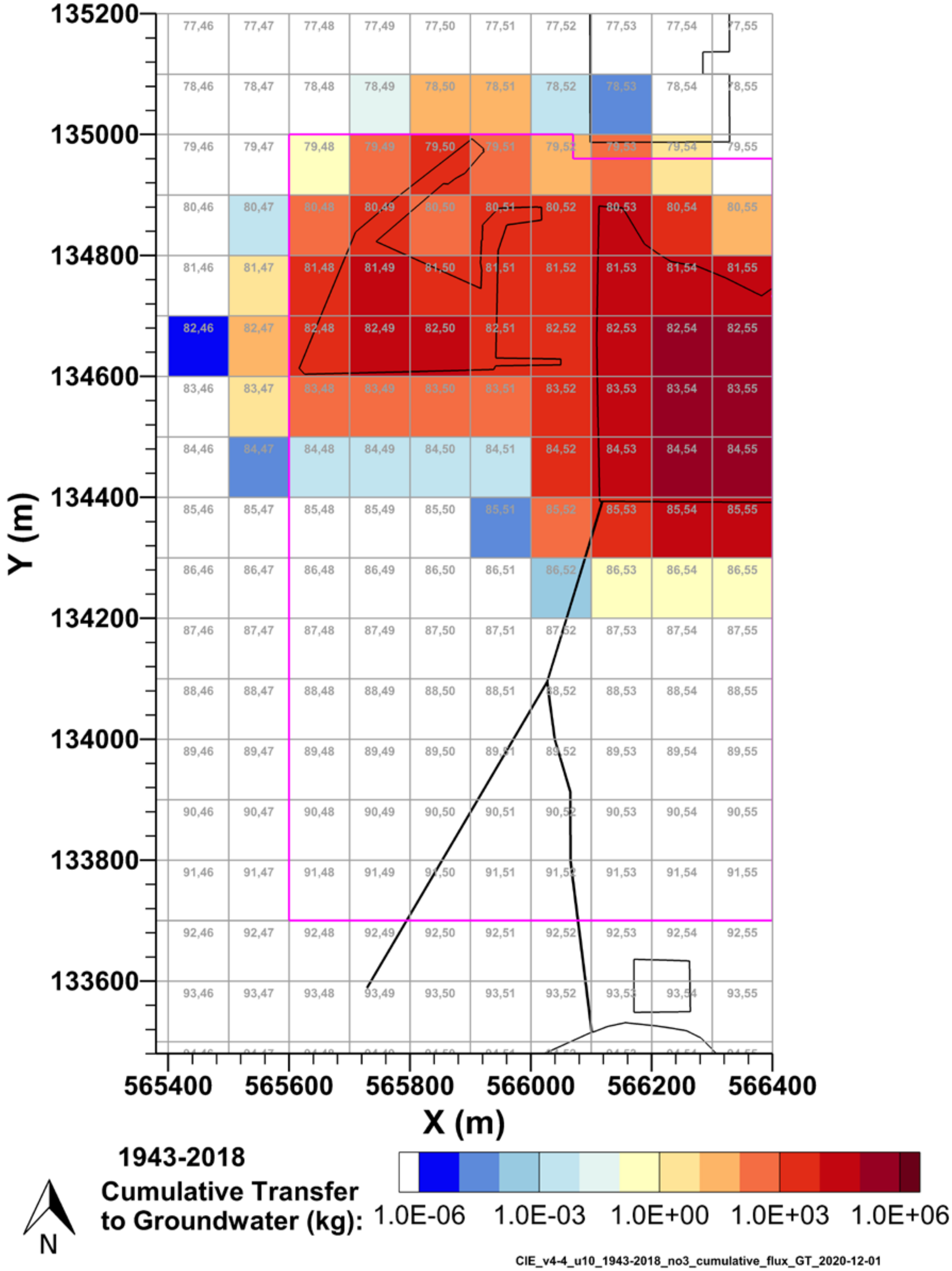
Figure 7-9. Chromium Flux to Groundwater, 3070

7.2 CN Fate and Transport Results

Due to a lack of inventory, transport of CN was not calculated in this model.

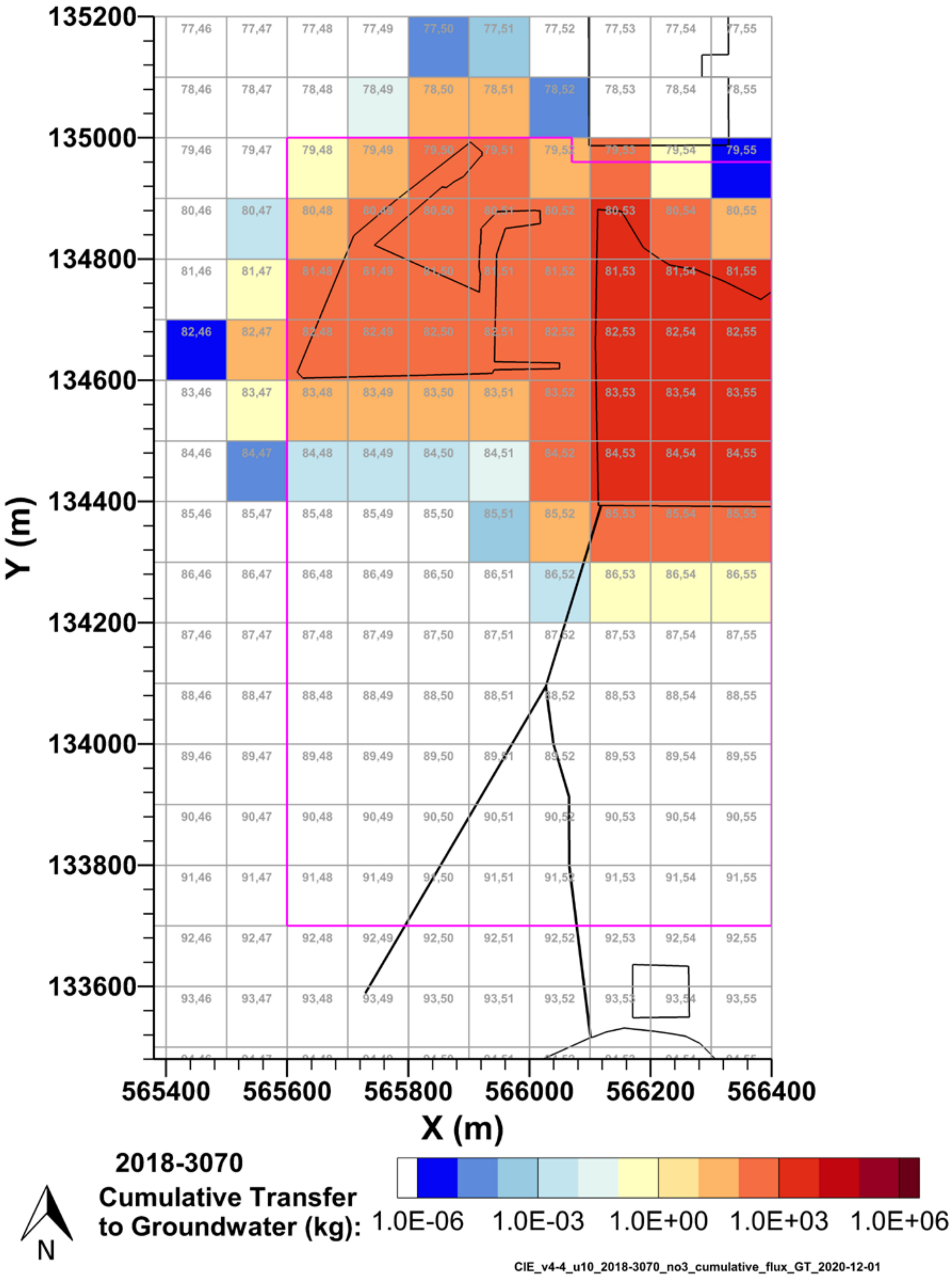
7.3 NO_3 Fate and Transport Results

This model simulated the release and transport of NO_3. The cumulative discharge of NO_3 into groundwater is shown aggregated by saturated zone model grid cell in Figure 7-10 and Figure 7-11 for 1943–2018 and 2018–3070, respectively. The inventory released to the U-10 West Area model and the transfer of NO_3 to groundwater are shown from 1943–2018 in Figure 7-12 and from 1943–3070 in Figure 7-13. Figure 7-14 through Figure 7-20 show the flux of NO_3 to groundwater in kg/m^2/yr. These figures are generated at times with peak fluxes (local maxima) and during periods with gradual decline, as shown in Figure 7-12 and Figure 7-13. A figure for 2018, Figure 7-18, is also included to demonstrate the flux conditions at the start of the 2018–3070 simulation.



Note: source zone outlined in pink.

Figure 7-10. Cumulative NO_3 Mass Discharged to Groundwater from the U-10 West Area Model from 1943–2018 per Saturated Zone Model Grid Cell



Note: source zone outlined in pink.

Figure 7-11. Cumulative NO_3 Mass Discharged to Groundwater from the U-10 West Area Model from 2018–3070 per Saturated Zone Model Grid Cell

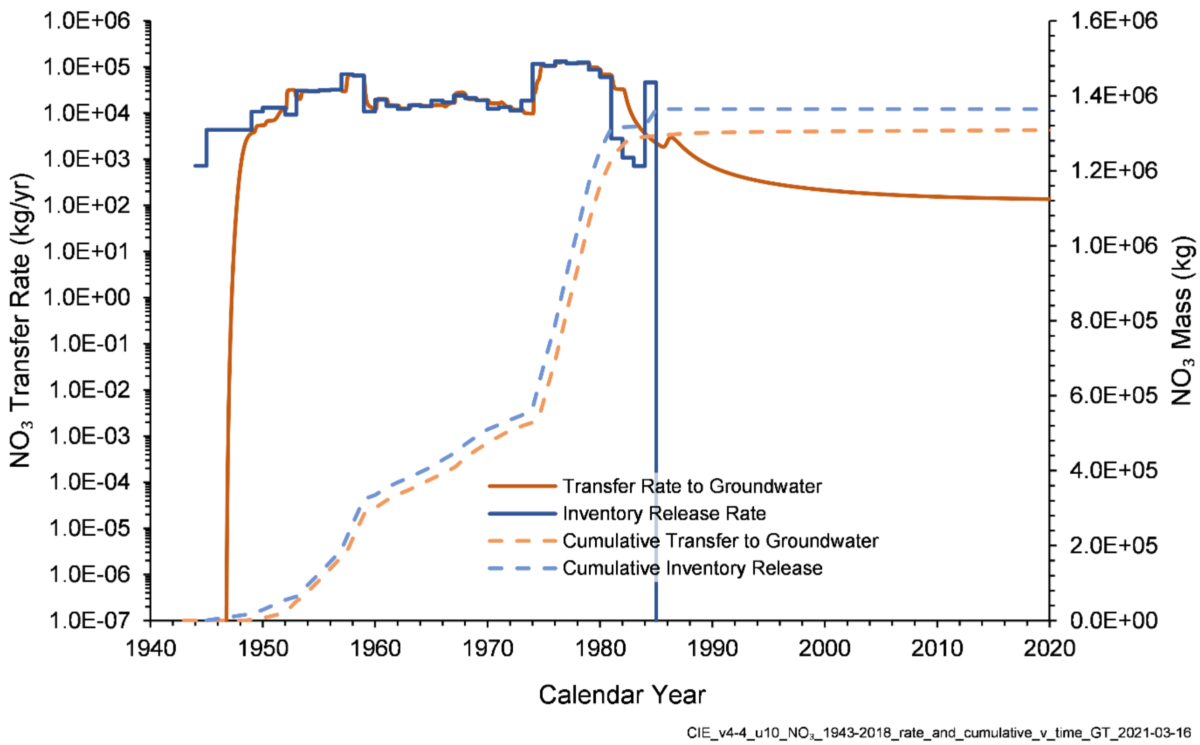


Figure 7-12. NO_3 Inventory Release from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–2018

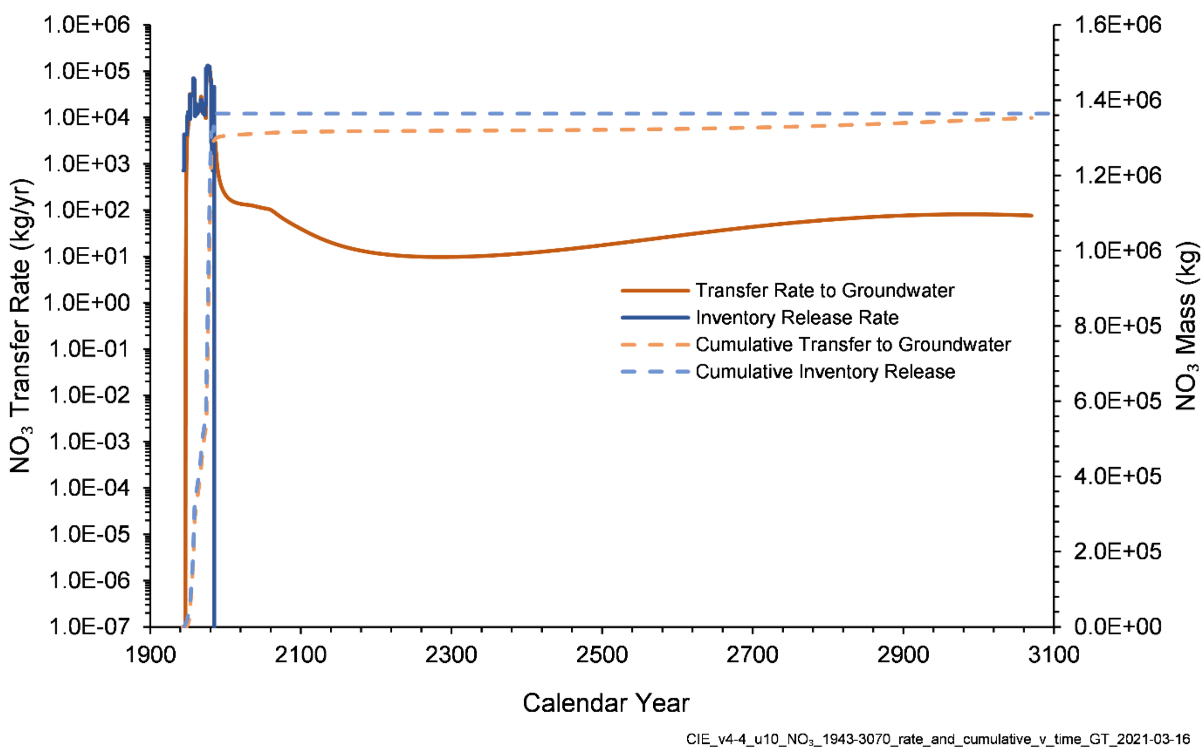
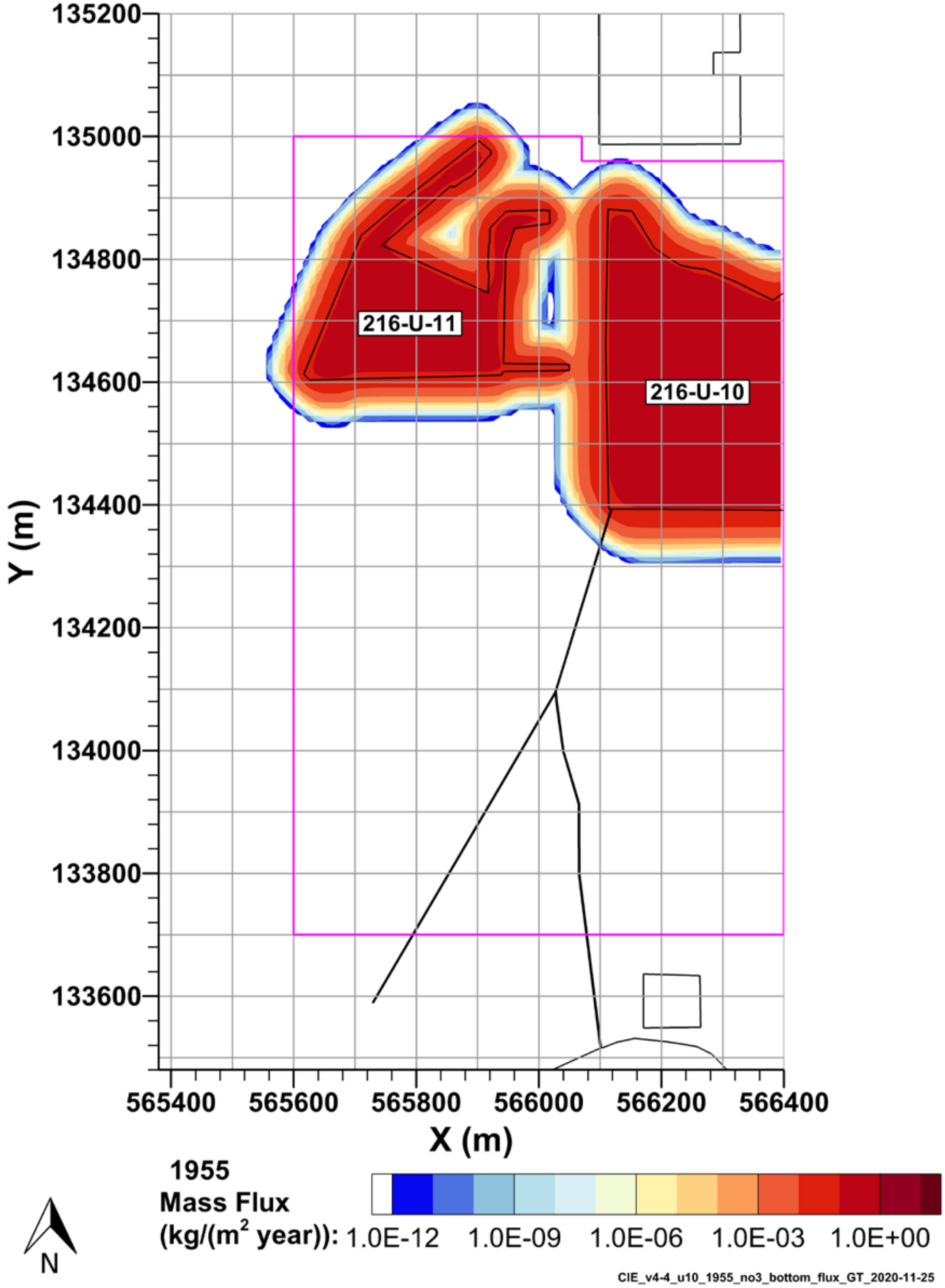
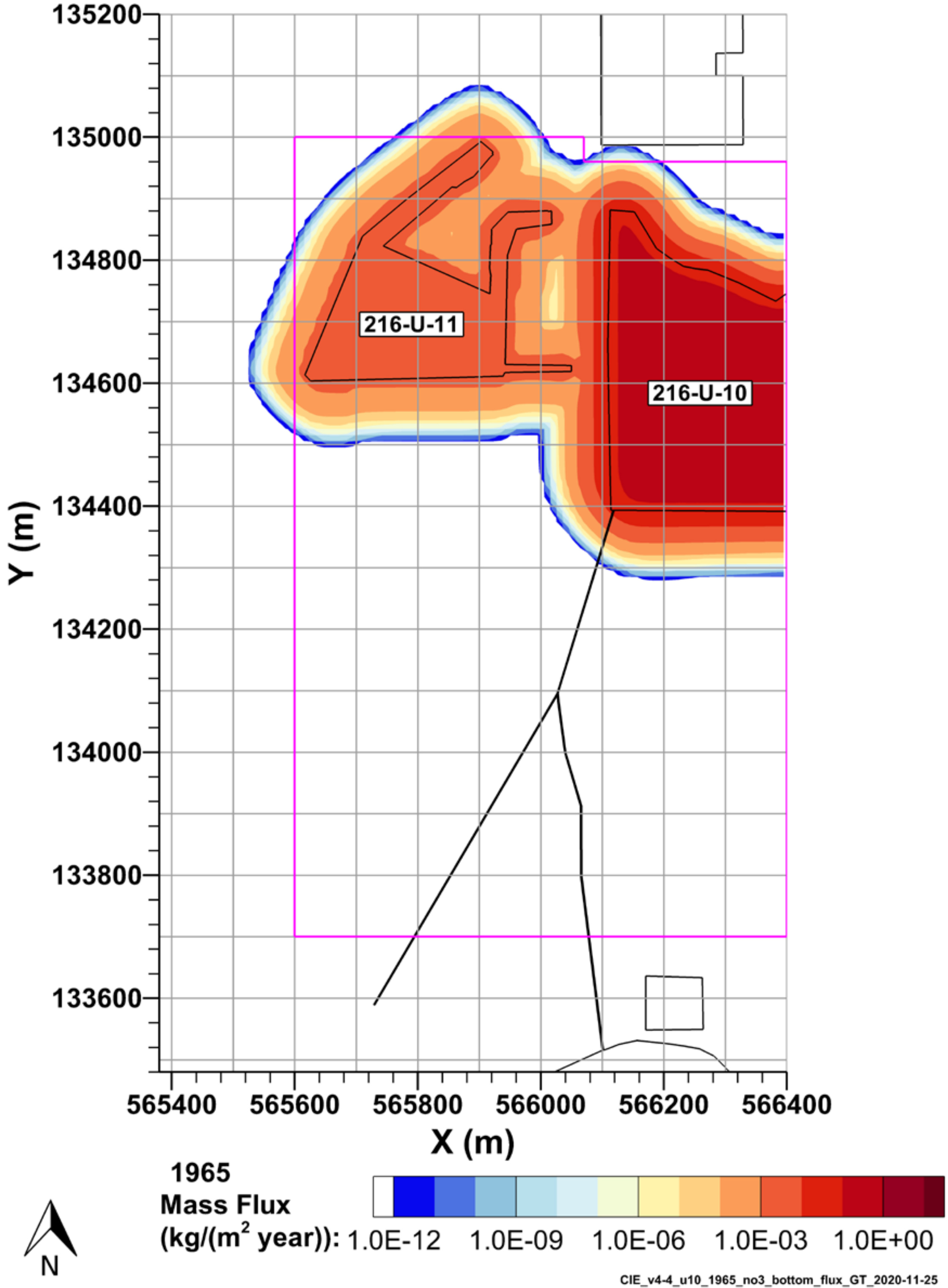


Figure 7-13. NO_3 Inventory Release from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–3070



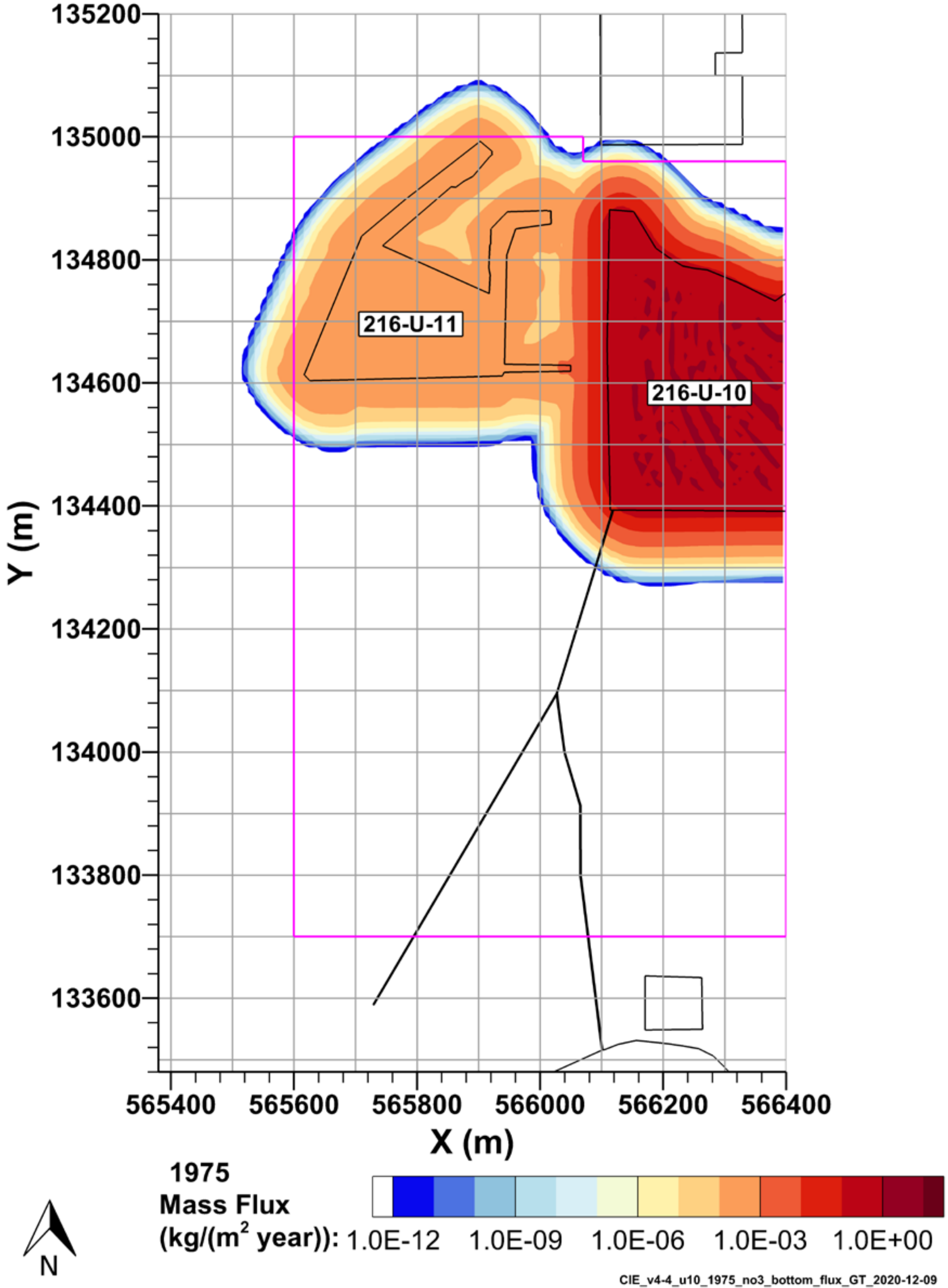
Note: source zone outlined in pink.

