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B. Document Number ECF-200UP1-14-0052 Revision 0

C. Title
Local-scale Simulation of Iodine-129 Plume for the Proposed Injection Wells at the 200-UP-1 Operable Unit

D. Proposed Internet Address

E. Required Information (MANDATORY)

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ADC Required (Print and Sign) ( ) No ( ) Yes Classified

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9. Release Level? (●) Public ( ) Limited

F. Complete for a Journal Article

1. Title of Journal

G. Complete for a Presentation

1. Title for Conference or Meeting _____
2. Group Sponsoring _____
3. Date of Conference _____
4. City/State _____
5. Will Information be Published in Proceedings? (●) No ( ) Yes
6. Will Material be Handed Out? (●) No ( ) Yes

H. Information Owner/Author/Requestor
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A-6001-401 (REV 5)

ENVIRONMENTAL CALCULATION COVER PAGE

Part 1: Completed by the Responsible Manager

Project: 200-UP-1 Remedial Design **Date:** 10/31/2014

Calculation Title & Description: Local-scale Simulation of Iodine-129 Plume for the Proposed Injection Wells at the 200-UP-1 Operable Unit

Preparer: H Rashid	**Basis of Qualification:** Education & experience; H Rashid has completed CHPRC-required modeler training and has a CHPRC-qualified installation of MODFLOW & Related Codes, Build 6 (Checked by WE Nichols, 10/17/2014)
Checker: A Mayenna	**Basis of Qualification:** Education & experience
Senior Reviewer: G Ruskauff	**Basis of Qualification:** Education & experience

Part 2: Completed by Preparer

Calculation No.: ECF-200UP1-14-0052 **Revision No.:** 0

Revision History:

Revision No.	Description	Date	Affected Pages ADD ROW
0	Initial issue	10/31/2014	All

Part 3: Document Review & Approval:

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Checker:	A Mayenna / Hydrogeologic Modeler (INTERA) NAME/POSITION SIGNATURE	11/14/2014 DATE
Senior Reviewer:	G Ruskauff / Principal Hydrogeologist (INTERA) NAME/POSITION SIGNATURE	11/14/14 DATE
Risk/Modeling Integration Manager: APPLICABLE IF CALCULATION IS A RISK ASSESSMENT OR USES AN ENVIRONMENTAL MODEL	AH Aly / Risk & Modeling Integration Manager (CHPRC) NAME/POSITION SIGNATURE	11/18/2014 DATE
Responsible Manager:	AH Aly / Risk & Modeling Integration Manager (CHPRC) NAME/POSITION SIGNATURE	11/18/2014 DATE

Environmental Calculation File

Local-Scale Simulation of Iodine-129 Plume Containment for the Proposed Injection Wells at the 200-UP-1 Operable Unit

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Terms

CHPRC	CH2M HILL Plateau Remediation Company
CPGW Model	Central Plateau Groundwater Model
DOE	U.S. Department of Energy
ECF	Environmental Calculation File
HISI	Hanford Information System Inventory (environmental database)
HSU	hydrostratigraphic unit
MODFLOW	MODular three-dimensional finite-difference groundwater FLOW model (software)
MODPATH	Particle tracking post processing code for MODFLOW (software)
TMR	Telescopic Mesh Refinement

1 Purpose

The purpose of this environmental calculation brief is to present the results of hydraulic containment modeling performed using a new local scale submodel derived from the Central Plateau Groundwater Model (CPGW Model) Version 6.3.3 (CP-47631, Rev. 2) and implemented in the CH2M HILL Plateau Remediation Company (CHPRC) versions of MODFLOW-2000. The results of the model are intended to support the hydraulic containment analysis of the Iodine-129 plume from the REDOX waste sites and 216-U-1 and 216-U-2 Cribs in the vicinity of the U Plant at the US Department of Energy's (DOE's) Hanford Site shown in Figure 1. U Plant is located in the 200 West Area of the Hanford Site; a more detailed map of this location including the model subdomain is shown in Figure 2.