Figure 7-14. NO_3 Flux to Groundwater, 1955



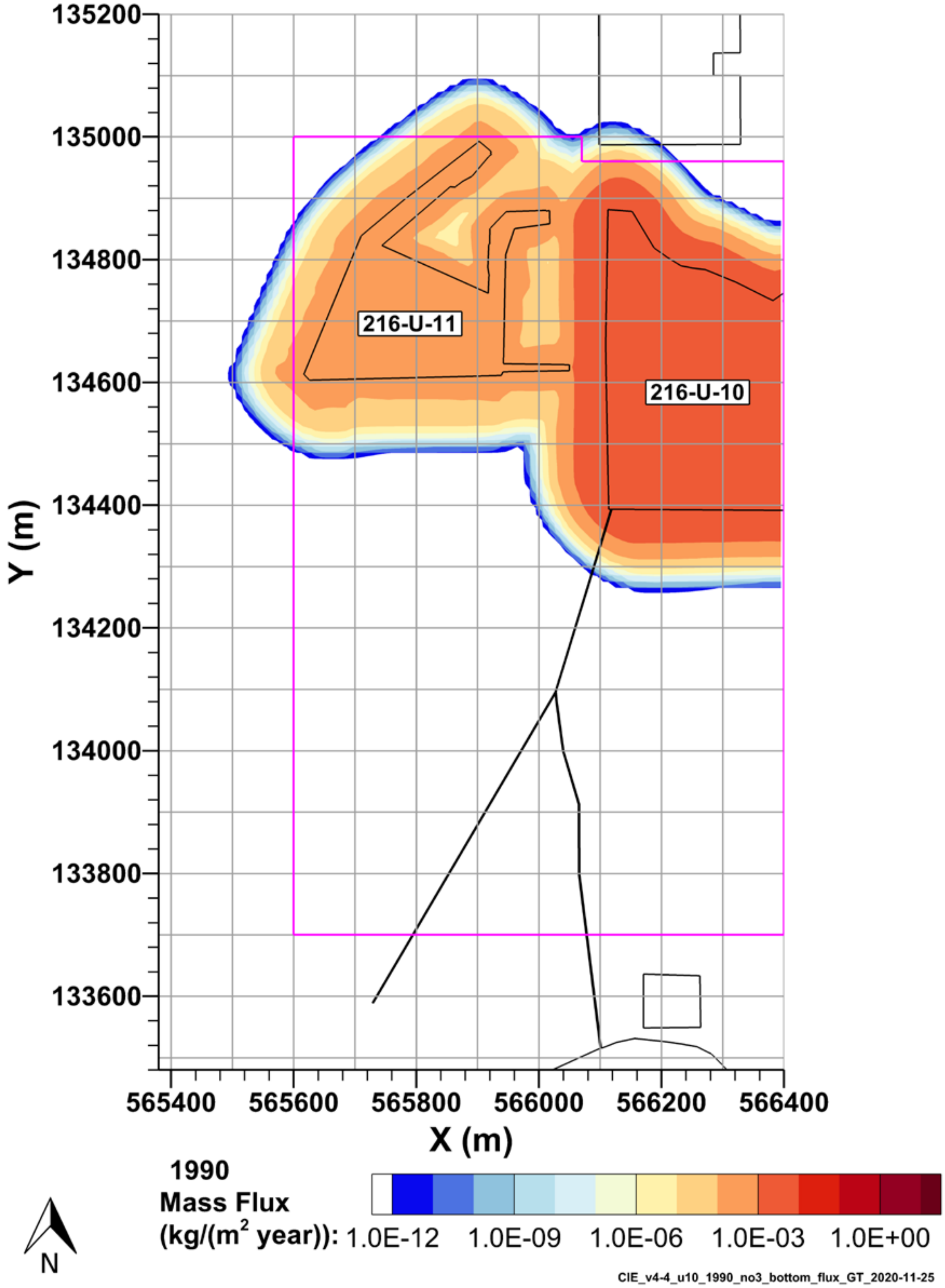
Note: source zone outlined in pink.

Figure 7-15. NO_3 Flux to Groundwater, 1965



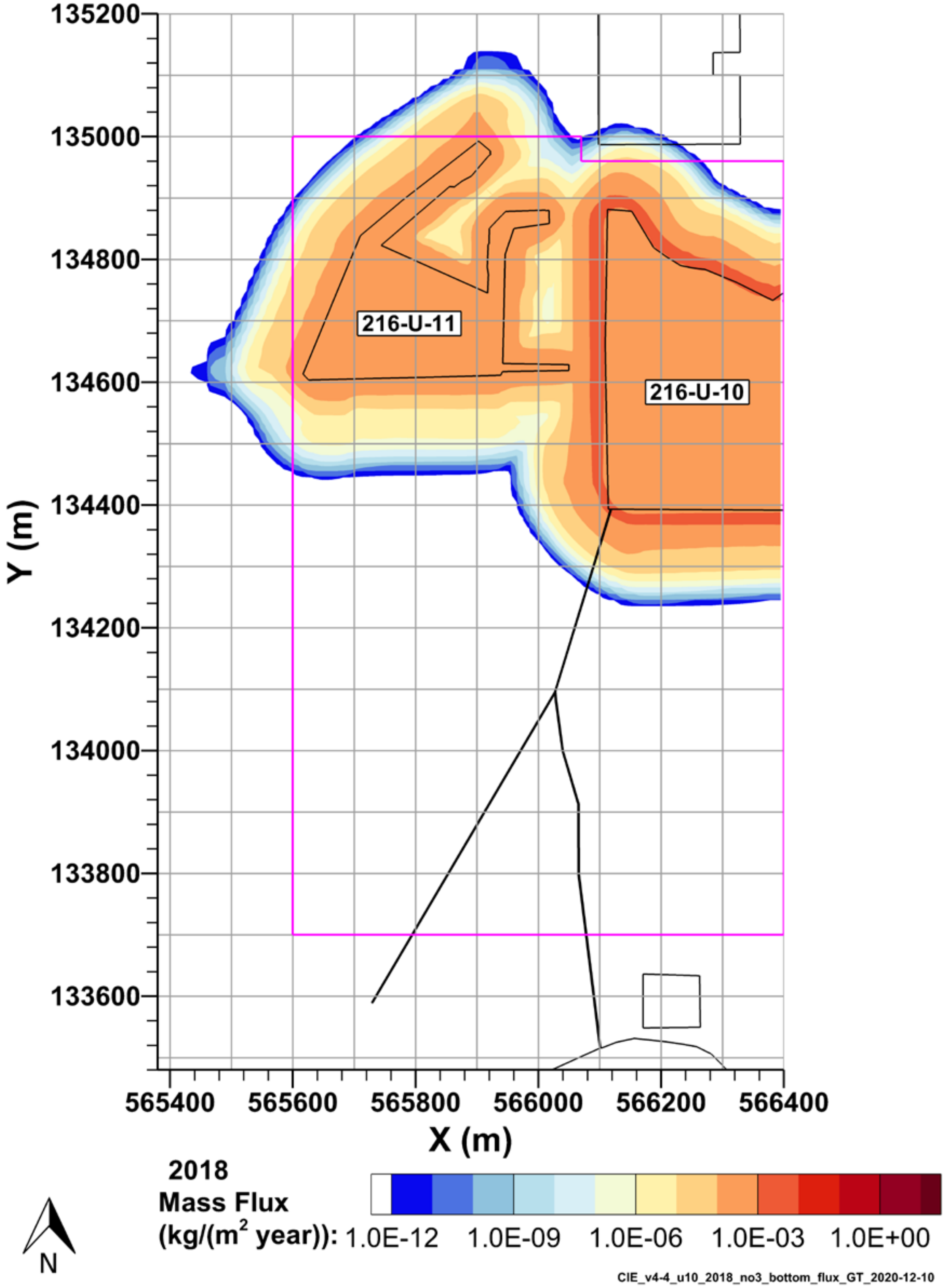
Note: source zone outlined in pink.

Figure 7-16. NO_3 Flux to Groundwater, 1975



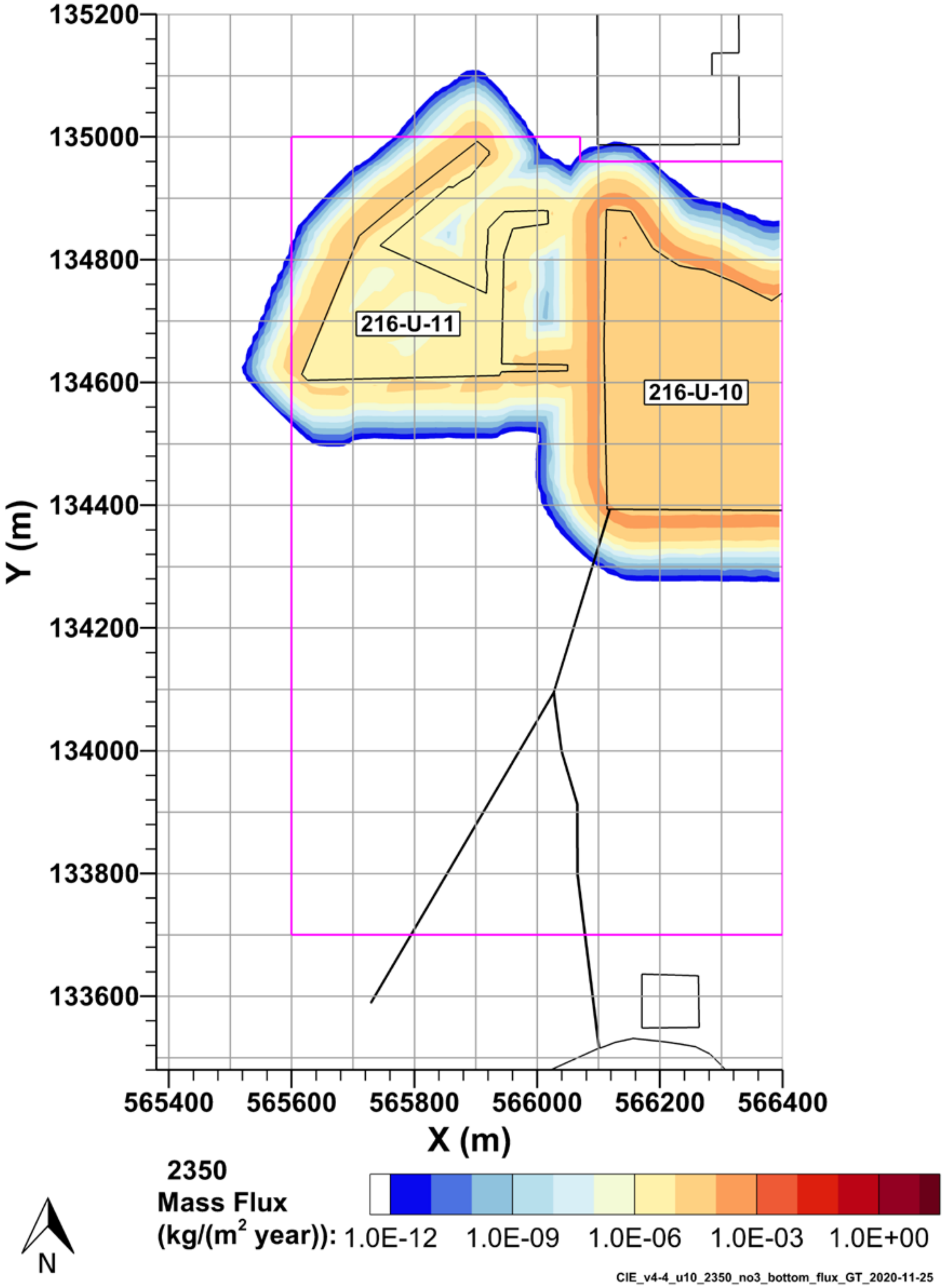
Note: source zone outlined in pink.

Figure 7-17. NO_3 Flux to Groundwater, 1990



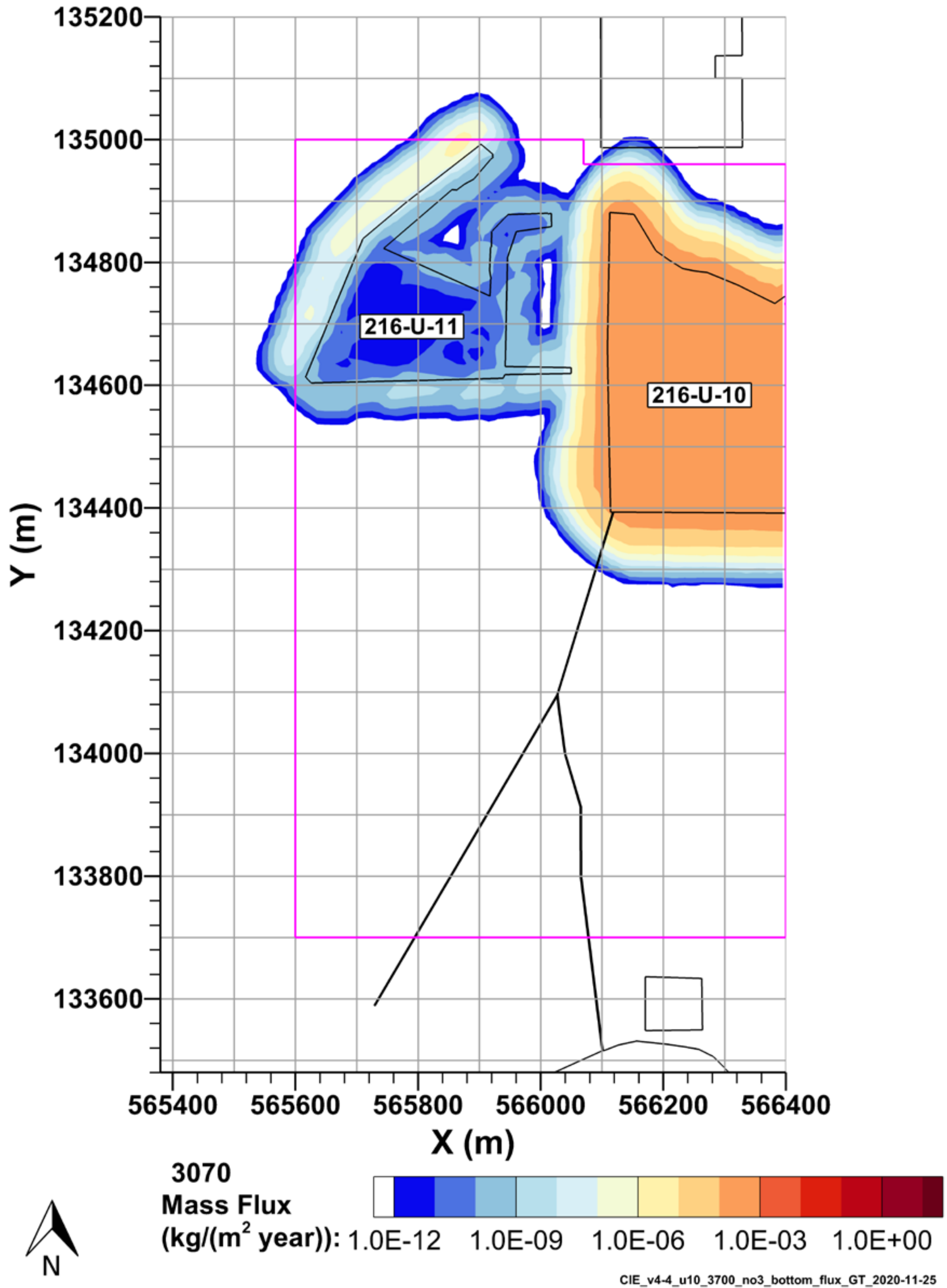
Note: source zone outlined in pink.

Figure 7-18. NO_3 Flux to Groundwater, 2018



Note: source zone outlined in pink.

Figure 7-19. NO_3 Flux to Groundwater, 2350

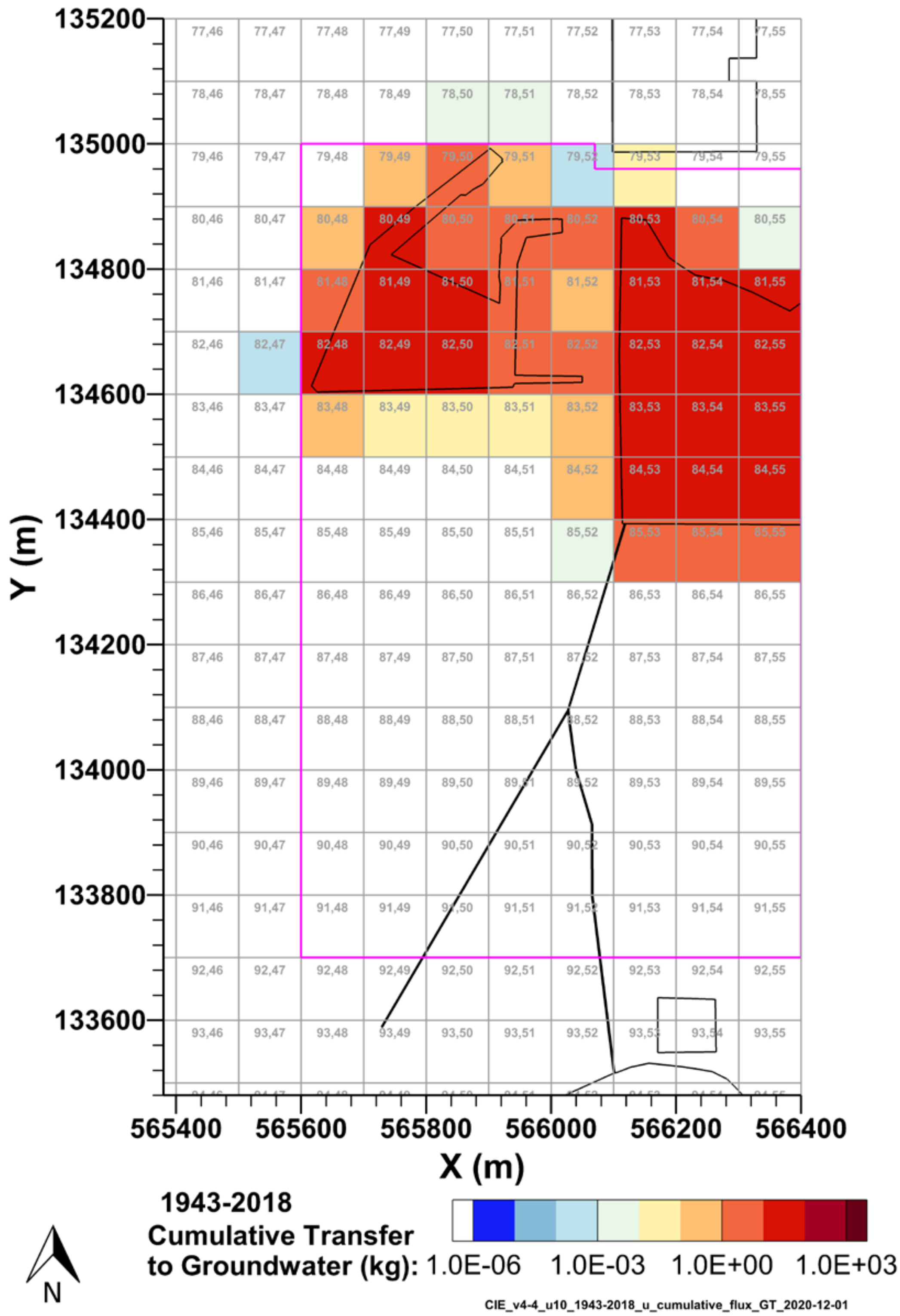


Note: source zone outlined in pink.