The hydraulic containment estimates presented in this calculation brief were generated with finer model grid spacing to verify the effectiveness of the proposed containment system in ECF-200UP1-14-0053 (Containment System for 200-UP-1 Iodine, Rev. 0) and will serve to guide subsequent refinement of the pump-and-treat system (i.e., location of wells, injection rates, and screen intervals). The containment system presented in ECF-200UP1-14-0053 was developed using the Central Plateau Groundwater model (CPGW Model) and led to the identification of an optimized set of three injection well locations and a range of injection rates that were used as the starting point for the analysis presented herein.

The local scale submodel used in this calculation employs telescopic mesh refinement of the CPGW Model to obtain higher resolution in the vicinity of the plume and extraction well locations, providing a more precise representation of the hydraulic containment system. The submodel simulates groundwater movement and contaminant fate and transport in three dimensions within the Hanford Site Central Plateau unconfined aquifer system, and also the associated impacts from hydraulic stresses imposed by extraction and injection wells. The discretization of the submodel is sufficiently fine to enable three dimensional evaluations of capture zones under different injection schedules and injection configurations. The outcome of the flow and transport simulations was (1) identification of an optimum set of wells, well screen intervals, and flow rates for a cost-effective injection system; and (2) demonstration that remedial action objectives (RAOs) will be met in the expected time frame.