Figure 7-20. NO_3 Flux to Groundwater, 3700

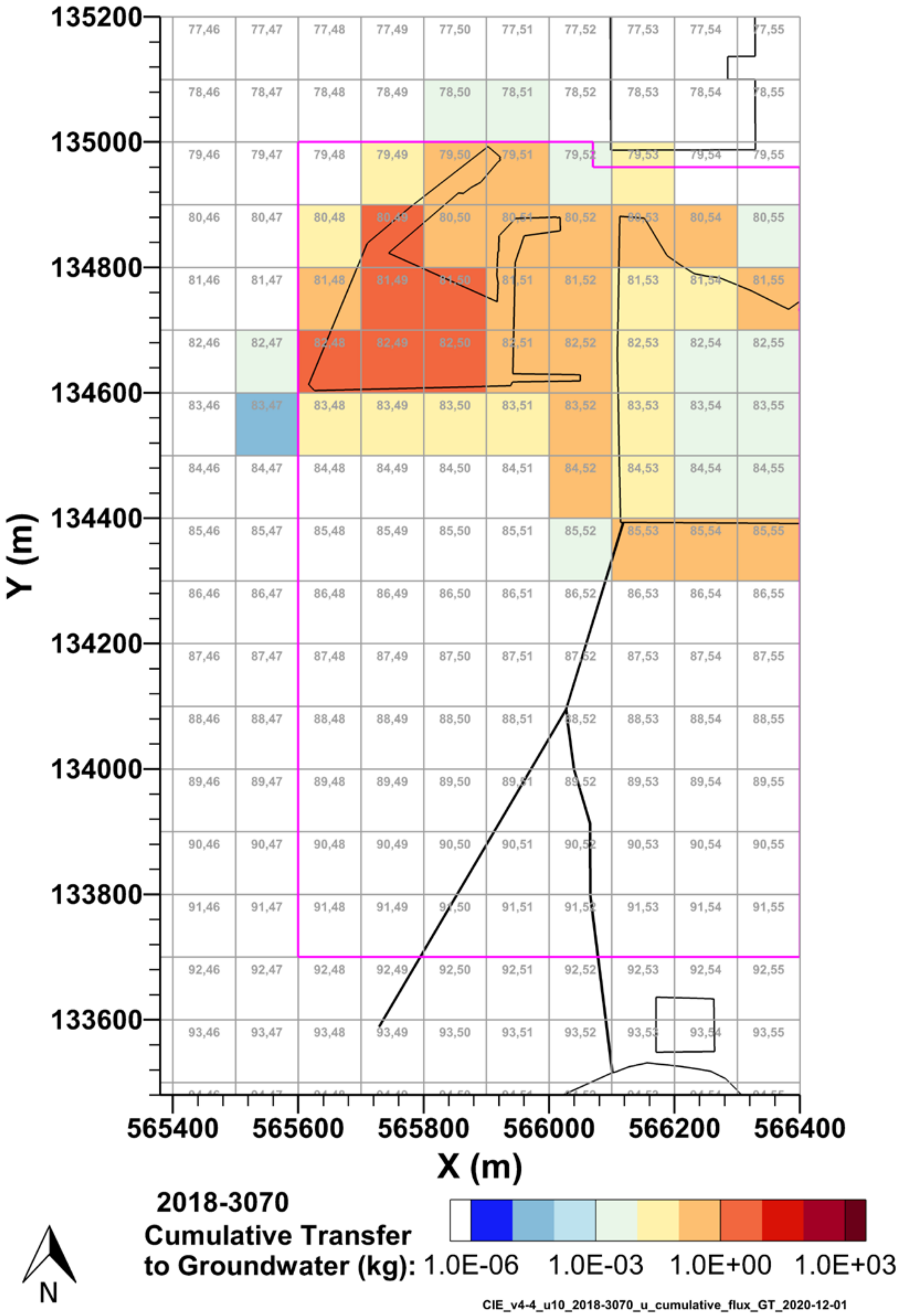
7.4 Total Uranium Fate and Transport Results

This model simulated the release and transport of total uranium. The cumulative discharge of total uranium into groundwater is shown aggregated by saturated zone model grid cell in Figure 7-21 and Figure 7-22 for 1943–2018 and 2018–3070, respectively. The inventory released to the U-10 West Area model and the transfer of total uranium to groundwater are shown from 1943–2018 in Figure 7-23 and from 1943–3070 in Figure 7-24. Figure 7-25 through Figure 7-29 show the flux of total uranium to groundwater in kg/m^2/yr. These figures are generated at times with peak fluxes (local maxima) and during periods with gradual decline, as shown in Figure 7-23 and Figure 7-24. A figure for 2018, Figure 7-28, is also included to demonstrate the flux conditions at the start of the 2018–3070 simulation.



Note: source zone outlined in pink.

Figure 7-21. Cumulative Total Uranium Mass Discharged to Groundwater from the U-10 West Area Model from 1943–2018 per Saturated Zone Model Grid Cell



Note: source zone outlined in pink.

Figure 7-22. Cumulative Total Uranium Mass Discharged to Groundwater from the U-10 West Area Model from 2018–3070 per Saturated Zone Model Grid Cell

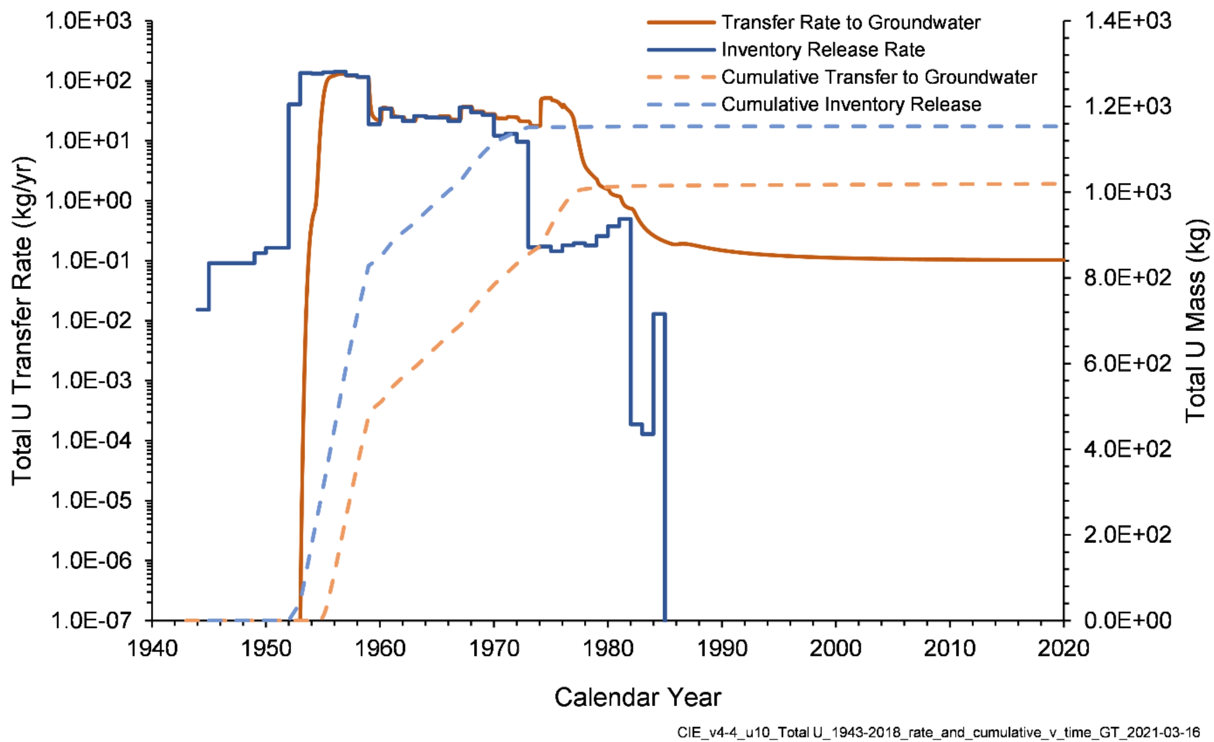


Figure 7-23. Total Uranium Inventory Release from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–2018

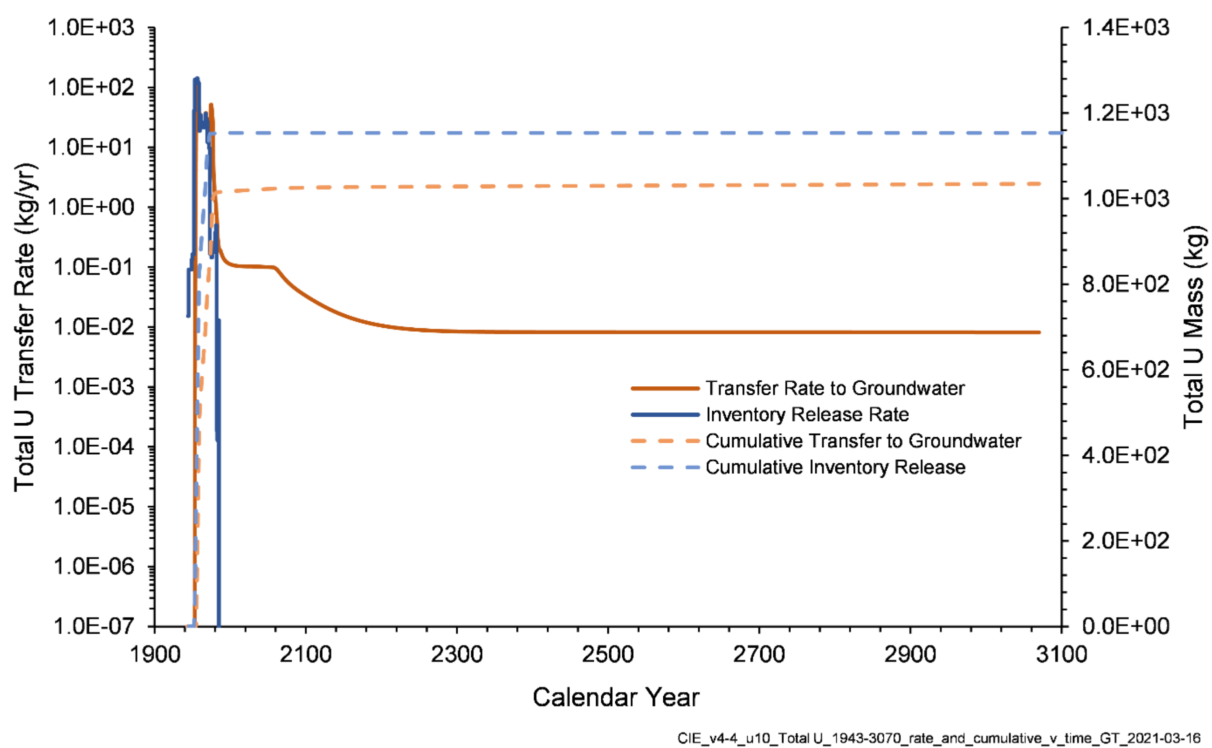
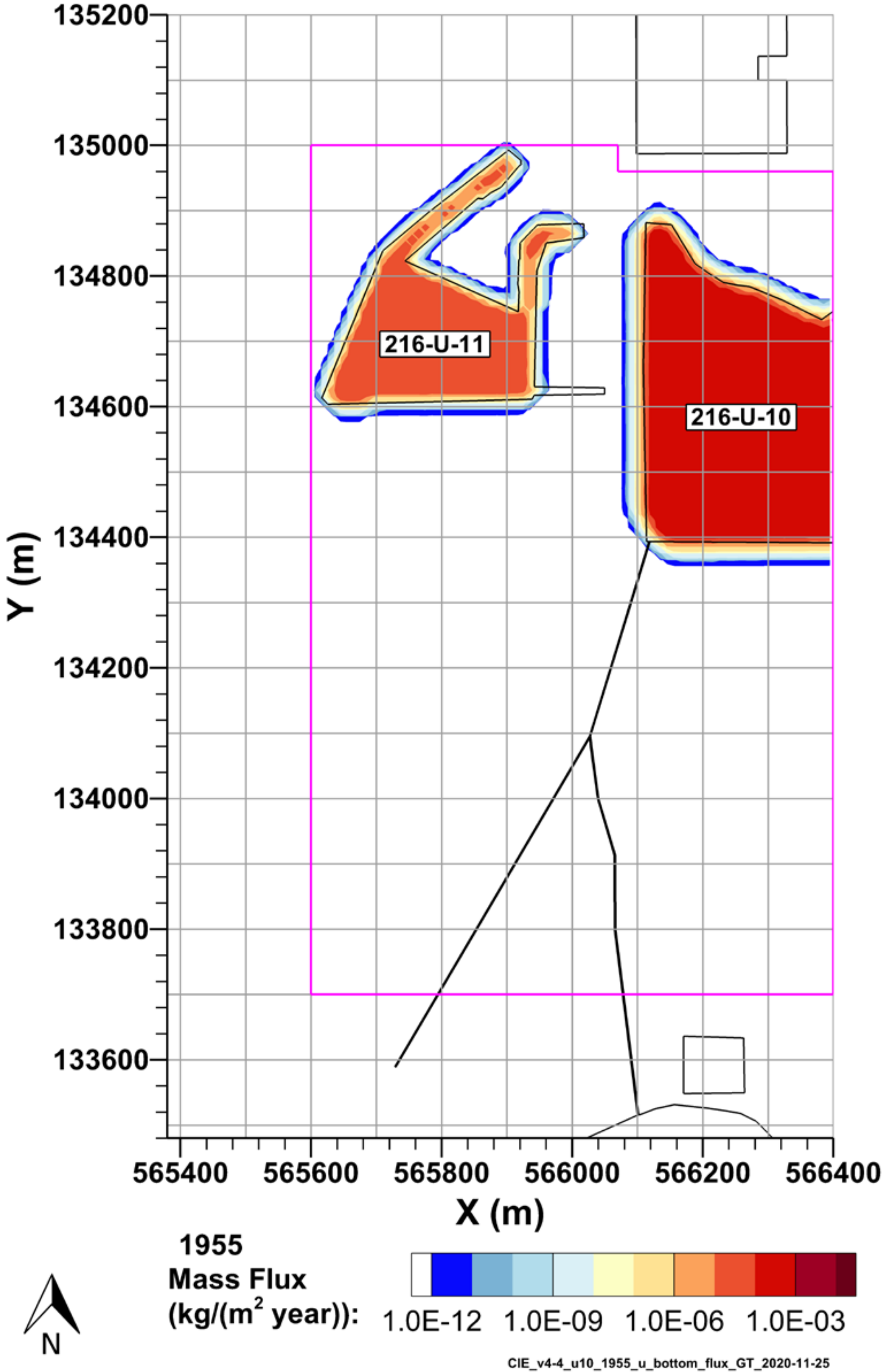
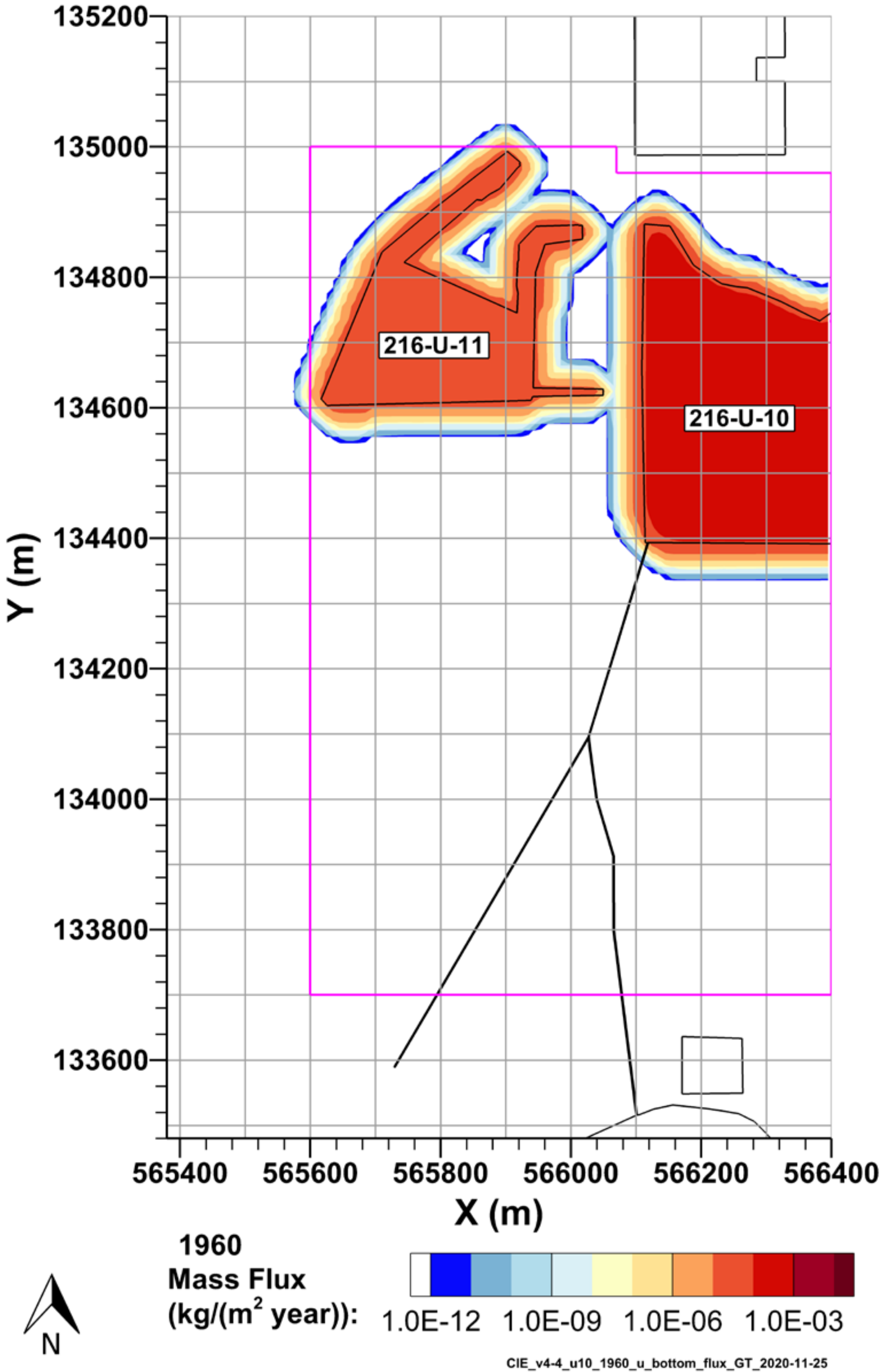


Figure 7-24. Total Uranium Inventory Release from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–3070



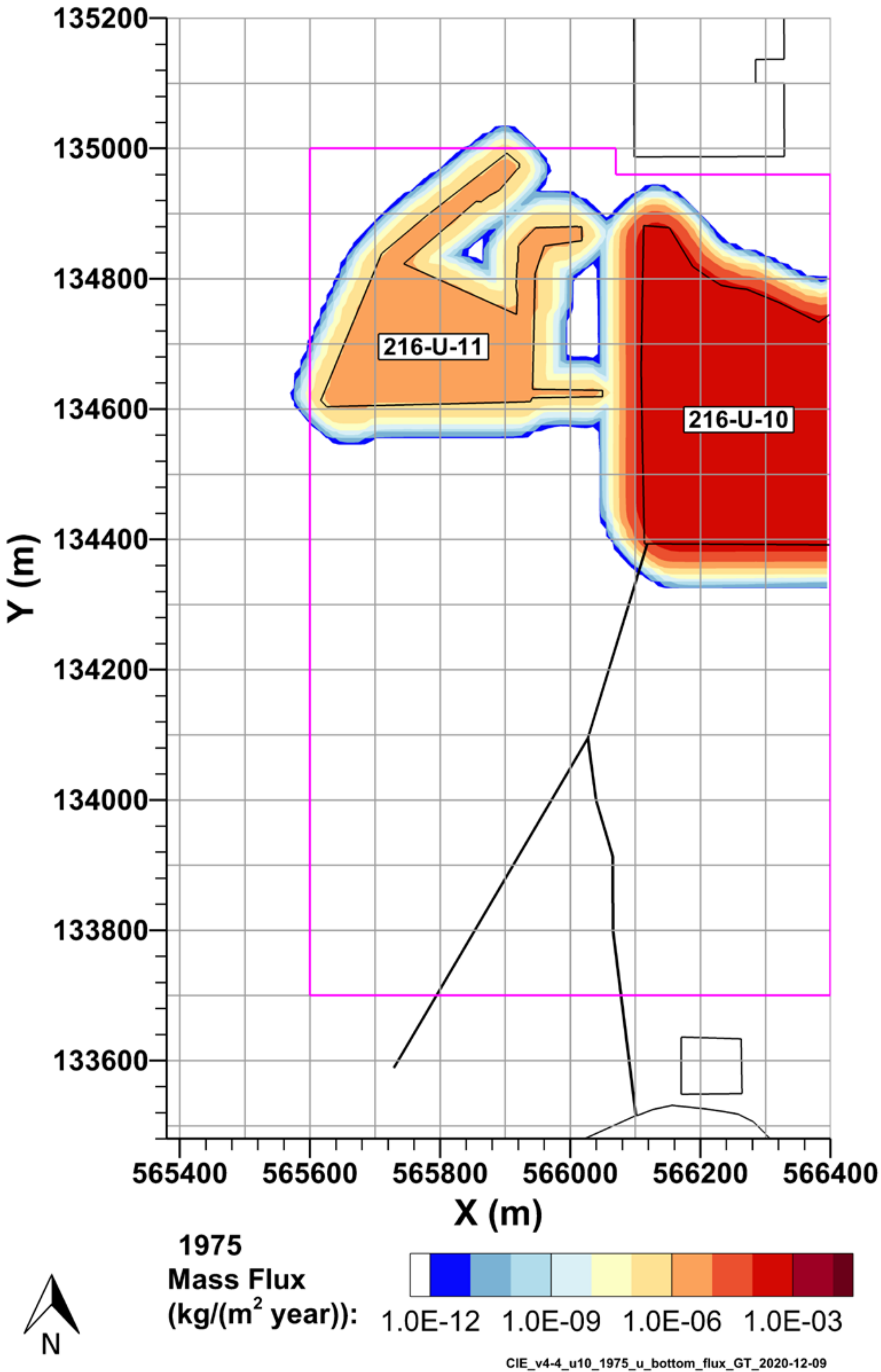
Note: source zone outlined in pink.