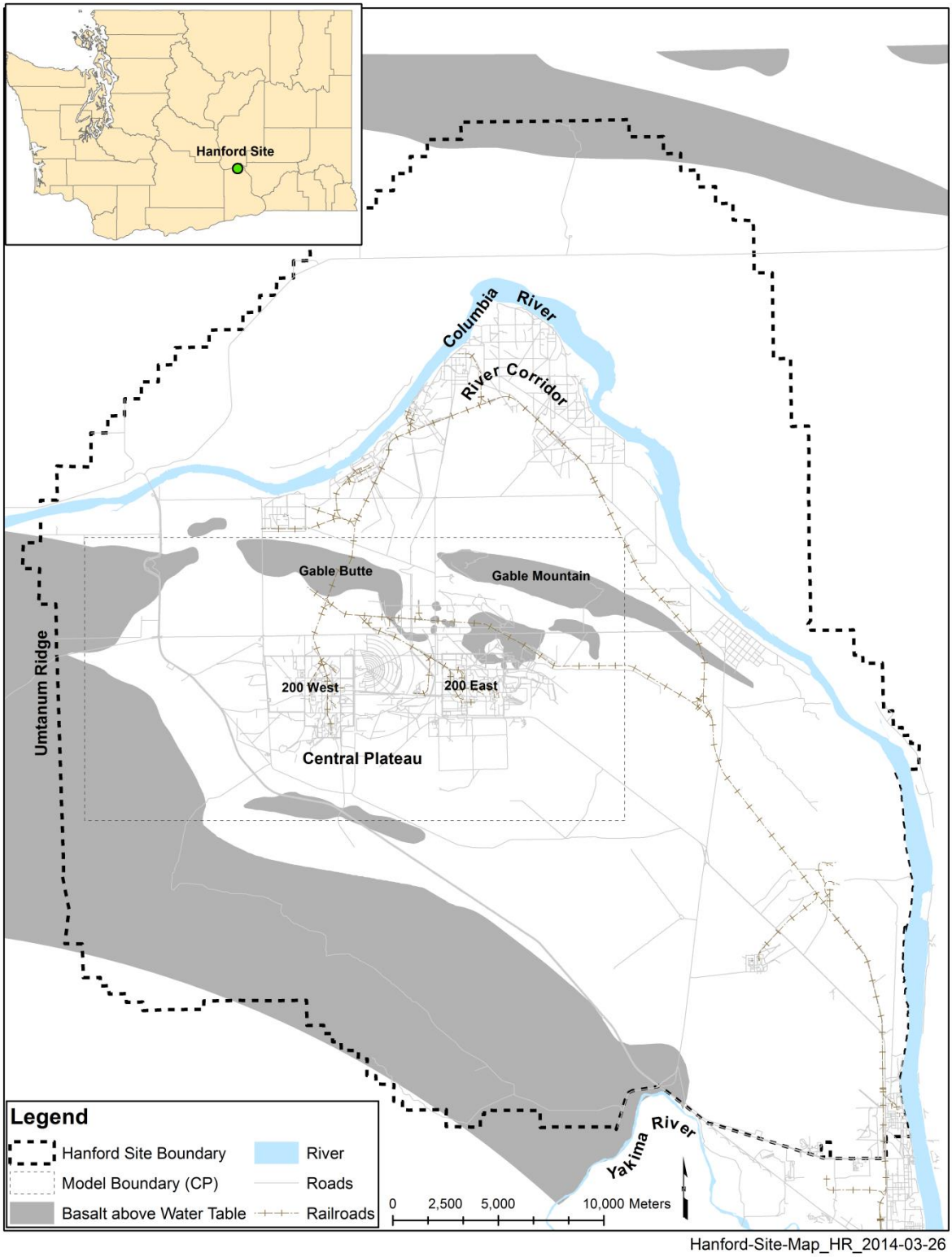

Figure 1. Hanford Site

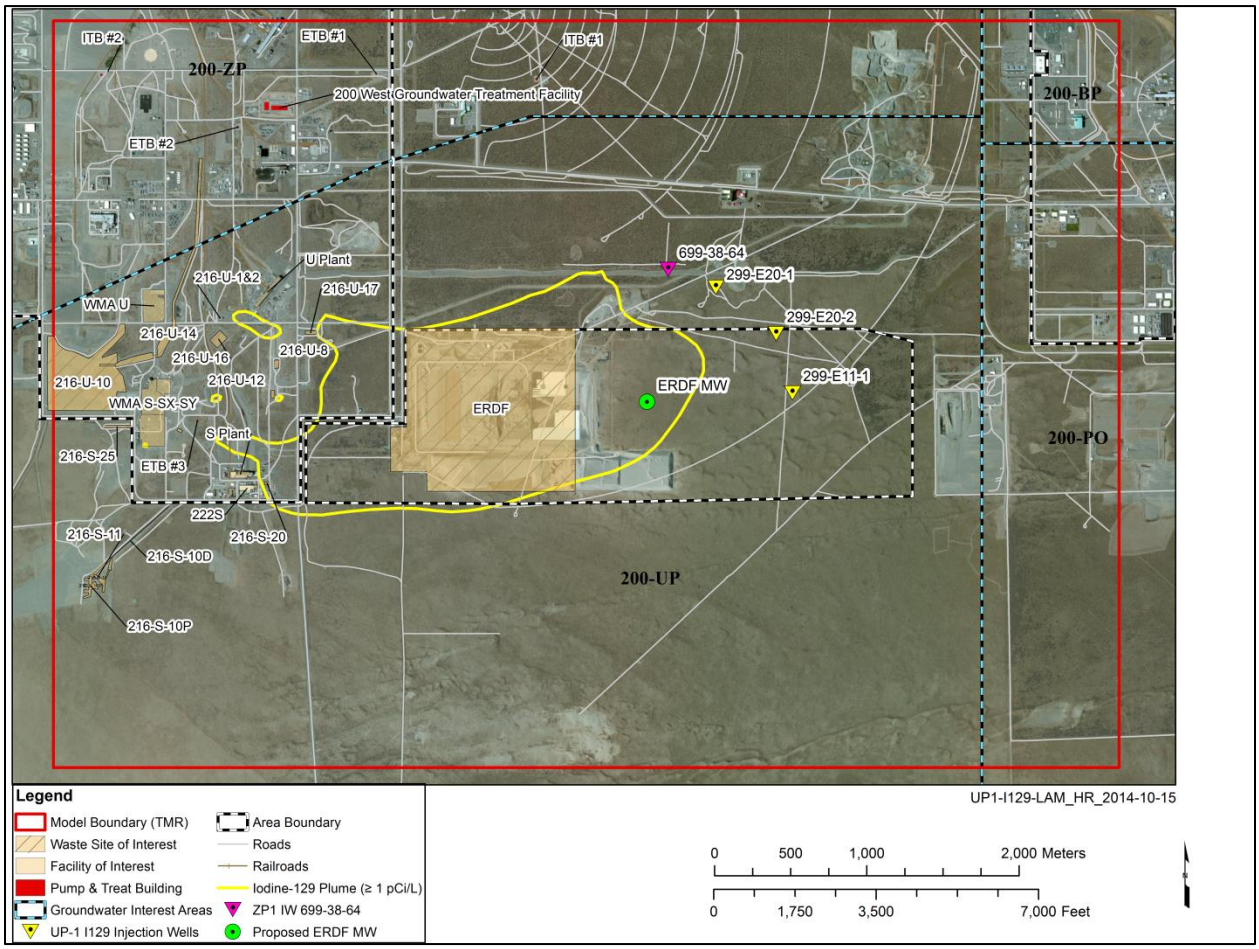

Figure 2. UP1 Vicinity Map for Iodine-129 Plume

2 Background

Iodine-129 plumes in 200-UP originate from U Plant and REDOX Plant waste sites (i.e. S Plant), although the latter were the primary sources (DOE/RL-2014-32 Rev.0). Iodine-129 occurs as two plumes, one from the 216-U-1 and 216-U-2 cribs near U Plant and a second from the REDOX Plant waste sites in the southern portion of the 200 West Area. These plumes merge downgradient and become indistinguishable. The boundary of the iodine-129 plume had been extended eastward during 2012 based on sample results from well 699-38-61 located 2.8 kilometers east of the 200 West Area boundary. The February 2012 sample result from this well was 2.0 pCi/L (above the 1 pCi/L cleanup level), but this result was not confirmed by sampling during 2013. This well was sampled during May and November with results of 0.61 and 0.74 pCi/L, respectively. Based on these values, the eastward extent of the plume was revised again to be consistent with plume depictions in previous years.

REDOX Waste Sites. The highest concentrations of iodine-129 within 200-UP, greater than 10 times the 1 pCi/L cleanup level, originate from the REDOX Plant waste sites and occur in a region extending 2 kilometers east into the 600 Area from the southeastern 200 West Area (DOE/RL-2014-32 Rev.0). The

maximum sample result in this plume during 2013 was 9.1 pCi/L in well 299-W22-88. High concentrations in this area occurred at 699-35-70, where the iodine-129 concentration was 37 pCi/L in March 2008. This well is now dry. High concentrations also occurred in 299-W22-9 located along the eastern boundary of the 200 West Area. This well became dry during 2006; the iodine-129 concentration was 30 pCi/L when this well was last sampled in 2005.

216-U-1 and 216-U-2 Cribs. The maximum iodine-129 sample result downgradient from these cribs during 2013 was 2.6 pCi/L in well 299-W19-49. This plume occurs at a shallow depth near the source, but deepens as the plume extends eastward. The plume is fully mixed vertically throughout the aquifer at well 699-38-70C, located 1.8 kilometers east of the cribs (see the plume cross section in DOE/RL-2011-01). Full mixing of the plume is attributed to vertical dispersion.

In the 200-UP-1 Groundwater Operable Unit Remedial Design / Remedial Action Work Plan (DOE/RL-2007-07, Draft B), two RAOs were identified:

- RAO #1: Return the 200-UP-1 OU groundwater to beneficial use as a potential drinking water source.
- RAO #2: Prevent human exposure to contaminated 200-UP-1 OU groundwater that exceeds acceptable risk levels for drinking water.

There currently exists no acceptable treatment for I-129, so the selected interim remedy calls for hydraulic containment of the I-129 plume (as well as an I-129 treatment technology evaluation, which is beyond the scope of this document). Hydraulic containment of the iodine-129 plume will be implemented until a subsequent remedial decision for the plume is made. Effective hydraulic containment is expected to rely on injection wells placed at the leading edge of the iodine-129 plume. Treated water from the 200 West Groundwater Treatment Facility will be pumped to the injection wells. It was initially estimated that three injection wells with a flow rate of 50 gpm per well (150 gpm total) will be needed to hydraulically control the plume.

There may be a continuing source of Iodine-129 coming from the vadose zone beneath the source waste sites and cribs. The scope of this remedial action is only the groundwater. Remediation of the source will be addressed as part of the source operable unit.

3 Methodology

The scope of this calculation is limited to hydraulic containment analysis. Simulation of contaminant transport of the local plume associated with the REDOX waste sites and 216-U-1 and 216-U-2 Cribs is specifically excluded from this scope. The predictive modeling timeframe begins in calendar year 2014 and continues for 10 years to demonstrate hydraulic containment performance.