Figure 7-25. Total Uranium Flux to Groundwater, 1955



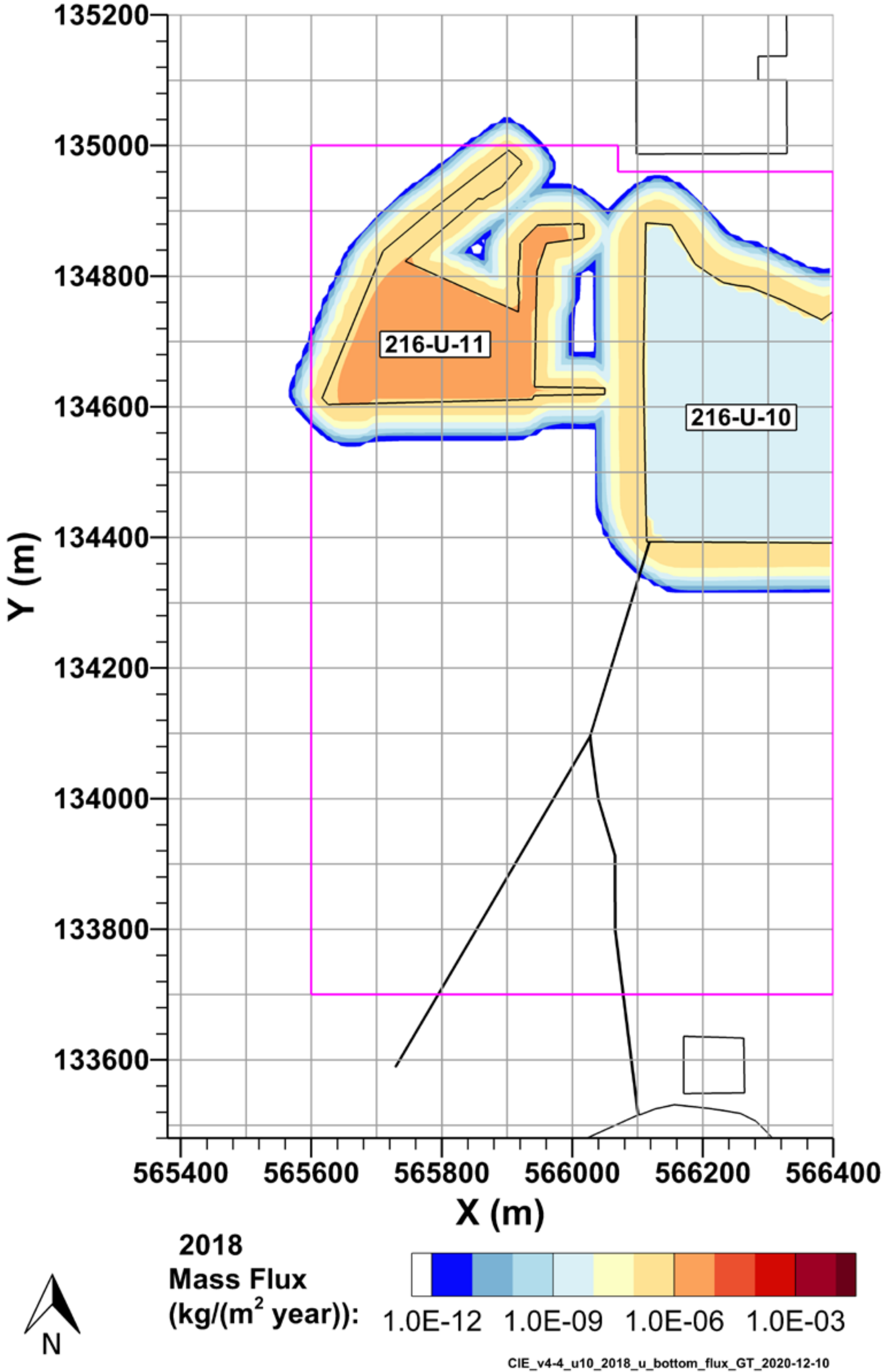
Note: source zone outlined in pink.

Figure 7-26. Total Uranium Flux to Groundwater, 1960



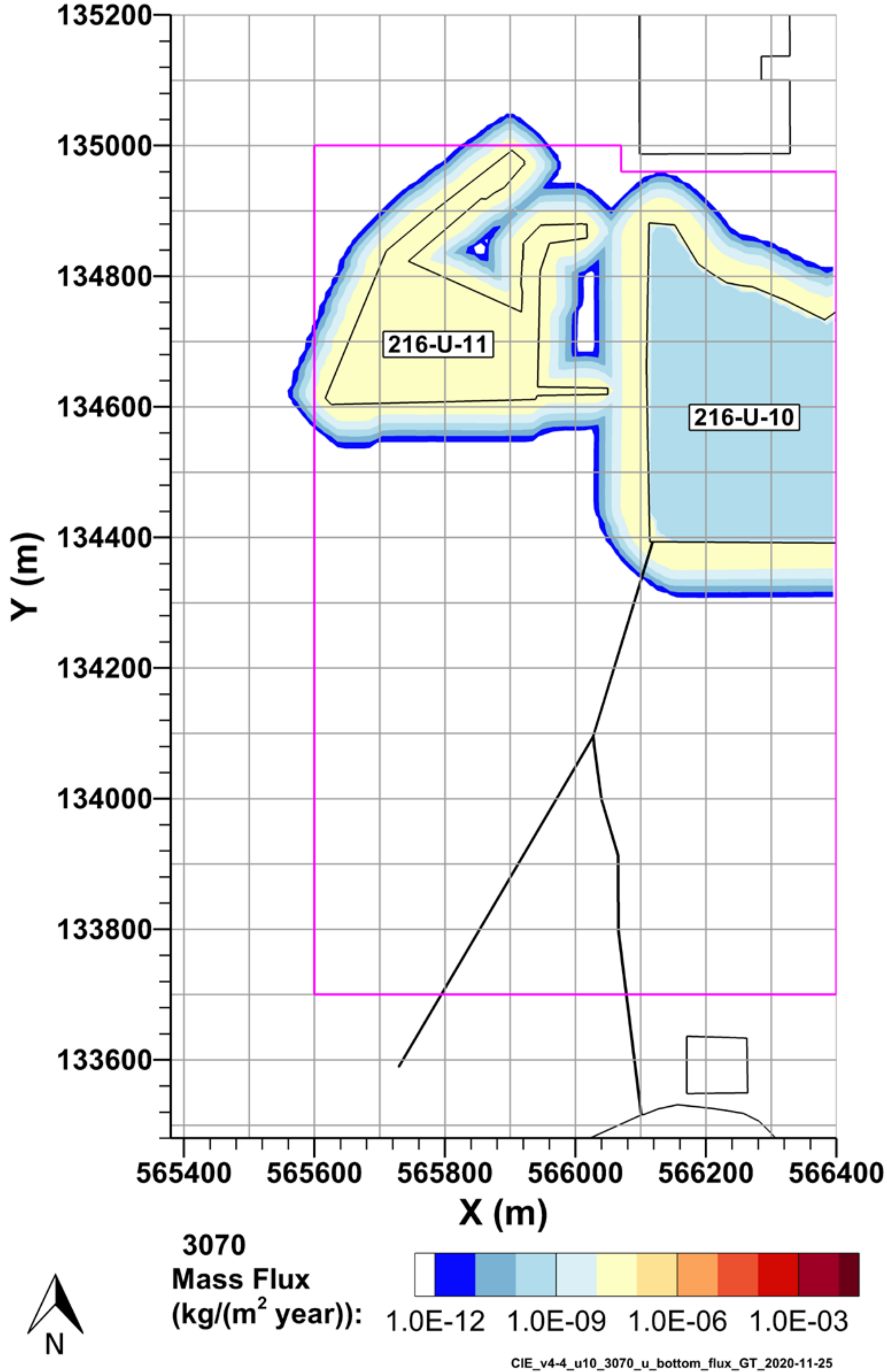
Note: source zone outlined in pink.

Figure 7-27. Total Uranium Flux to Groundwater, 1975



Note: source zone outlined in pink.

Figure 7-28. Total Uranium Flux to Groundwater, 2018

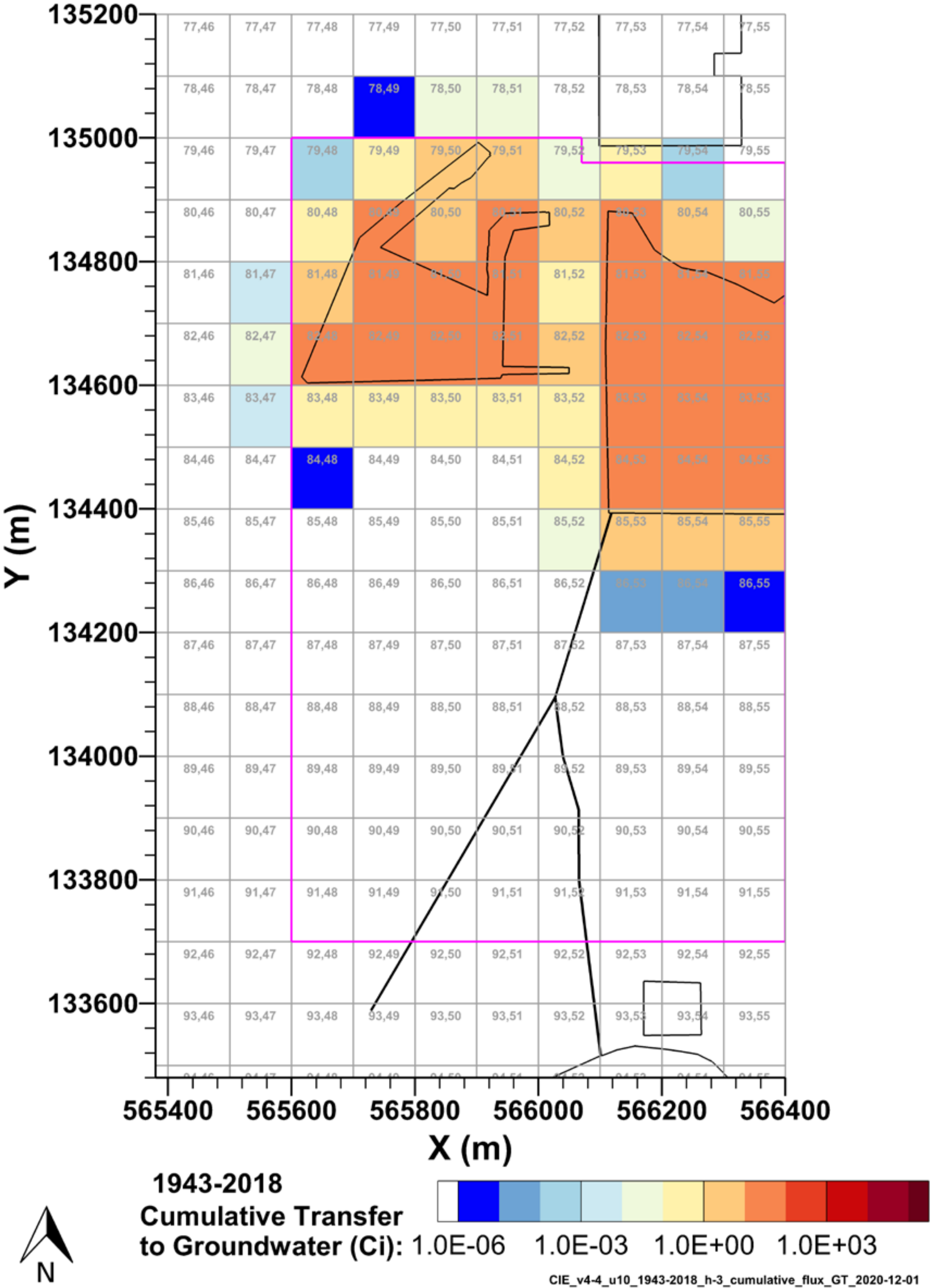


Note: source zone outlined in pink.

Figure 7-29. Total Uranium Flux to Groundwater, 3070

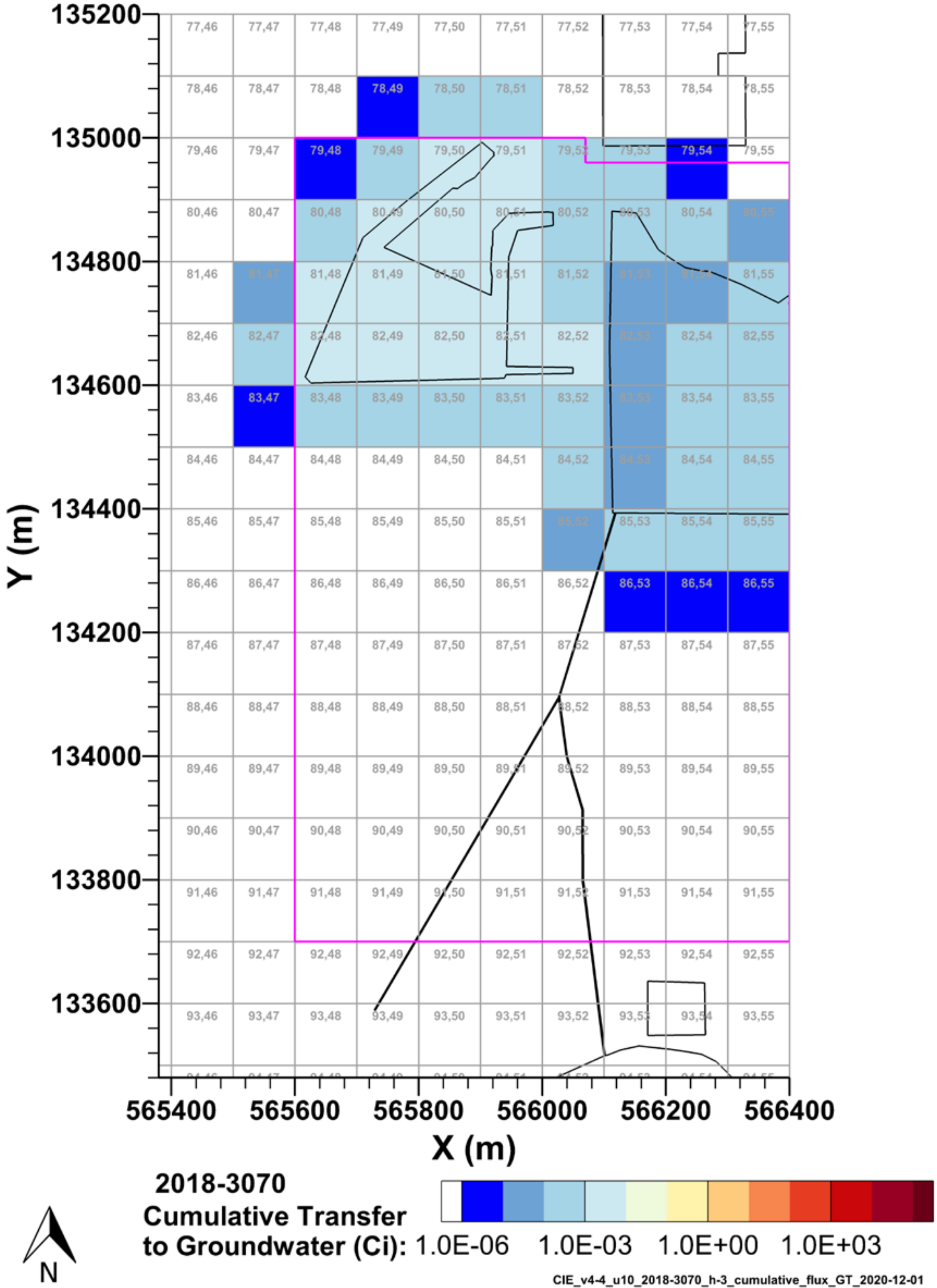
7.5 H-3 Fate and Transport Results

This model simulated the release and transport of H-3. The cumulative discharge of H-3 into groundwater is shown aggregated by saturated zone model grid cell in Figure 7-30 and Figure 7-31 for 1943–2018 and 2018–3070, respectively. The inventory released to the U-10 West Area model and the transfer of H-3 to groundwater are shown from 1943–2018 in Figure 7-32 and from 1943–3070 in Figure 7-33.



Note: source zone outlined in pink.

Figure 7-30. Cumulative H-3 Activity Discharged to Groundwater from the U-10 West Area Model from 1943–2018 per Saturated Zone Model Grid Cell



Note: source zone outlined in pink.

Figure 7-31. Cumulative H-3 Activity Discharged to Groundwater from the U-10 West Area Model from 2018–3070 per Saturated Zone Model Grid Cell

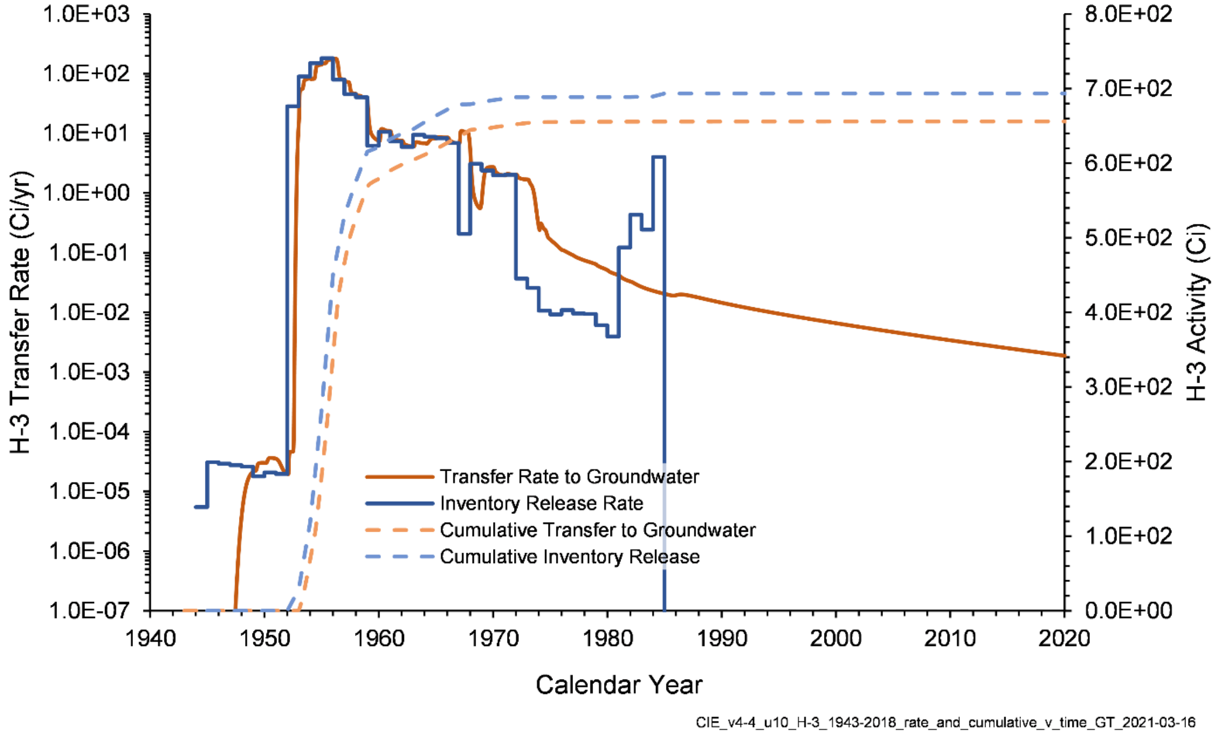


Figure 7-32. H-3 Inventory Release from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–2018

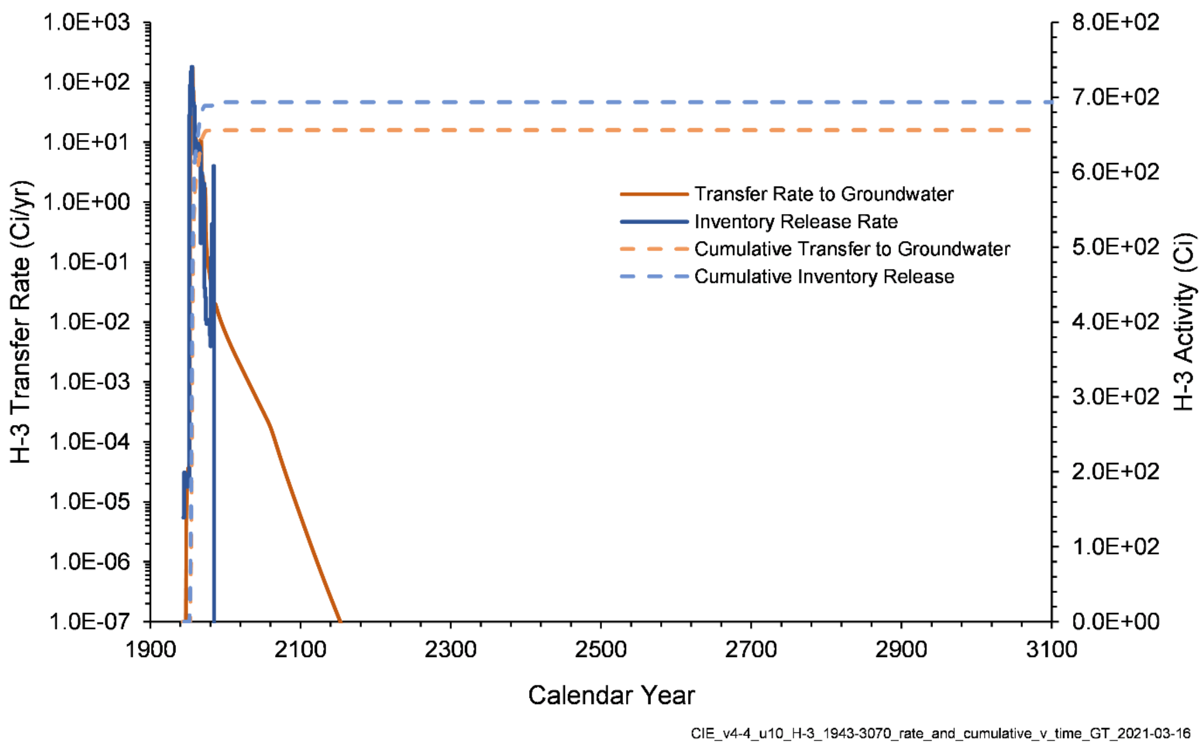
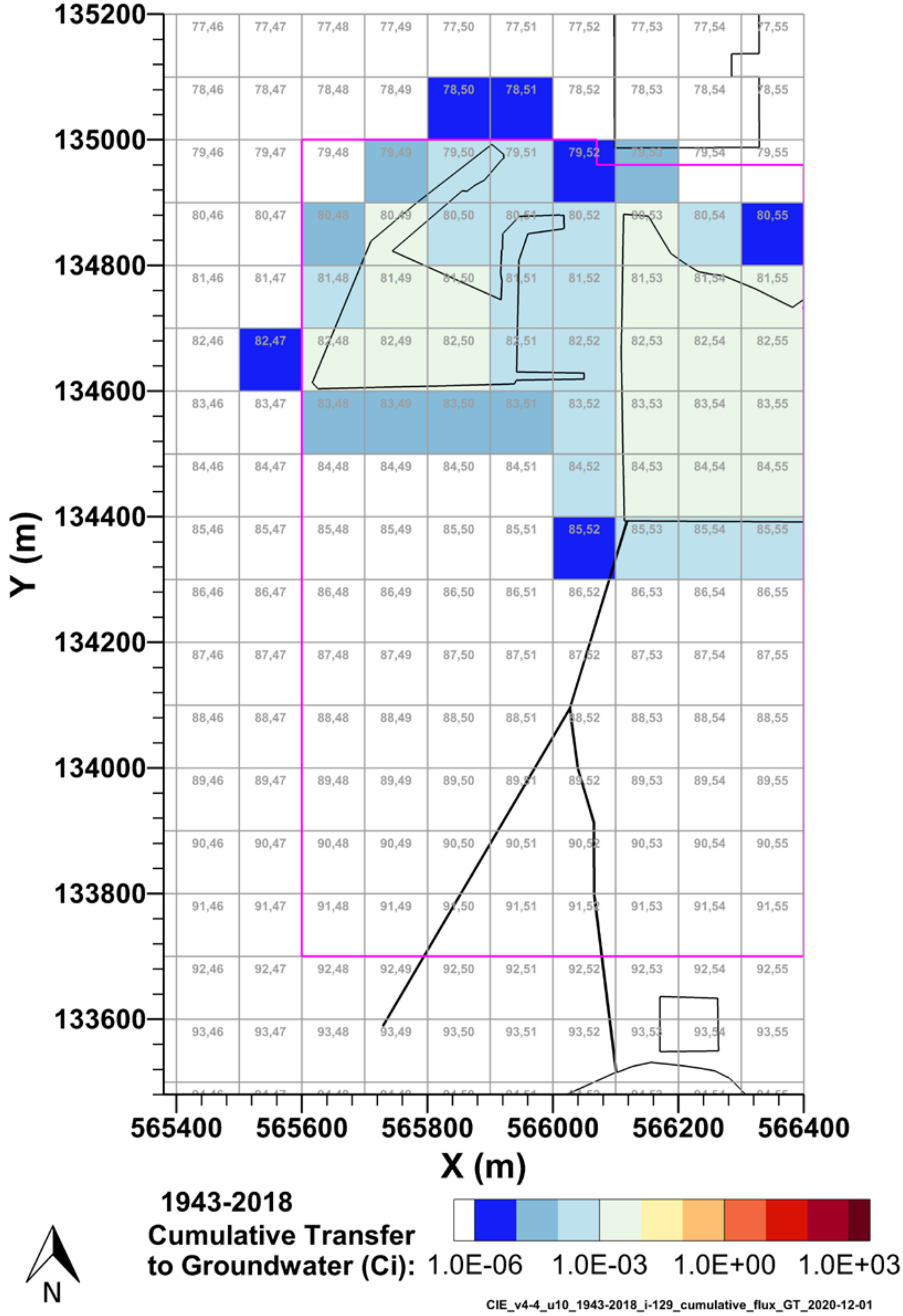


Figure 7-33. H-3 Inventory Released from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–3070

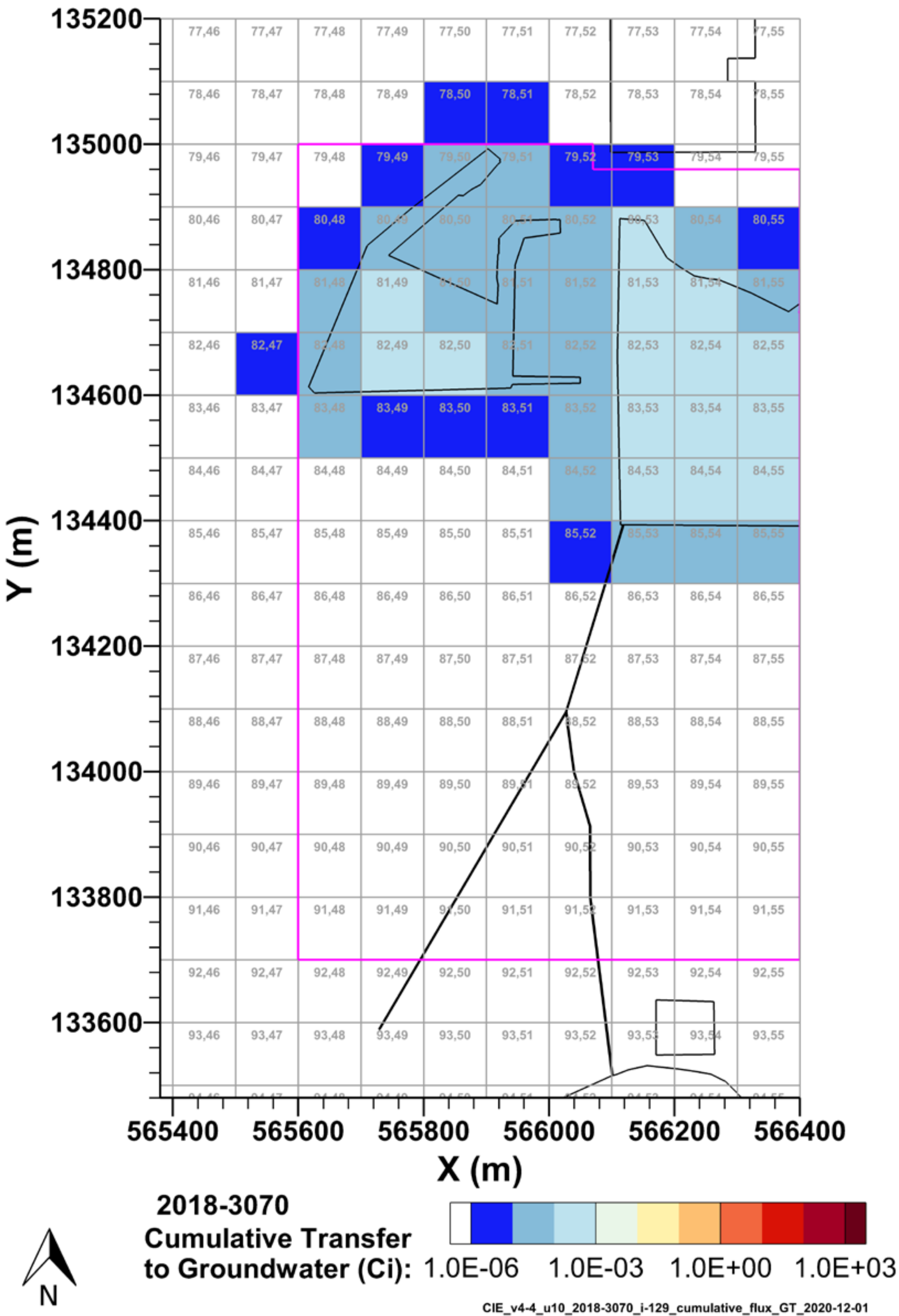
7.6 I-129 Fate and Transport Results

This model simulated the release and transport of I-129. The cumulative discharge of I-129 into groundwater is shown aggregated by saturated zone model grid cell in Figure 7-34 and Figure 7-35 for 1943–2018 and 2018–3070, respectively. The inventory released to the U-10 West Area model and the transfer of I-129 to groundwater are shown from 1943–2018 in Figure 7-36 and from 1943–3070 in Figure 7-37. Figure 7-38 through Figure 7-42 show the flux of I-129 to groundwater in $Ci/m^2/yr$. These figures are generated at times with peak fluxes (local maxima) and during periods with gradual decline, as shown in Figure 7-36 and Figure 7-37. A figure for 2018, Figure 7-41, is also included to demonstrate the flux conditions at the start of the 2018–3070 simulation.



Note: source zone outlined in pink.

Figure 7-34. Cumulative I-129 Activity Discharged to Groundwater from the U-10 West Area Model from 1943–2018 per Saturated Zone Model Grid Cell



Note: source zone outlined in pink.

Figure 7-35. Cumulative I-129 Activity Discharged to Groundwater from the U-10 West Area Model from 2018–3070 per Saturated Zone Model Grid Cell

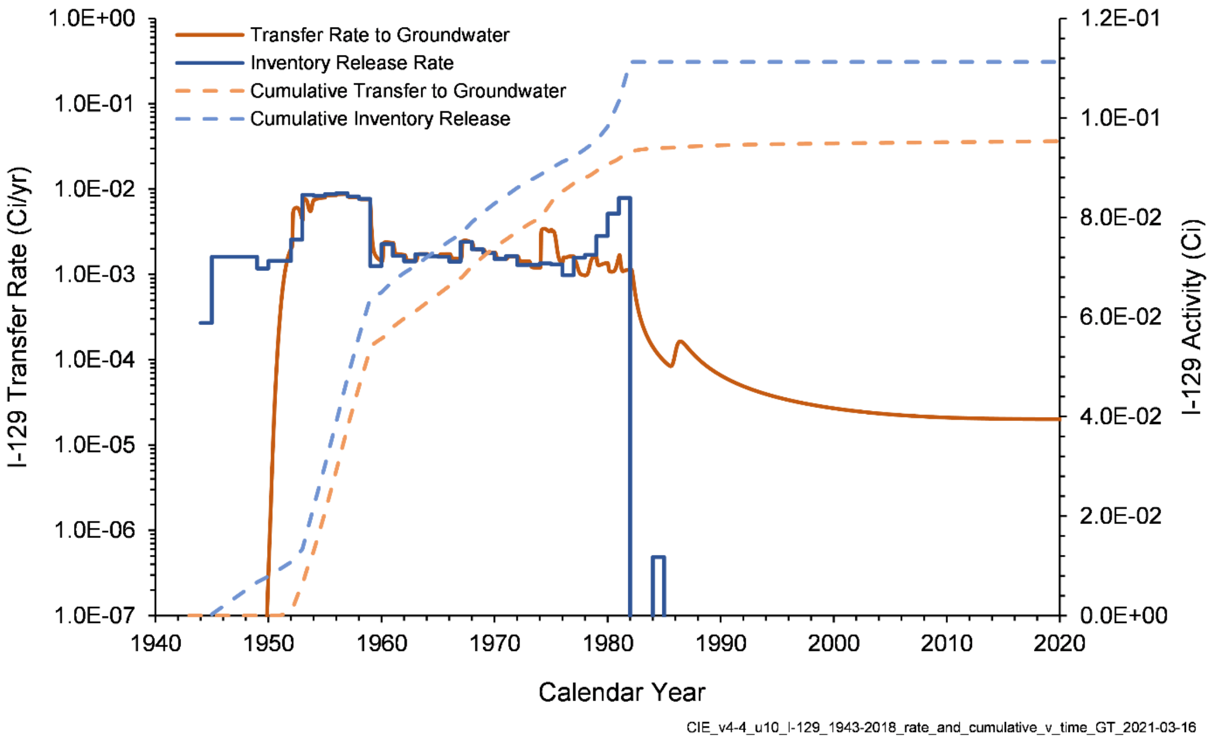


Figure 7-36. I-129 Inventory Released from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–2018

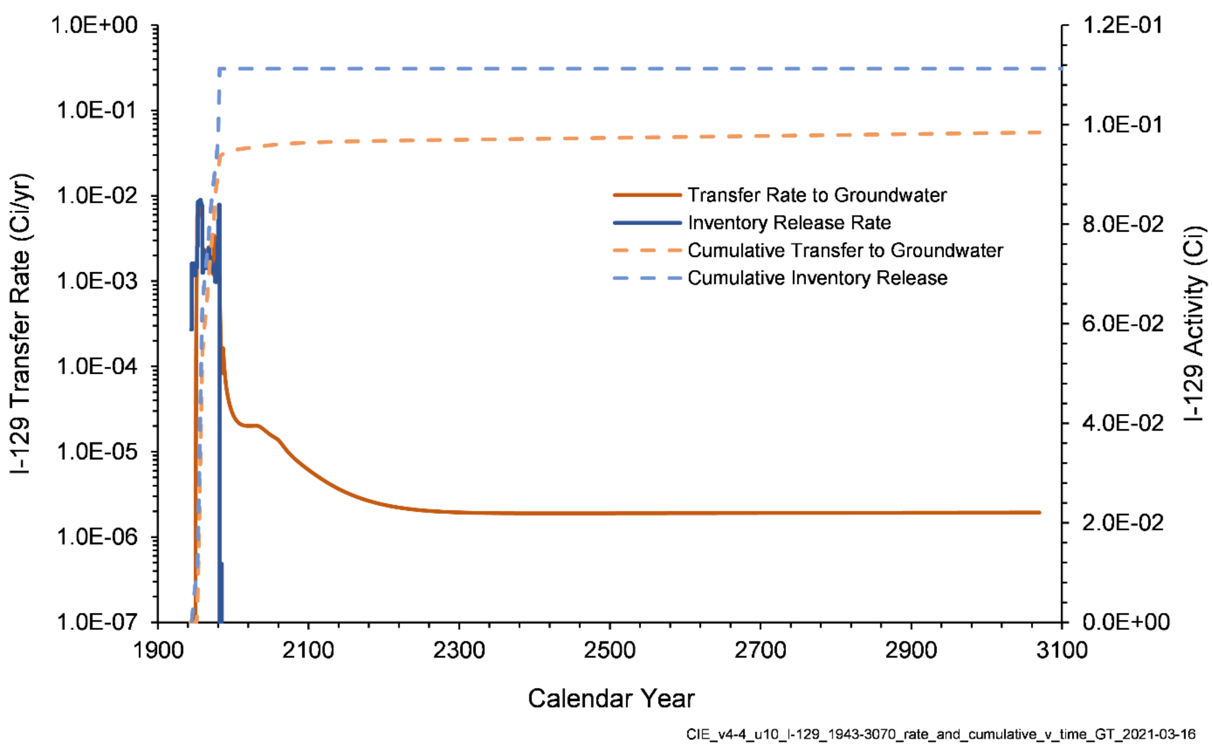
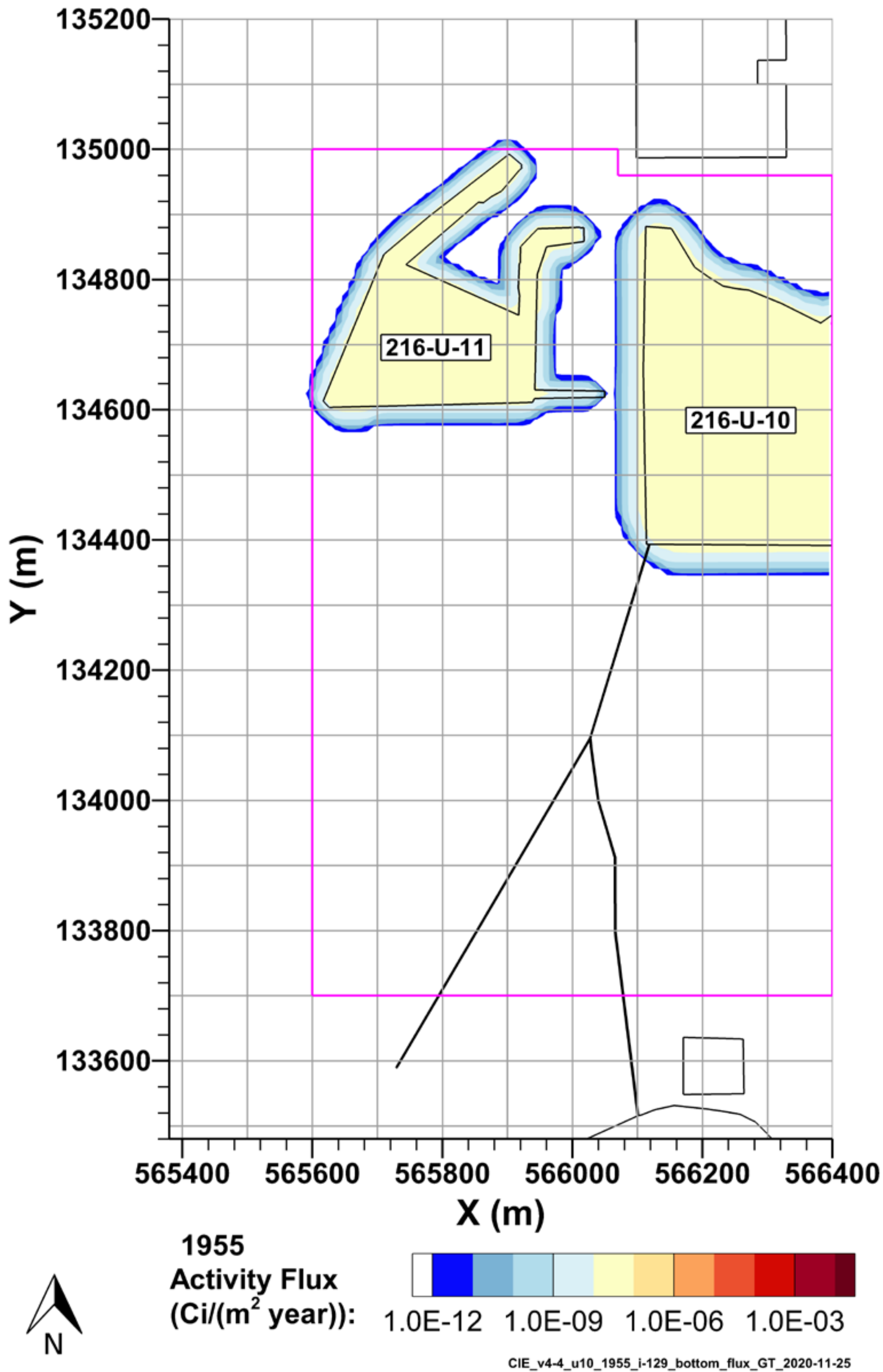
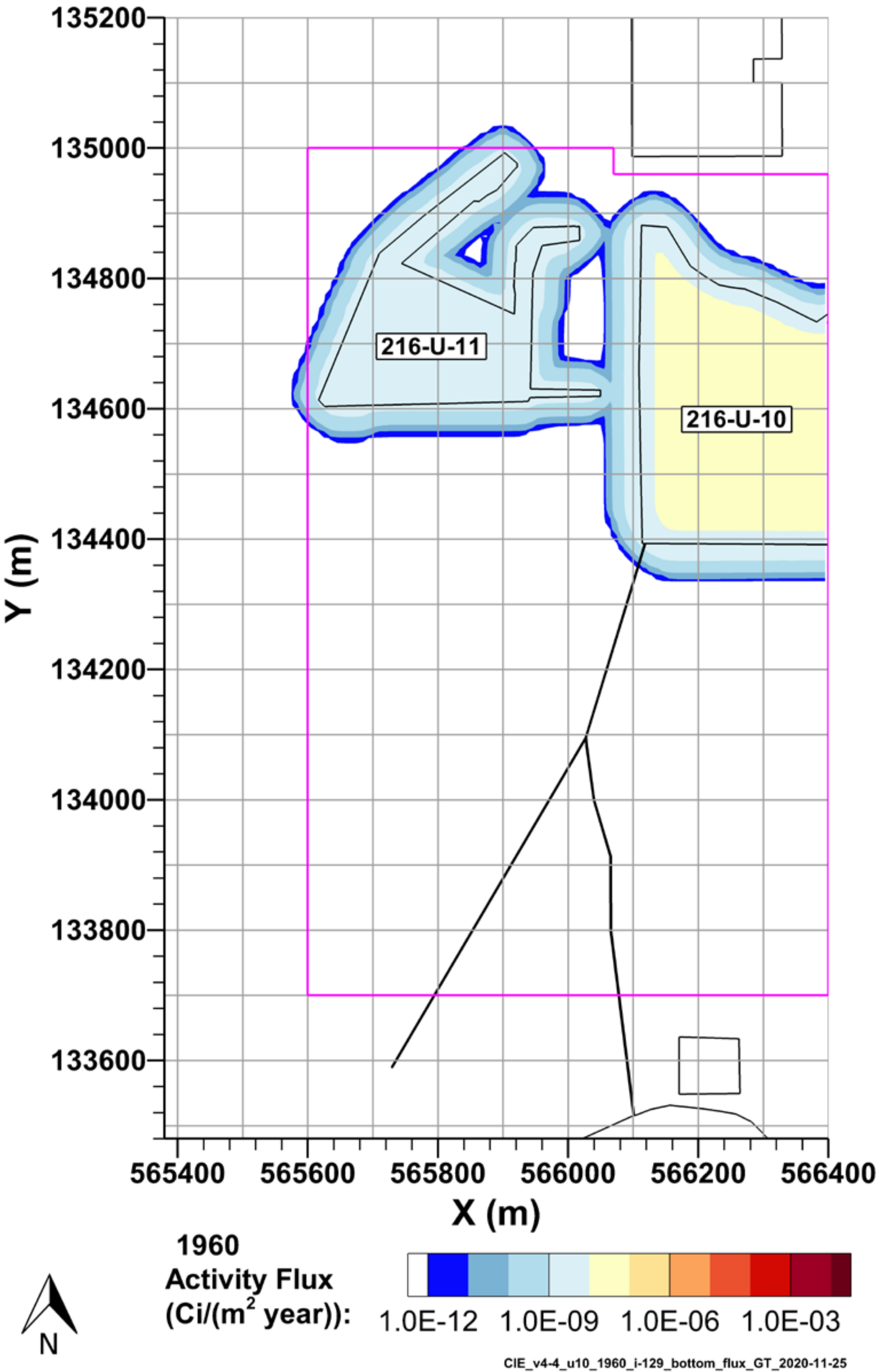


Figure 7-37. I-129 Inventory Released from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–3070



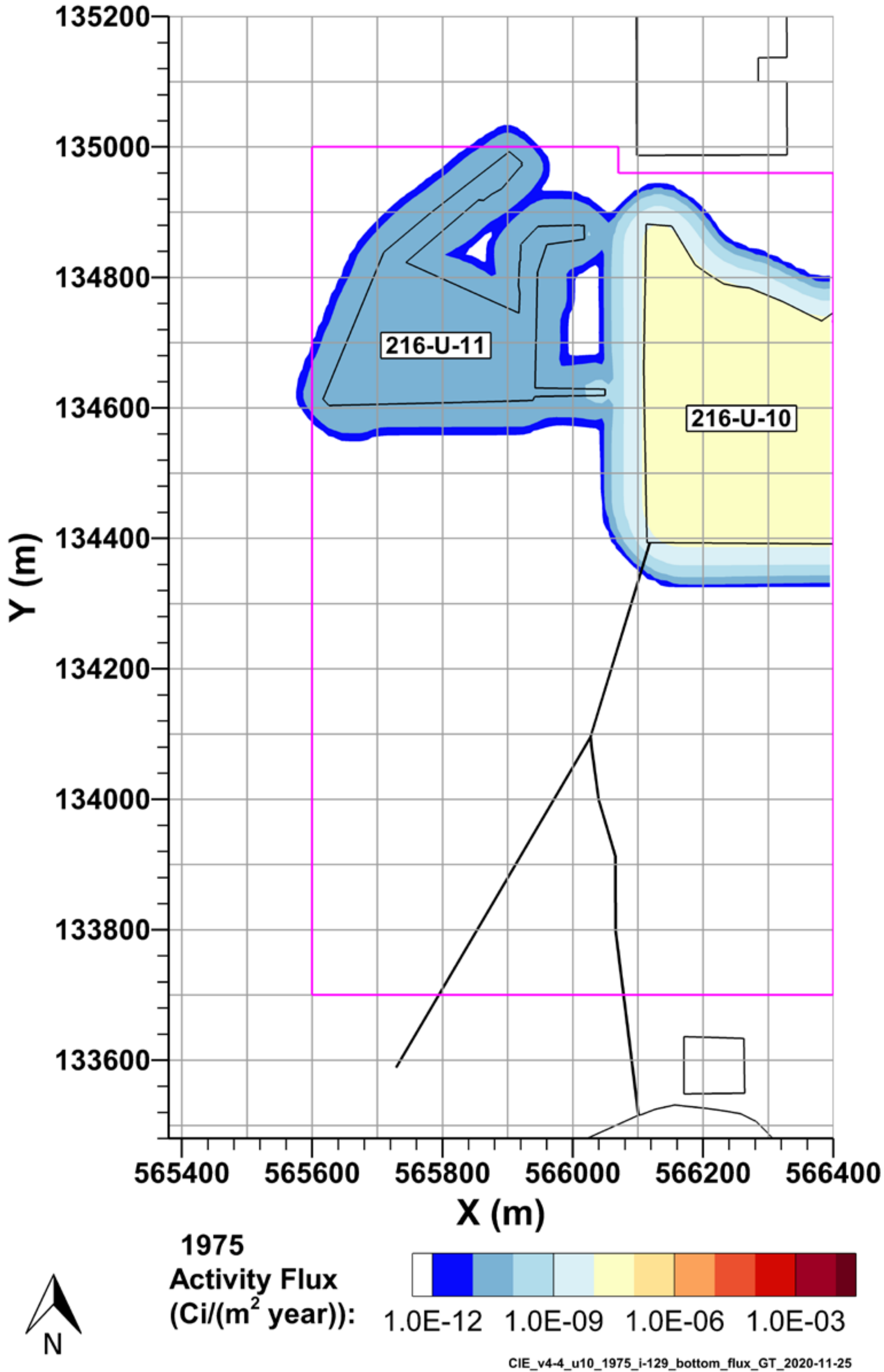
Note: source zone outlined in pink.