The remedial action will be utilizing three new injection wells which are in the planning stage. The location, screen interval, and injection rates are supplied by the modeling result of ECF-200UP1-14-0053 (Containment System for 200-UP-1 Iodine, Rev. 0).

The 200-UP-1 Iodine-129 submodel was constructed as follows:

1. CPGW Model was used as the base model. The model results of ECF-200UP1-14-0053 was used to get the location of three injection wells, injection rates for the wells, and well screen intervals.

Time discretization for the submodel was kept as same as CPGW model of ECF-200UP1-14-0053

2. Groundwater Vistas' Telescopic Mesh Refinement (TMR) option was used to extract the submodel from the larger scale CPGW Model
3. The resulting head values of the CPGW Model in ECF-200UP1-14-0053 was used to calculate the Constant Head boundary for the submodel
4. The boundary of the submodel is located far enough from the Iodine-129 plume injection wells so that injection at the Iodine-129 injection wells does not influence the boundary. The Constant Head boundaries extracted from both the CPGW Model (i.e., without the Iodine-129 injection wells) and model results of ECF-200UP1-14-0053 (i.e., with the Iodine-129 injection wells) were compared to check for any influence on the submodel boundary. Difference in Constant Head boundary was less than 0.1 m which can be considered as negligible boundary effect
5. The identified domain, depicted in Figure 3, was used to extract the submodel from the larger scale model
6. The finite-difference grid was refined to obtain higher resolution in the focus area of the submodel, namely the plume and extraction well locations
7. Hydraulic properties and boundary conditions were mapped onto the refined grid from the CPGW model
8. MODFLOW dataset for the submodel was created using Groundwater Vistas and a forward-run was performed
9. Heads at different locations of the submodel, both uniform and refined grids, and the larger scale model were compared to ascertain the appropriateness of the submodel boundary, numerical stability of the submodel, and overall uniformity of simulated head trends
10. Submodel boundary and grid refinement were adjusted if any model boundary influence or numerical instability or irregularity of simulated head trends were observed. Steps 2 through 9 were repeated until all irregularities were resolved

Once the 200-UP-1 Iodine-129 Groundwater submodel was developed, it was available for use to estimate hydraulic containment of the Iodine-129 plume. This setup is considered as Base Case scenario for this document. The MODPATH software was used to calculate forward particle tracks leading to the plume migration for the proposed design scenario. The particle tracks identify the location of the Iodine-129 plume within the aquifer contained by the injection wells as a function of time from commencement of injection. The GIS resources (i.e., shapefile) used for this document are stored in Intera Inc. server (\\Psc-amber\dfs\Projects\PSC\HanfordData\2013_base_files).