Figure 7-38. I-129 Flux to Groundwater, 1955



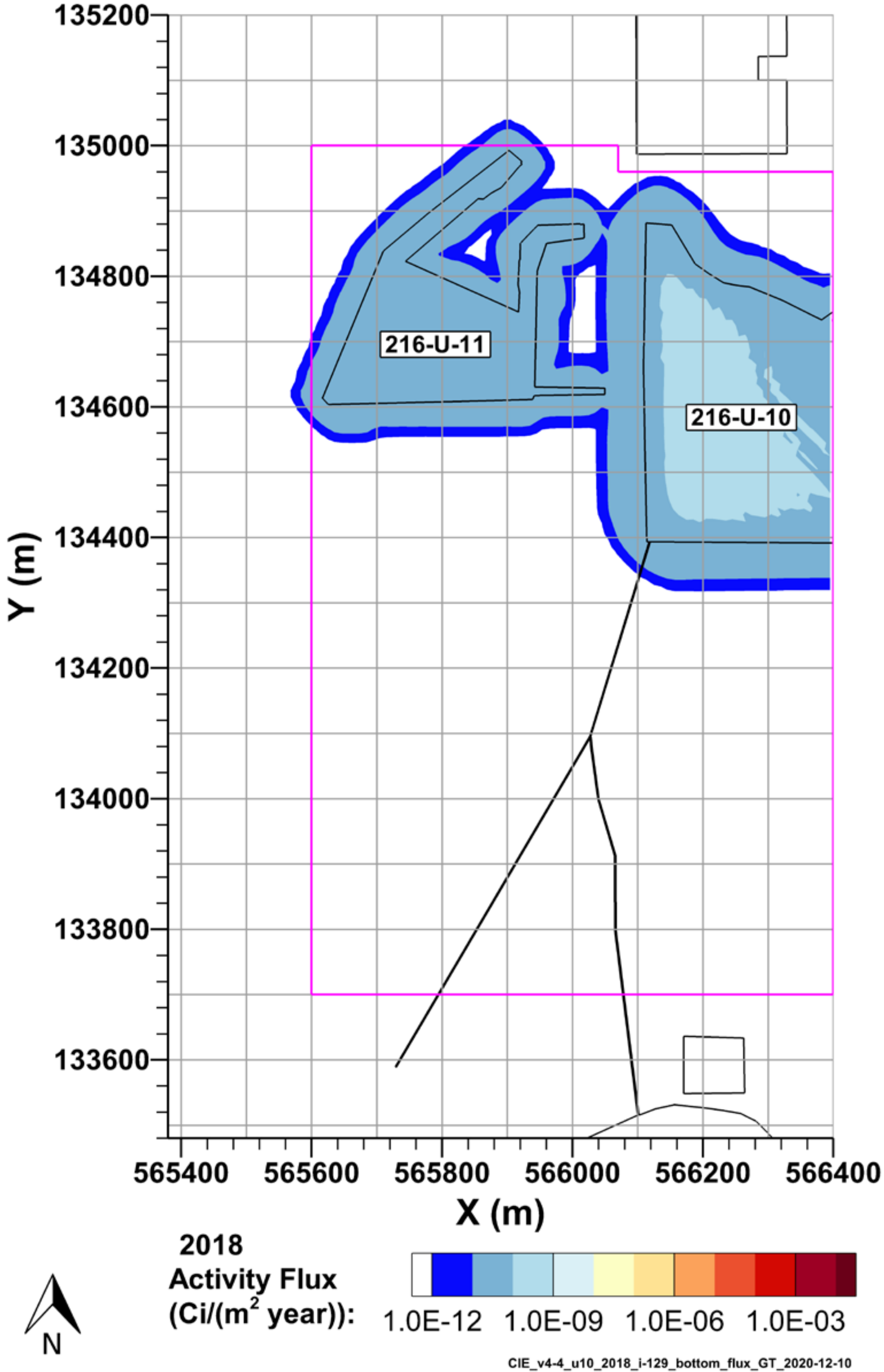
Note: source zone outlined in pink.

Figure 7-39. I-129 Flux to Groundwater, 1960



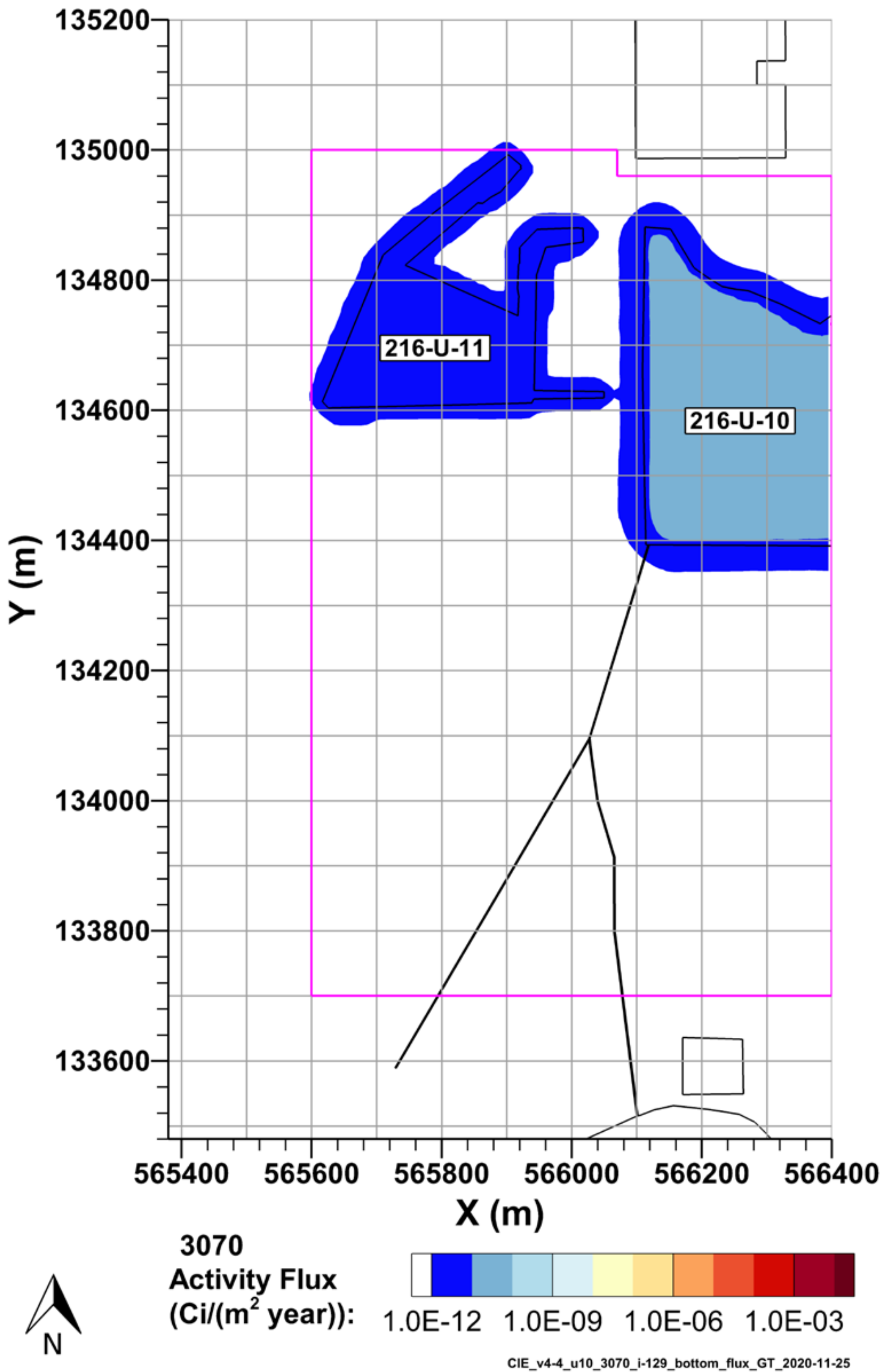
Note: source zone outlined in pink.

Figure 7-40. I-129 Flux to Groundwater, 1975



Note: source zone outlined in pink.

Figure 7-41. I-129 Flux to Groundwater, 2018



Note: source zone outlined in pink.

Figure 7-42. I-129 Flux to Groundwater, 3070

7.7 Sr-90 Fate and Transport Results

This model simulated the release and transport of Sr-90. No Sr-90 was discharged to groundwater at a cumulative activity above 1.0E-6 Ci per saturated zone model grid cell at any point during modeling. The inventory released to the U-10 West Area model and the transfer of Sr-90 to groundwater are shown from 1943–2018 in Figure 7-43 and from 1943–3070 in Figure 7-44.

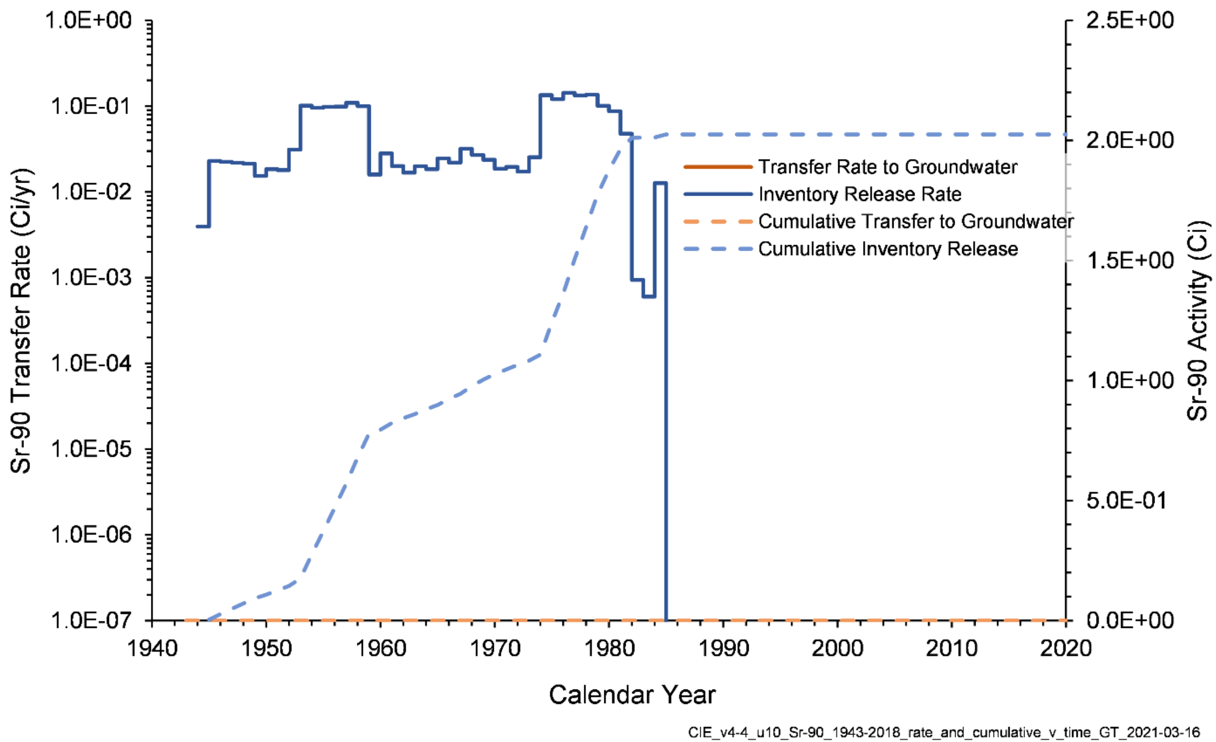


Figure 7-43. Sr-90 Inventory Released from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–2018

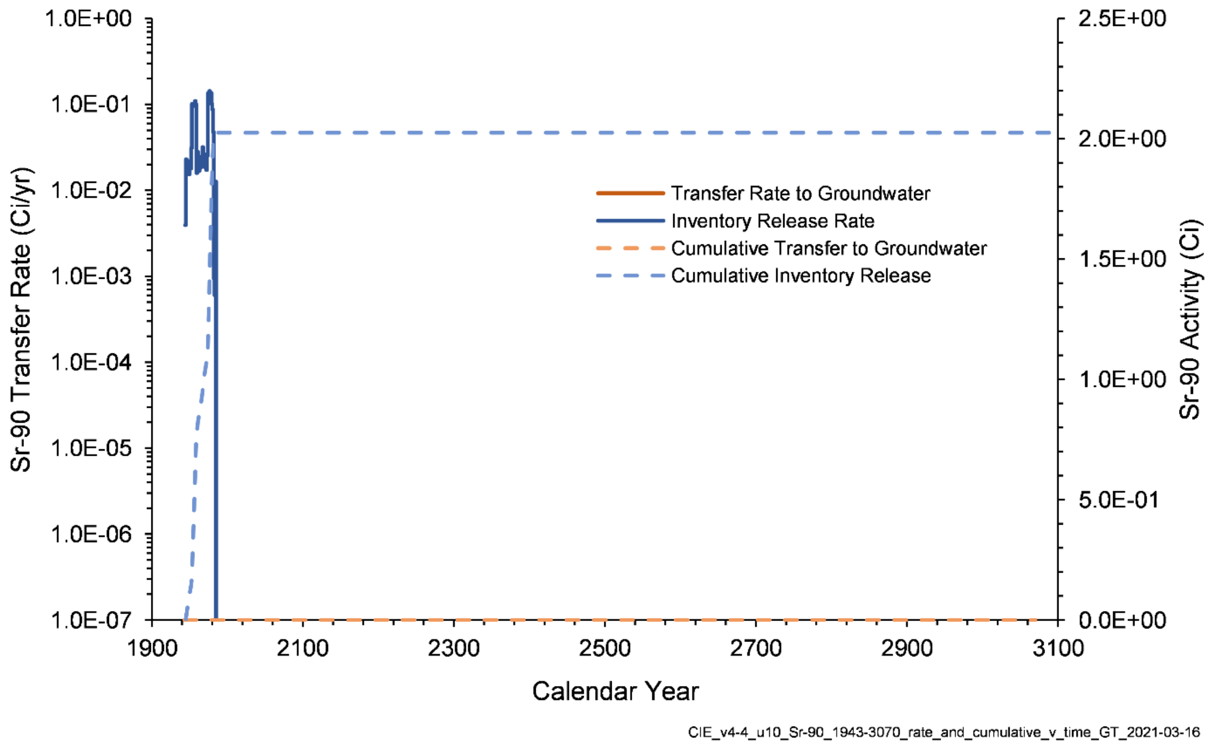
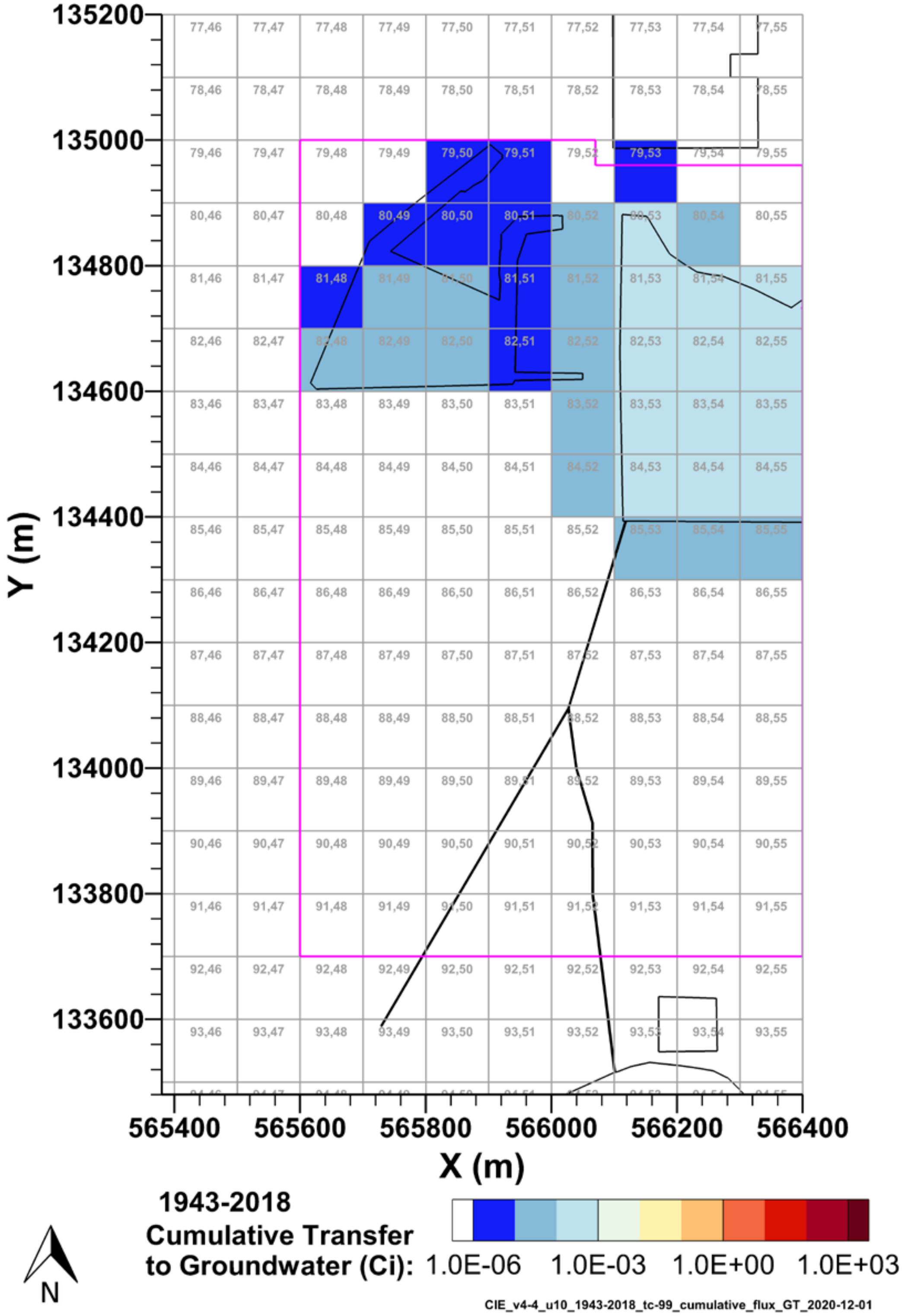


Figure 7-44. Sr-90 Inventory Released from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–3070

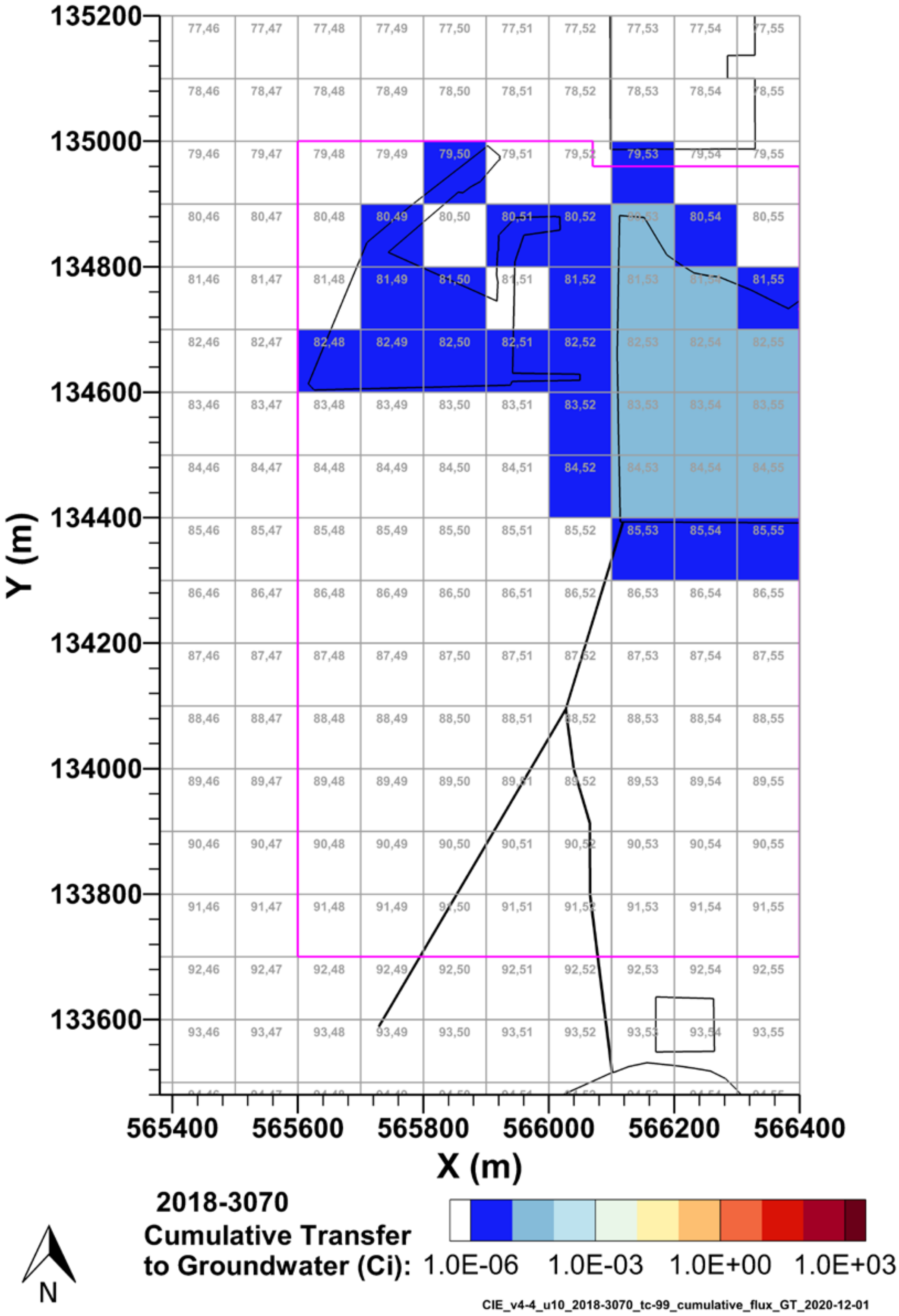
7.8 Tc-99 Fate and Transport Results

This model simulated the release and transport of Tc-99. The cumulative discharge of Tc-99 into groundwater is shown aggregated by saturated zone model grid cell in Figure 7-45 and Figure 7-46 for 1943–2018 and 2018–3070, respectively. The inventory released to the U-10 West Area model and the transfer of Tc-99 to groundwater are shown from 1943–2018 in Figure 7-47 and from 1943–3070 in Figure 7-48.



Note: source zone outlined in pink.

Figure 7-45. Cumulative Tc-99 Activity Discharged to Groundwater from the U-10 West Area Model from 1943–2018 per Saturated Zone Model Grid Cell



Note: source zone outlined in pink.

Figure 7-46. Cumulative Tc-99 Activity Discharged to Groundwater from the U-10 West Area Model from 2018–3070 per Saturated Zone Model Grid Cell

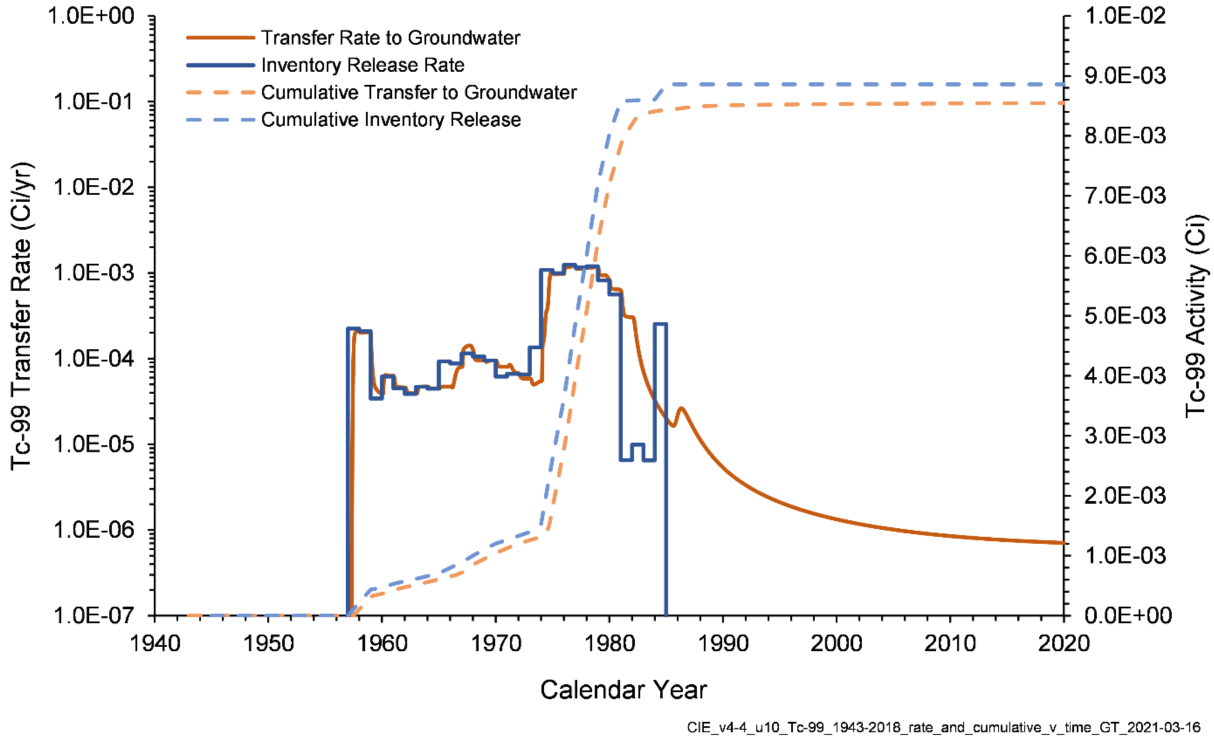


Figure 7-47. Tc-99 Inventory Released from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–2018

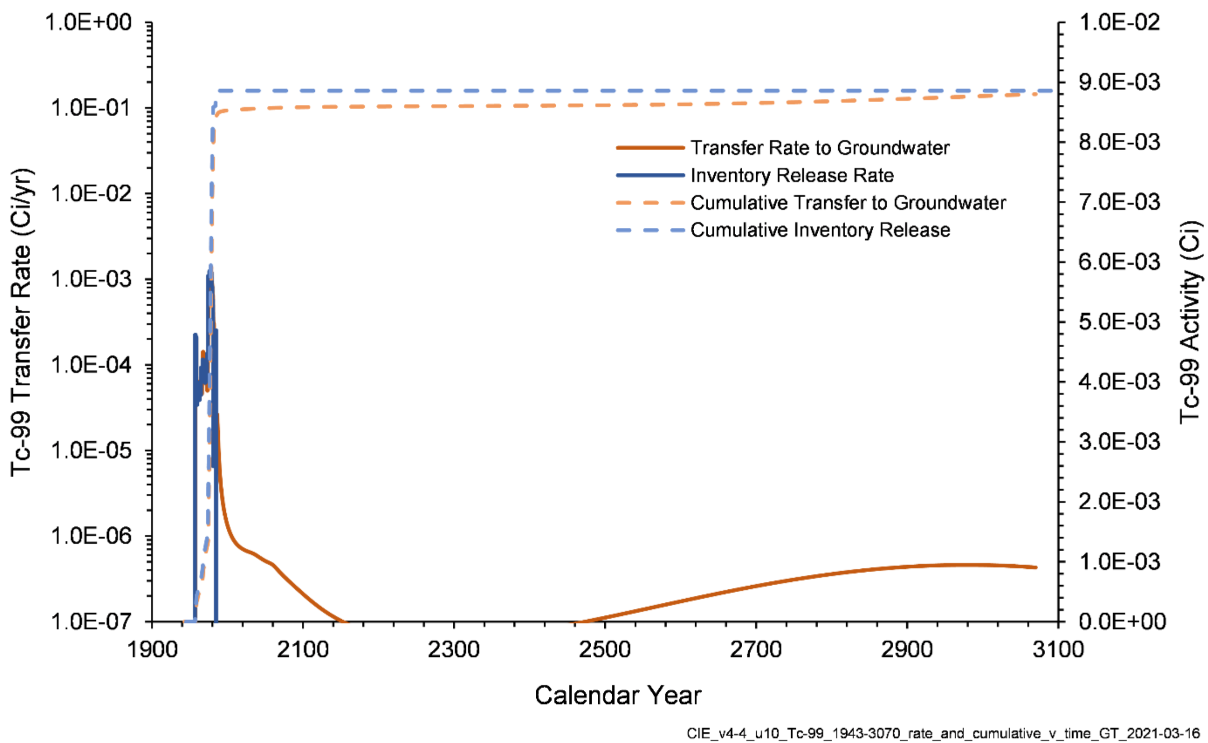


Figure 7-48. Tc-99 Inventory Released from Waste Sites and Transfer Rate to Groundwater for the U-10 West Area Model from 1943–3070

8 References

CHPRC-00176, 2016, *STOMP Software Management Plan*, Rev. 4, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00211, 2016, *STOMP Software Test Plan*, Rev 3, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00222, 2016, *STOMP Functional Requirements Document* Rev 2, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00269, 2017, *STOMP Requirement Traceability Matrix*, Rev. 5, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00515, 2017, *STOMP Acceptance Test Report*, Rev. 5, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-04032, 2020, *Composite Analysis / Cumulative Impact Evaluation (CACIE) Utility Codes Integrated Software Management Plan*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

CP-57037, 2020, *Model Package Report: Plateau to River Groundwater Model Version 8.3*, Rev. 2, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1601635.

CP-60925, 2018, *Model Package Report: Central Plateau Vadose Zone Geoframework*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1432798.

CP-61786, 2019, *Inventory Data Package for the Hanford Site Composite Analysis*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1576745.

CP-63515, *Model Package Report: Central Plateau Vadose Zone Models*, Rev. 1 pending, Central Plateau Cleanup Company, Richland, Washington.

CP-63883, 2020, *Vadose Zone Flow and Transport Parameters Data Package for the Hanford Site Composite Analysis*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1608425.

CP-64710, 2020, *Inventory Data Package for the Hanford Site Cumulative Impacts Evaluation*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

CP-64711, 2020, *Hanford Site Disposition Baseline for the Cumulative Impacts Evaluation – No Further Action Scenario*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

DOE O 414.1D Chg 1 (Admin Chg), 2013, *Quality Assurance*, U.S. Department of Energy, Washington, D.C. Available at: https://www.directives.doe.gov/directives-documents/400-series/0414.1-BOrder-d-admchg1.

DOE/RL-91-52, 1992, *U Plant Source Aggregate Area Management Study Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/D196110688.

DOE/RL-2009-122, 2012, *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0092247.

DOE/RL-2018-69, 2019, *Cumulative Impact Evaluation Technical Approach Document*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-04154.

DOE-RL, 2020, Waste Information Data System General Summary Report, Hanford Site Database, queried July, 2020, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

ECF-HANFORD-15-0019, 2020, *Hanford Site-wide Natural Recharge Boundary Condition for Groundwater Models*, Rev. 3, Central Plateau Cleanup Company, Richland, Washington.

ECF-HANFORD-17-0120, 2018, *Preparation of the March 2017 Hanford Site Water Table and Potentiometric Surface Maps*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0066758H.

ECF-HANFORD-18-0035, 2020, *Central Plateau Vadose Zone Geoframework*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1603767.

ECF-HANFORD-18-0074, 2020, *Application of the Recharge Estimation Tool (RET) to Prepare Spatially and Temporally Variable Recharge Boundary Conditions for Hanford Site Composite Analysis Vadose Zone Models*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/biblio/1643127-application-recharge-estimation-tool-ret-prepare-spatially-temporally-variable-recharge-boundary-conditions-hanford-site-composite-analysis-vadose-zone-models.

ECF-HANFORD-19-0032, 2021, *Distribution of Infiltration in the 216-U-10, 216-B-3 Pond, and 216-T-4 Pond Systems 1944-1997*, Rev. 1, Central Plateau Cleanup Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1776586.

ECF-HANFORD-19-0062, 2020, *Vadose Zone Model for U-10 West Area for Composite Analysis*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1669106.

ECF-HANFORD-19-0094, 2020, *Calculation of Moisture-Dependent Anisotropic Parameters Supporting the Hanford Site's Composite Analysis, Cumulative Impact Evaluation, and Performance Assessments*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1595470.

ECF-HANFORD-19-0121, 2020, *Selection of Vadose Zone Flow and Transport Properties with Gravel Fraction Corrections for the Hanford Site Composite Analysis and Cumulative Impact Evaluation*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1605425.

ECF-HANFORD-20-0122, *Cumulative Impact Evaluation Vadose Zone Model for the PFP Area, No Further Action Scenario*, Rev. 0 pending, Central Plateau Cleanup Company, Richland, Washington.

ECF-HANFORD-20-0126, *Cumulative Impact Evaluation Vadose Zone Model for the S Farms Area, No Further Action Scenario*, Rev. 0 pending, Central Plateau Cleanup Company, Richland, Washington.

ECF-HANFORD-20-0131, *Cumulative Impact Evaluation Vadose Zone Model for the U Farm Area, No Further Action Scenario*, Rev. 0 pending, Central Plateau Cleanup Company, Richland, Washington.

ECF-HANFORD-21-0005, *Predictive Contaminant Transport Simulation with the P2R Model for the Cumulative Impact Evaluation No Further Action Scenario*, Rev. 0 pending, Central Plateau Cleanup Company, Richland, Washington.

Farrow, C.R., M., Williams, M., Oostrom, P., Allena, and D., Fryar, 2019, "Prediction of Long-Term Contaminant Flux from the Vadose Zone to Groundwater for Fluctuating Water Table Conditions at the Hanford Site," AGU Fall Meeting Abstracts.

Green, T.R., J.E., Constantz, and D.L., Freyberg, 1996, "Upscaled Soil-Water Retention Using Van Genuchten's Function," *Journal of Hydrologic Engineering* 1(3):123–130.

Khaleel, R., T.C.J., Yeh, and Z., Lu, 2002, "Upscaled Flow and Transport Properties for Heterogeneous Unsaturated Media," *Water Resources Research* 38(5):11-1–11-12.

Mualem, Y., 1976, "A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media," *Water Resources Research* 12(3):513-522.

NQA-1, 2008, *Quality Assurance Requirements for Nuclear Facility Applications*, American Society of Mechanical Engineers, New York, New York.

NUREG/CR-5965, 1994, *Modeling Field Scale Unsaturated Flow and Transport Processes*, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C.

Oostrom, M., M.J., Truex, M.L, Rockhold, and T.C., Johnson, 2017, "Deep Vadose Zone Contaminant Flux Evaluation at the Hanford BY-Cribs Site Using Forward and Imposed Concentration Modeling Approaches," Environmental Processes 4(4):771–797.

PNNL-11216, 1997, *STOMP: Subsurface Transport Over Multiple Phases Application Guide*, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://stomp-userguide.pnnl.gov/training/guides/application.pdf.

PNNL-12030, 2000, *STOMP: Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide*, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://stomp-userguide.pnnl.gov/training/guides/theory.pdf.

PNNL-13895, 2003, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-13895rev1.pdf.

PNNL-14702, 2006, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.

PNNL-15782, 2006, *STOMP: Subsurface Transport Over Multiple Phases Version 4.0: User's Guide*, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://stomp-userguide.pnnl.gov/training/guides/userguide.pdf.

PNNL-17154, 2008, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-17154.pdf.

PNNL-24705, 2015, *Assessment of Hexavalent Chromium Natural Attenuation for the Hanford Site 100 Area*, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://www.osti.gov/biblio/1224514-assessment-hexavalent-chromium-natural-attenuation-hanford-site-area.

PNNL-25146, 2016, *Scale-Dependent Solute Dispersion in Variably Saturated Porous Media,* RPT-IGTP-009, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-25146.pdf.

RHO-HS-SR-84-3 4QLIQ, 1985, *Radioactive Liquid Wastes Discharged to Ground in the 200 Areas during 1984*, Rockwell Hanford Operations, Richland, Washington.

RPP-ENV-58782, 2016, *Performance Assessment of Waste Management Area C,* Hanford Site, Washington, Rev. 0, Washington River Protection Solutions, Richland, Washington. Available at: https://pdw.hanford.gov/document/0065503H.

RPP-RPT-59197, 2016, *Analysis of Past Waste Tank Leaks and Losses in the Vicinity of Waste Management Area C, Hanford Site, Washington*, Rev. 1, Washington River Protection Solutions, Richland, Washington. https://pdw.hanford.gov/document/0072362H.

van Genuchten, M.T., 1980, "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils," *Soil Sci. Soc. Am. J.* 44(5):892-898. Available at: https://www.ars.usda.gov/arsuserfiles/20360500/pdf_pubs/P0682.pdf.

Ye, M., R., Khaleel, and T.C.J., Yeh, 2005, "Stochastic Analysis of Moisture Plume Dynamics of a Field Injection Experiment," *Water Resources Research* 41(3):W03013.1–W03013.13.

Yeh, T.C.J., R., Khaleel, and K.C., Carroll, 2015, *Flow Through Heterogeneous Geologic Media*, Cambridge University Press, New York, New York.

Zachara, J.M., C.C. Ainsworth, G.E. Brown, Jr., J.G. Catalano, J.P. McKinley, O. Qafoku, S.C. Smith, J.E. Szecsody, S.J. Traina, and J.A. Warner, 2004, "Chromium Speciation and Mobility in a High Level Nuclear Waste Vadose Zone Plume," *Geochimica et Cosmochimica Acta* 68(1):13-30.

Zhang, Z.F. and R., Khaleel, 2010, "Simulating Field-Scale Moisture Flow Using a Combined Power-Averaging and Tensorial Connectivity-Tortuosity Approach," *Water Resources Research* 46(9):W09505.1–W09505.14.

Zhang, Z.F., A.L., Ward, and G.W., Gee, 2003, "A Tensorial Connectivity–Tortuosity Concept to Describe the Unsaturated Hydraulic Properties of Anisotropic Soils," *Vadose Zone Journal* 2(3):313–321.

Appendix A

Checking Documentation for the U-10 West Area Model

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Contents

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A1 Introduction

This appendix contains documentation of checks completed for the modeling effort.

Model Check 1 – Steady State Input File and Recharge				
Model (full name):	U-10 West Area Model			
Modeler Name:	Christopher Farrow			
Checker Name:	Praveena Allena			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Checklist follows sections in CIE-Steady-State-Checking-Guide*.pptx, **located in \CAVE\v4-4\supportfiles\CheckingDocs\ss** The checklist is in \CAVE\v4-4\ModelName\checklists				
Tool Qualification and Tool Input Checks				
Completed tool qualification checks (pages 4-5 of *CIE-Steady-State-Checking-Guide*.pptx*)	☒		☒	
Completed OC_SS_gen.f tool input check (Pages 7-9)	☒		☒	
Completed SS_input_gen_cie.f tool input check (Pages 10-11)	☒		☒	
Input File Card Checks				
Completed Simulation Title Card Check (Page 13)	☒		☒	
Completed Solution Control Card Check (Page 14)	☒		☒	
Completed Grid Card Check (Page 15)	☒		☒	
Completed Inactive Node Card Check (Page 16)	☒		☒	

Model Check 1 – Steady State Input File and Recharge – Page **1** of **3**

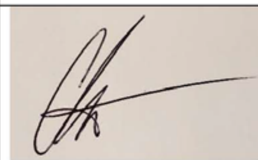
Model Check 1 – Steady State Input File and Recharge				
Model (full name):	U-10 West Area Model			
Modeler Name:	Christopher Farrow			
Checker Name:	Praveena Allena			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Completed Rock/Soil Zonation Card Check (Page 17)	☒		☒	
Completed Mechanical Properties Card Check (Page 18)	☒		☒	
Completed Hydraulic Properties Card Check (Page 19)	☒		☒	
Completed Saturation Function Card Check (Page 20)	☒		☒	
Completed X-Aqueous Relative Permeability Card Check (Page 21)	☒		☒	
Completed Y-Aqueous Relative Permeability Card Check (Page 22)	☒		☒	
Completed Z-Aqueous Relative Permeability Card Check (Page 23)	☒		☒	
Completed Initial Conditions Card Check (Page 24)	☒		☒	
Completed Source Card Check (Page 25)	☒		☒	
Completed Surface Flux Card Check (Page 26)	☒		☒	
Completed Output Control Card Check (Page 27)	☒		☒	

Model Check 1 – Steady State Input File and Recharge – Page **2** of **3**

Model Check 1 – Steady State Input File and Recharge				
Model (full name):	U-10 West Area Model			
Modeler Name:	Christopher Farrow			
Checker Name:	Praveena Allena			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Recharge Checks				
Completed high-level 2D recharge plot checks (Pages 29-31)	☒		☒	
Completed spot checks and timeseries comparisons (Page 32)	☒		☒	
The checklist is located on \CAVE\v4-4\supportfiles\ModelName\checklists. Both Modeler and Checker need to date and sign the document.				
	Modeler		***Checker***	
Name	***Christopher Farrow***		Praveena Allena	
Signature and Date	 ***16 September, 2020***		APraveena 09-17-2020	

Model Check 1 – Steady State Input File and Recharge – Page **3** of **3**

Model Check 2 – Part A: Output Control and Surface Cards				
Model (full name):	U-10 West Area Model			
Modeler Name:	Christopher Farrow			
Checker Name:	Praveena Allena			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Checklist follows sections in CIE-PartA-Checking-Guide-*.pptx, **in \CAVE\v4-4\supportfiles\CheckingDocs\PartA** The checklist is in \CAVE\v4-4\ModelName\checklists				
Tool Qualification Checks				
Completed tool qualification checks (pages 5-6 of *CIE-PartA-Checking-Guide*.pptx*)	☒		☒	
Tool Input Checks				
Completed ca_build_surface_flux.py tool input check (Pages 8-9)	☒		☒	
Completed OC_TR_gen_cie.f tool input check (Pages 10-13)	☒		☒	
Tool Output Checks				
Surface Flux Card Generator Checks (Pages 15-19)	☒		☒	
Output Card Generator Checks (Pages 21-23)	☒		☒	

The checklist is located on \CAVE\v4-4\supportfiles\ModelName\checklists. Both Modeler and Checker need to date and sign the document.		
	Modeler	***Checker***
Name	***Christopher Farrow***	Praveena Allena
Signature and Date	 ***18 September, 2020***	 09-25-2020

Model Check 2 – Part-A – Page **2** of **2**

Model Check 3 – Transport XPRT Part B				
Model (full name):	U-10 West Area Model			
Modeler Name:	J. McDonald			
Peer Reviewer Name:	G. Tartakovsky			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Checklist follows sections in CIE-PartB-Checking-Guide-*.pptx, **in \CAVE\v4-4\supportfiles\CheckingDocs\PartB** The checklist is in \CAVE\v4-4\ModelName\checklists				
Tool Qualification Checks				
Completed 5 tool qualification checks (pages 7-11 of *CIE-PartB-Checking-Guide-*.pptx*)	☒		☒	
Tool Input Checks				
Completed *ca-src2stomp.pl* tool input check (Pages 13-17)	☒		☒	
Completed *xprt_2018_input_gen_cie.f* tool input check (Pages 19-27)	☒		☒	
Source Card Checks				
Completed site list comparison with model map (Page 29)	☒		☒	
Completed construction of source-check spreadsheet(s) (Page 33)	☒		☐	N.A.
Completed site areas comparison (Page 34)	☒		☒	
Completed operation years comparison (Page 35)	☒		☒	

Model Check 3 –XPRT-PartB – Page **1** of **3**

Model Check 3 – Transport XPRT Part B				
Model (full name):	U-10 West Area Model			
Modeler Name:	J. McDonald			
Peer Reviewer Name:	G. Tartakovsky			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Completed cumulative inventory comparison (Page 36)	☒		☒	
Completed operation years comparison (Pages 37 and 39)	☒		☒	
Completed yearly inventory comparison (Pages 38-39)	☒		☒	
For sfarms model only: Completed special case check for 241-SX-115 site (Page 40)	☐	N.A.	☐	N.A.
For tfarms model only: Completed special case check for 241-T-106 site (Pages 41-42)	☐	N.A.	☐	N.A.
For bcomplex model only: Completed special case check for 241-BX-102 site (Page 43)	☐	N.A.	☐	N.A.
Input File Check				
Completed Simulation Title Card check (Page 45)	☒		☒	
Completed Solution Control Card check (Page 46-47)	☒		☒	
Completed direct *input_cie_SS* copy check (Page 46)	☒		☒	
Completed Water Table Boundary check (Page 49)	☒		☒	
Completed Solute/Fluid Interaction Card check (Page 50)	☒		☒	

Model Check 3 –XPRT-PartB – Page **2** of **3**

Model Check 3 – Transport XPRT Part B				
Model (full name):	U-10 West Area Model			
Modeler Name:	J. McDonald			
Peer Reviewer Name:	G. Tartakovsky			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Completed Solute/Porous Media Interaction Card check (Page 51-52)	☒		☒	
Completed Initial Conditions Card Check (Page 53)	☒		☒	

The checklist is located on \CAVE\v4-4\supportfiles\ModelName\checklists. Both Modeler and Checker need to date and sign the document.