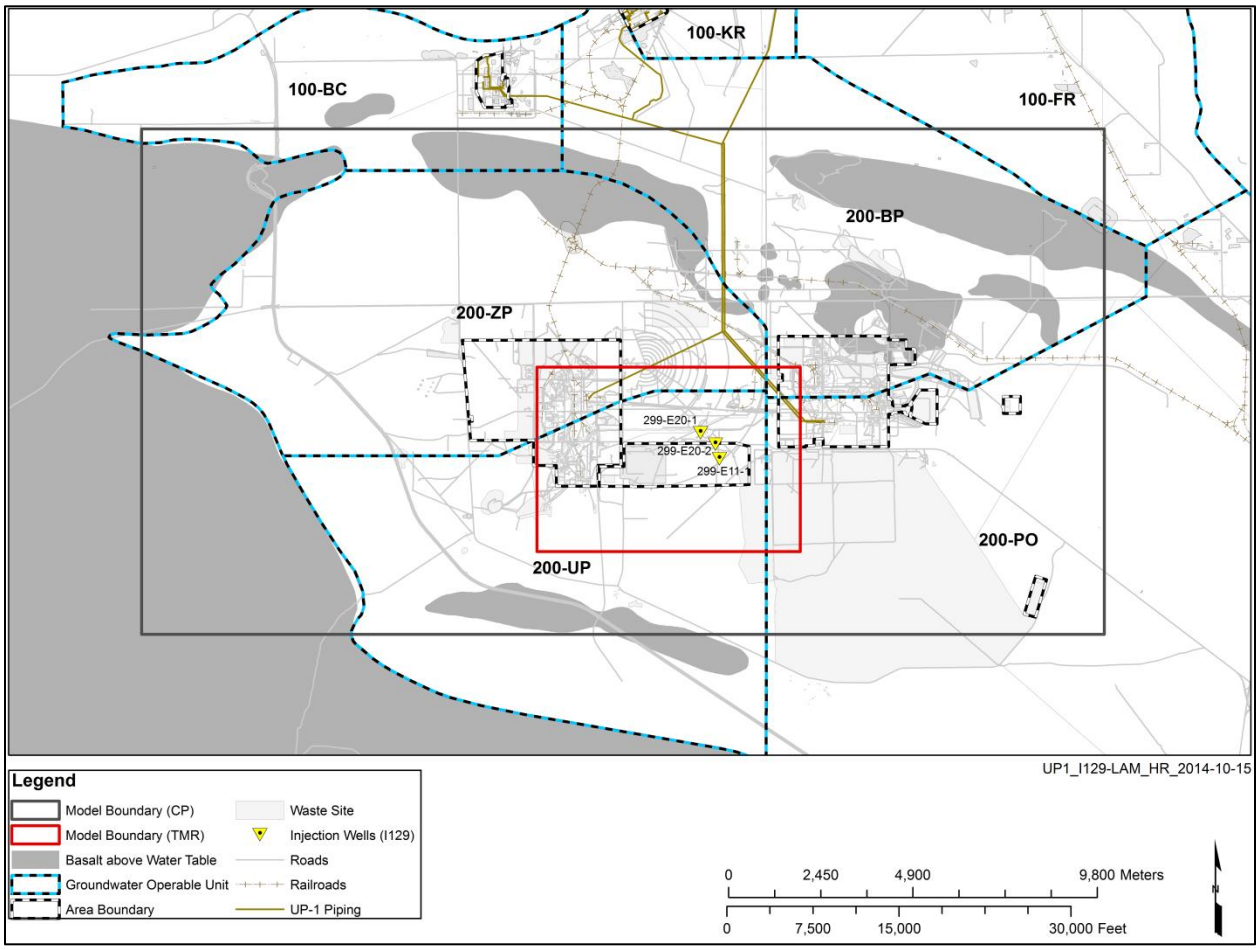

Figure 3. Central Plateau Groundwater Model Version 6.3.3 Domain and Coinciding 200-UP-1 Iodine-129 Submodel Domain

4 Assumptions and Inputs

4.1 Submodel Domain

The submodel domain extends 7000 meters west to east, and 4900 meters south to north and is located as shown in Figure 2 and Figure 3. This area represents the maximum areal extent, with some added buffer, to which the optimized injection rates associated with the UP-1 Iodine-129 plume containment design affected the results of the CPGW Model in ECF-200UP1-14-0053 (i.e., the submodel boundary is not impacted by the Iodine-129 injection wells).

The local grid was refined from the extracted portion of the CPGW Model to provide suitable resolution for simulating details of hydraulic containment near the targeted Iodine-129 plume. The CPGW Model is discretized with a grid spacing of 100 by 100 m, and 7 layers. The 200-UP-1 Iodine-129 submodel was refined to 2 by 2 m spacing at and near the injection wells; then gradually increased to 100 by 100 m spacing farther from the area of interest. The minimum (most southwest) corner of the domain sits at an easting of 566150 meters and a northing of 132050 meters, and their respective maximums are 573150

and 136950 meters (Washington state plane coordinate system, south zone). Figure 4 shows the horizontal gridding of the submodel along with the location of the wells, Iodine-129 plume footprint, and Constant Head boundary.