	Modeler	***Checker***
Name	***J. McDonald***	***G. Tartakovsky***
Signature and Date	10/12/2020	10/09/2020

Model Check 4 – Transport XPRT Part C				
Model (full name):	U-10 West Area Model			
Modeler Name:	J. McDonald			
Peer Reviewer Name:	G. Tartakovsky			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Checklist follows sections in CIE-PartC-Checking-Guide-*.pptx, **in \CAVE\v4-4\supportfiles\CheckingDocs\PartC** The checklist is in \CAVE\v4-4\ModelName\checklists				
Tool Qualification Check				
Completed tool qualification check (Page 7)	☒		☒	
Tool Input Checks				
Completed *xprt_mb_input_gen_cie.f* tool input check (Pages 9-10)	☒		☒	
input_XPRT-MB Check				
Completed Simulation Title Card check (Page 12)	☒		☒	
Completed Solution Control Card check (Pages 13-14)	☒		☒	
Completed direct *input_XPRT-2018* direct copy check (Page 15)	☒		☒	
Completed Solute-Fluid Interaction Card check (Page 16)	☒		☒	

Model Check 4 –XPRT-PartC – Page **1** of **2**

Model Check 4 – Transport XPRT Part C				
Model (full name):	U-10 West Area Model			
Modeler Name:	J. McDonald			
Peer Reviewer Name:	G. Tartakovsky			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Completed Output Control Card check (Page 17)	☒		☒	
Completed Surface Card check (Page 18)	☒		☒	

The checklist is located on \CAVE\v4-4\supportfiles\ModelName\checklists. Both Modeler and Checker need to date and sign the document.

	Modeler	***Checker***
Name	J. McDonald	G. Tartakovsky
Signature and Date	[signature] 10/21/2020	[signature] 10/29/2020

Model Check 5 – Transport XPRT Part D				
Model (full name):	U-10 West Area Model			
Modeler Name:	J. McDonald			
Peer Reviewer Name:	Praveena Allena			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
Checklist follows sections in CIE-PartD-Checking-Guide-*.pptx, **in \CAVE\v4-4\supportfiles\CheckingDocs\PartD** The checklist is in \CAVE\v4-4\ModelName\checklists				
Tool Qualification Checks				
Completed tool qualification check (Page 7 of *CIE-PartD-Checking-Guide-*.pptx*)	☒		☒	
Tool Input Checks				
Completed *xprt_3070_input_gen_cie.f* tool input check (Page 9)	☒		☒	
Input File Check				
Completed Simulation Title Card check (Page 11)	☒		☒	
Completed Solution Control Card check (Page 12)	☒		☒	
Completed direct *input_XPRT-2018* direct copy check (Page 13)	☒		☒	
Completed Output Control Card check (Page 14)	☒		☒	
The checklist is located on \CAVE\v4-4\supportfiles\ModelName\checklists. Both Modeler and Checker need to date and sign the document.				

Model Check 5 – Transport XPRT Part D				
Model (full name):	U-10 West Area Model			
Modeler Name:	J. McDonald			
Peer Reviewer Name:	Praveena Allena			
Task/Action/Operation	***Modeler***		***Checker***	
	Status	Comment	Status	Comment
	Modeler		***Checker***	
Name	***J. McDonald***		Praveena Allena	
Signature and Date	10/14/2020		10-16-2020	

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Appendix B

Cross-Sections of the Hydrostratigraphy in the U-10 West Area Model

(Electronic Appendix)

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Contents

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B1 Introduction

This appendix is a folder containing two subfolders, SouthToNorth and WestToEast. Both contain images of cross-sections through the model showcasing the hydrostratigraphy; the first from south to north and the second from west to east.

The contents of this appendix are stored in the Environmental Modeling Management Archive (EMMA) indexed to this Electronic Calculation File (ECF) by document number.

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Appendix C

Charts of Recharge to the U-10 West Area Model as Defined by the Recharge Evolution Tool

(Electronic Appendix)

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Contents

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C1 Introduction

This appendix is a folder of images. Each image is a map of the annual recharge rate at the surface of the model, as assigned by the Recharge Evolution Tool, per grid cell in the model for each year where any recharge rate is different than the preceding year.

The contents of this appendix are stored in the Environmental Modeling Management Archive (EMMA) indexed to this Electronic Calculation File (ECF) by document number.

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Appendix D

Software Installation and Checkout Forms

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Contents

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D1 Introduction

This appendix shows the completed Software Installation and Checkout form.

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: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Bld 6

EXECUTABLE INFORMATION:

2. Executable Name (include path):

Following STOMP serial and parallel mode executable files in directory [REDACTED]/bin on head node and each compute node (compute-0-0 through compute-0-8, inclusive):

```
--------------------------------  --------------------------
MD5 File Signature                Executable File Name
--------------------------------  --------------------------
4a0f738b74620bc8df4d05290b513a44  eSTOMP1-chprc06-20200204-gaia.x
6536b8e12d8c5b83dca76f2c947b6153  stomp-wae-bcg-chprc06i.x
e0cdf04bc1a2f6c55c5a1b499939f663  stomp-wae-bcg-chprc06l.x
86c58db6fac5d1b4e6cbe13041b2568b  stomp-wae-bcg-chprc07i.x
6e72340bb39f6056e232fe5ff241c4d4  stomp-wae-bd-chprc06i.x
3f837a0fb8d9f47dbcada686f542d7fc  stomp-wae-bd-chprc06l.x
7e5b4cc36a8991b3d5a8ea2ed155ce47  stomp-wae-cgsq-chprc06i.x
00a898c0c3ec06817485781ad1c9ec46  stomp-wae-cgsq-chprc06l.x
f18ff5ab5667065d8ab12657344fb6a0  stomp-wae-cgst-chprc06i.x
061af86cf21ad8435b046d0efabe971b  stomp-wae-cgst-chprc06l.x
3c8111a9855dc0e430bf3c8a7abcf37e  stomp-w-bcg-chprc06i.x
20436d615a94955a2ce8eecdb8cba546  stomp-w-bcg-chprc06l.x
8b3df29df21d040189c3e2a50ef823bb  stomp-w-bd-chprc06i.x
066a289a75aedb933eb2536da5d7d1ff  stomp-w-bd-chprc06l.x
c8e62ad7a0d9b6fca39d8a8952ef5d8e  stomp-w-cgsq-chprc06i.x
28ad16806e1307aca51fd7bf89793e75  stomp-w-cgsq-chprc06l.x
6c25051016db2fe1f883a7caaaab1e97  stomp-w-cgst-chprc06i.x
ff9ff6f29b3469419ffaece87d7e772b  stomp-w-cgst-chprc06l.x
0c3e3fba40f5b93e71bcf9586432fd27  stomp-w-r-bcg-chprc06i.x
78492aee80a8c2d0a4e82aabf4a9c213  stomp-w-r-bcg-chprc06l.x
84b129786aba9c4be884e15e45a67389  stomp-w-r-bd-chprc06i.x
e990f1566c8099a8d54508de3da9cd88  stomp-w-r-bd-chprc06l.x
18a589a2b55aab2db290efea19b39351  stomp-w-r-cgsq-chprc06i.x
656995947 6772a137df35ce874821889  stomp-w-r-cgsq-chprc06l.x
```

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

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

Tellus Subsurface Modeling Platform (serial STOMP executables) and compiled directly on Gaia for eSTOMP.

5. Operating System (include version number):

[REDACTED] 2.6.18-308.4.1.el5 #1 SMP Tue Apr 17 17:08:00 EDT 2012 x86_64 x86 64 x86 64 GNU/Linux (for serial STOMP executables).

INSTALLATION AND CHECKOUT INFORMATION:

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

GAIA Subsurface Flow and Transport Modeling Platform (Linux Cluster)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Bld 6

7. Operating System (include version number):

[REDACTED] 3.10.0-693.5.2.el7.x86_64 #1 SMP Fri Oct 20 20:32:50 UTC 2017 x86_64 x86 64 x86 64 GNU/Linu

8. Open Problem Report? ◉ No ○ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[REDACTED]/test/stomp/build-6 on head node and each compute node of Gaia

10. Procedure(s):

CHPRC-00211 Rev 3, STOMP Software Test Plan

11. Libraries:

N/A (static linking)

12. Input Files:

Input files for ITC-STOMP-1, ITC-STOMP-2, and ITC-STOMP-2
(Baseline for comparison are results files from ATC-STOMP-1, ATC-STOMP-2, and ATC-STOMP-3 prepared on Tellus during acceptance testing)

13. Output Files:

plot.* files produced by STOMP in testing

14. Test Cases:

ITC-STOMP-1, ITC-STOMP-2, and ITC-STOMP-3

15. Test Case Results:

All PASS, all tests run, on all nodes of Gaia.

16. Test Performed By: WE Nichols

17. Test Results: ◉ Satisfactory, Accepted for Use ○ Unsatisfactory

18. Disposition (include HISI update):

Accepted, entry added to HISI. Installation applicable to all approved Gaia users who have completed STOMP required reading training assignment. Includes all acceptance tested STOMP executables EXCEPT eSTOMP reactive transport (will test this later).

Prepared By:

19. WILLIAM NICHOLS (Affiliate) Digitally signed by WILLIAM NICHOLS (Affiliate) Date: 2020.02.05 11:27:03 -08'00'

Software Owner (Signature)	Print	Date
WILLIAM NICHOLS (Affiliate)	WE Nichols	

20. Test Personnel:

Sign	Print	Date
	WE Nichols	

Approved By:

21. Software SME (Signature)	Print	Date
	N/R (per CHPRC-00211 Rev 1)	

A-6005-149 (REV 0)

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Appendix E

Title Pages for Cited Electronic Data Modeling Transmittals

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Contents

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E1 Introduction

This appendix contains the cover sheets for the electronic model data transmittals cited in this environmental calculation file. The electronic model data transmittals cover sheets presented in this appendix are EMDT-IN-0047[1], *SALDS Liquid Disposal Volumes and Tritium Inventory*, Rev. 0, and EMDT-GR-0035[2], *Waste Site and Structure Footprint Shapefiles for Inclusion in Updated Composite Analysis*, Rev. 0.

[1] EMDT-IN-0047, *SALDS Liquid Disposal Volumes and Tritium Inventory*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

[2] EMDT-GR-0035, *Waste Site and Structure Footprint Shapefiles for Inclusion in Updated Composite Analysis*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

ENVIRONMENTAL MODELING DATA TRANSMITTAL COVER PAGE

No.: EMDT -IN-0047 **Revision No:** 0

(Request EMDT number for Modeling Team Leader)

Title: SALDS Liquid Disposal Volumes and Tritium Iventory **Date:** 3/12/2020

1. Data Description

Provide the description of data set or data type.

Water and tritium releases to the State-Approved Land Disposal Site (SALDS) from the start of operations in December 1995 through September 2017, and the estimated future water and tritium releases for October 2017 through the end of operations in Year 2065.

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 demonstrates the properties of interest.

The data will be used as input to simulations of tritium migration through the vadose zone. SALDS receives treated effluent from the Effluent Treatment Facility (ETF) operated by Washington River Protection Solutions (WRPS), and WRPS provided the data of past water and tritium releases to SALDS and estimated future water and tritium releases. These data will be incorporated into a flow and transport model of the vadose zone beneath SALDS using the Subsurface Transport over Multiple Phases (STOMP) model code.

3. Data Sources

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

RPP-CALC-61876, 2017, Estimated Tritium Discharges to the State Approved Land Disposal Site for Use in Groundwater Modeling, Rev. 0, Washington River Protection Solutions, Richland, Washington. Contains the estimated future water and tritium releases to the SALDS starting in October 2017 and includes the methodology for estimating the releases.

RPP-CALC-61950, 2018, Fate and Transport Analysis of Historical and Future Tritium Releases from the State Approved Land Disposal Site, FY 2018, Rev. 0, Washington River Protection Solutions, Richland, Washington. Table A-1 in Appendix A contains the historical water and tritium releases from SALDS for December 1995 through September 2017. This appendix also lists the estimated future releases for October 2017 through Year 2065.

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 purpose of the model simulations is to evaluate future migration and fate of tritium from the SALDS as part of the Composite Analysis (CA) and Cumulative Impacts Evaluation (CIE) activities. Historical releases of water and tritium from SALDS and estimates of future water and tritium releases are necessary inputs to the modeling.

5. Prior Use

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.

ENVIRONMENTAL MODELING DATA TRANSMITTAL COVER PAGE (Continued)

No.: EMDT -IN-0047 | Revision No: 0

(Request EMDT number for Modeling Team Leader)

Title: SALDS Liquid Disposal Volumes and Tritium Iventory | Date: 3/12/2020

5. Prior Use

These data were acquired and used for groundwater model simulations of tritium migration and fate from SALDS to meet requirements of the SALDS disposal permit (ST0004500). This work was performed in FY 2018 and is documented in RPP-CALC-61950. Historical releases from SALDS have been used for numerous Hanford Site model applications. For example, the data are used annually in groundwater modeling to evaluate operation of the 200 West Pump-and-Treat system (e.g., ECF-HANFORD-19-0014). These applications are reviewed by a checker and senior reviewer as part of the modeling process.

ECF-HANFORD-19-0014, 2019, Description of Groundwater Calculations and Assessments for the Calendar Year 2018 (CY 2018) 200 Areas Pump and Treat Report, Rev. 0, CH2M Hill Plateau Remediation Company, Richland, Washington.

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 of water and tritium releases to the SALDS used for the CA/CIE modeling were acquired from Table A-1 of Appendix A in RPP-CALC-61950. Thus, historical releases were used through September 2017 and the estimated future releases were used from October 2017 through Year 2065. The water volumes in Table A-1 have units of gallons. These were summed and converted to cubic meters per year for input to the STOMP model preprocessor using the following equation and rounding the results to 3 significant figures:

Volume (m3/yr) = Volume (gal/yr) * 3.78541 (L/gal) * 0.001 (m3/L)

Tritium releases in Table A-1 are in units of curies and no unit conversions were needed.

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

No database queries were performed.

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 on water volumes and tritium concentrations in the effluent released to the SALDS are reported quarterly to the Washington State Department of Ecology by WRPS in Discharge Monitoring Reports (DMRs). DMRs filed since 2015 are available online at the Washington State Department of Ecology website (permit number ST0004500).

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).

ENVIRONMENTAL MODELING DATA TRANSMITTAL COVER PAGE (Continued)

No.: EMDT-IN-0047 | Revision No: 0

(Request EMDT number for Modeling Team Leader)

Title: SALDS Liquid Disposal Volumes and Tritium Iventory | Date: 3/12/2020

8. Data Quality Considerations

The historical data on water and tritium releases contained in Table A-1 of RPP-CALC-61950 were compared to values in the DMRs and were deemed acceptable for vadose zone transport simulations (see part 10 of the EMDT). The estimates of future water discharges and tritium releases in RPP-CALC-61876 are the best available estimates of future releases to the SALDS.

9. Assumptions and Limitations on Data Use

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

The assumptions used to prepare the estimates of future water and tritium releases to the SALDS are documented in RPP-CALC-61876. Future estimates of facility operation are always uncertain, but the information contained in RPP-CALC-61876 and in Table A-1 of RPP-CALC-61950 are the best available to support simulations of tritium migration and fate from the SALDS.

DATA CONFIGURATION ITEM SUBMITTAL:

Data Provider Submittal:

Position: JP McDonald / Sr. Hydrogeologist

John McDonald — [signature] — 3/12/2020

Print First and Last Name — *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.

The water volume and tritium release values contained in Table A-1 of RPP-CALC-61950 were spot checked against data from the DMRs. The tritium release values matched well, but some differences were noted in the water discharge volumes. Thus, a check of all water volumes against the DMRs was performed. Differences of greater than 1 percent occurred for the following months:

Oct 1997: 2,619,889 gal in Table A-1; 2,570,000 gal in DMR (1.9% difference)
Oct 1998: 3,262,365 gal in Table A-1; 2,468,000 gal in DMR (32.2% difference)
Mar 1999: 1,030,350 gal in Table A-1; 1,009,000 gal in DMR (2.1% difference)
Apr 1999: 2,622,182 gal in Table A-1; 2,895,000 gal in DMR (9.4% difference)
Nov 2001: 3,705,367 gal in Table A-1; 3,769,000 gal in DMR (1.7% difference)
Feb 2012: 1,820,569 gal in Table A-1; 1,988,000 gal in DMR (8.4% difference)

Input to the STOMP model consists of annual values distributed evenly throughout the year. In terms of annual volumes, the differences are low:

1997: 15,262,603 gal sum from Table A-1; 15,213,054 gal sum from DMR (0.3% difference)
1998: 28,322,095 gal sum from Table A-1; 27,527,000 gal sum from DMR (2.9% difference)
1999: 23,068,191 gal sum from Table A-1; 23,320,000 gal sum from DMR (1.1% difference)
2001: 25,922,535 gal sum from Table A-1; 25,985,000 gal sum from DMR (0.2% difference)
2012: 9,454,636 gal sum from Table A-1; 9,623,000 gal sum from DMR (1.7% difference)

These differences were deemed acceptable for vadose zone transport simulations and the data from Table A-1 can be used for input to the STOMP model.

11. Summary of Data Review

ENVIRONMENTAL MODELING DATA TRANSMITTAL COVER PAGE (Continued)	
No.: EMDT -IN-0047	Revision No: 0
(Request EMDT number for Modeling Team Leader)	
Title: SALDS Liquid Disposal Volumes and Tritium Iventory	Date: 3/12/2020
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 an confidence in the data acquisition and subsequent processing methodology is warranted.	
Is documentation technically adequate, complete, and correct?	☒ Yes ☐ No
Are uncertainties and limitations on appropriate use of data discussed?	☒ Yes ☐ No
Are the assumptions, constraints, bounds, or limits on the data identified?	☒ Yes ☐ No
APPROVAL OF DATA CONFIGURATION ITEM:	
Data Reviewer Approval:	
Position: M Oostrom / Principal Hydrogeologist	
MART OOSTROM — *Print First and Last Name*	[signature] — *Signature* — 03/12/20 *Date*

EMDT accepted for Composite Analysis input in Data Readiness Review on 10/8/2020.

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-GR-0035 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Waste Site and Structure Footprint Shapefiles for Inclusion in Updated Composite Analysis **Date:** 06/24/2019

1. Data Description

Provide the description of data set or data type.

Ehsit is a shapefile of known or suspected waste sites across the Hanford site (3,390 features in this version). Bggenexs is a shapefile of existing buildings/structures across the Hanford site (2,443 features in this version).

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.

These shapefiles provide the footprints to identify features commonly modeled/reported. They identify the location of where these features are on the Hanford site and the extent of their domains.

3. Data Sources

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

These were obtained as part of the data transfer to create the 2017 HIGRV. These files were originally sent as a feature dataset within an ArcGIS geodatabase by Margo Aye at Jacobs, to Jose Lopez at INTERA via email on 7/26/2018.

The original geodatabase and shapefiles can be found at:

[redacted]\Data\MargoAye@Jacobs

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.

This dataset has supported, and still supports, a variety of Hanford projects. These can be used as visual aids by generating figures for reports, presentations, or for discussions. Attributes, such as inventory, are also mapped to these features to evaluate their impact. Excluding this dataset would impact a project's ability to identify a site spatially with a reliable source.

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.

Ehsit and bggenexs have been used to support the Hanford Groundwater Annual Reports. Figures in the report incorporate these datasets. The Hanford Interactive Groundwater Viewer (HIGRV) of the annual report also use these datasets.

CH2MHILL

Environmental Modeling Data Transmittal Cover Page

No.: EMDT-GR-0035 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Waste Site and Structure Footprint Shapefiles for Inclusion in Updated Composite Analysis **Date:** 06/24/2019

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.

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

As mentioned in section 3, these files were given to INTERA by Margo Aye. Margo Aye is the GISP Lead Soil and Ground Water at Jacobs. Margo retrieved this data from the Mission Support Alliance (MSA) Central Mapping Services server. Ehsit was retrieved on 12/14/2017 and bggenexs on 12/17/2017.

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.

Not applicable.

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).

Waste site (and structure) data are compiled using a variety of methods including translations from annotated field maps, estimates based on published reports, and digitizing from aerial photography/scanned drawings/global positioning surveys. Mapped location is based on the best available information at the time. As new data becomes available, mapped location is modified to account for newly identified information.

9. Assumptions and Limitations on Data Use

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

Due to the explanation in section 8, there may be a level of uncertainty behind this dataset. None of the mapped locations are absolute. Features may have changed/removed/added throughout different iterations of this dataset.

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Environmental Modeling Data Transmittal Cover Page

No.: EMDT-GR-0035 **Revision No.:** 0

[Request EMDT number from Modeling Team Leader]

Title: Waste Site and Structure Footprint Shapefiles for Inclusion in Updated Composite Analysis **Date:** 06/24/2019

Data Configuration Item Submittal:

Data Provider Submittal

Jose Lopez/GIS Analyst
NAME/POSITION

Jose Lopez
SIGNATURE

6-24-19
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

I reviewed this document and the data provided by Margo Aye on July 26, 2018. The information stated herein is accurate.

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

Leonard Habel, P.E. Engineer
NAME/POSITION

SIGNATURE

6/24/2019
DATE

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