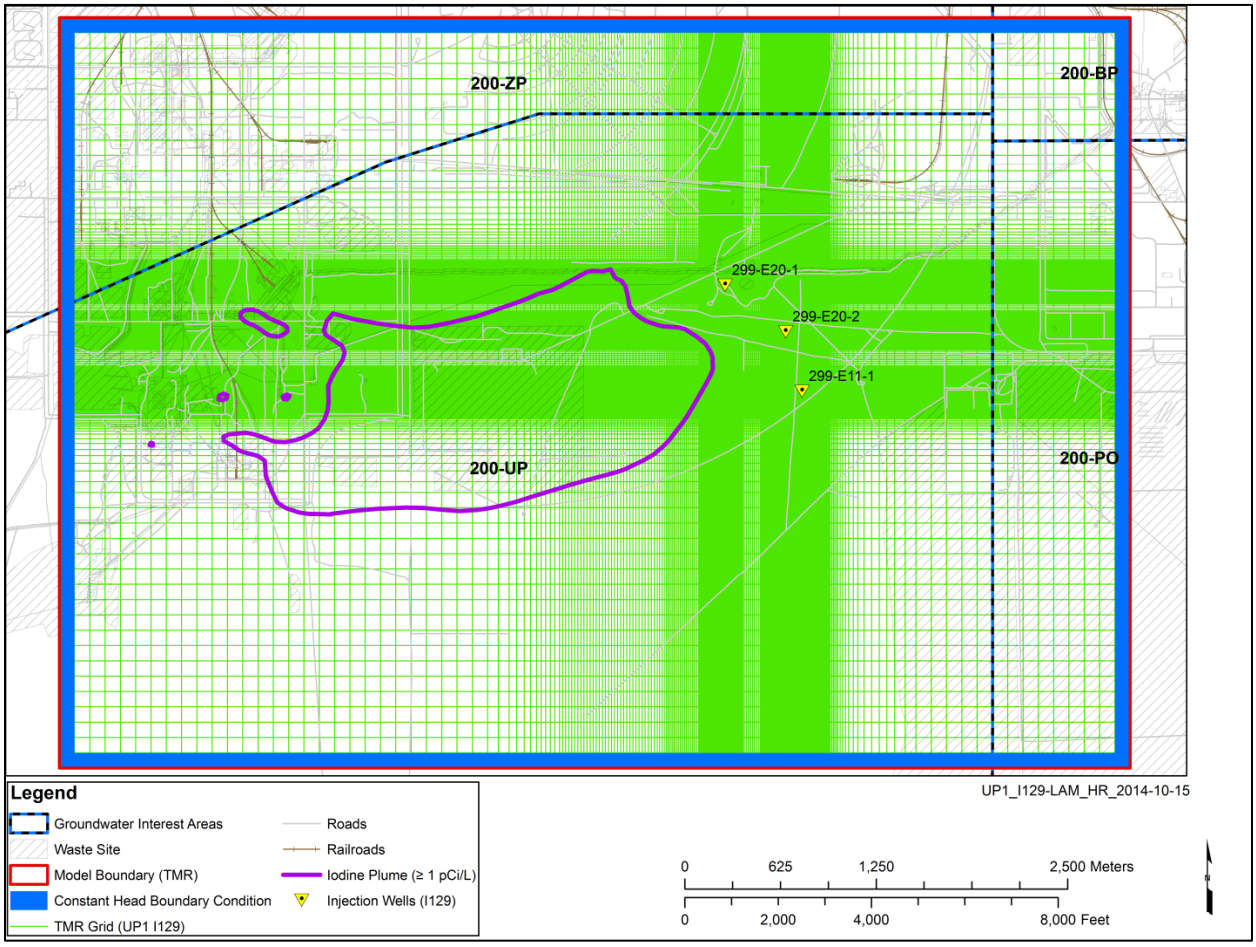

Figure 4. Horizontal Numerical Grid Discretization for The 200-UP-1 Iodine-129 Submodel

The hydrogeologic unit identification and hydraulic parameters are consistent with those determined for the Central Plateau Groundwater Model. Layers 1 through 5 of the 200-UP-1 Iodine-129 model are composed mostly of Ringold gravel Units E and C (Lindsey 1995); including sand facies of the Upper Ringold Unit where it directly overlies the other E and C units. A small portion in the north-east side of the model is composed of Hanford coarse grained unit and Cold Creek unit. Layer 6 is composed of a finer grained unit Ringold Lower Mud including Ringold Units B and D (Lindsey 1995). Layer 7 is composed entirely of Ringold Unit A (Lindsey 1995), a gravel and sand facies that is dominated by sand in the western part of the Pasco Basin. An east-west aligned cross section (Looking north) though the submodel is presented in Figure 5 (a vertical exaggeration of 20 was used). The cross section details the HSU, vertical grid spacing, and 2013 water table. Hydraulic Parameters are summarized in Table 1.

Table 1. Hydraulic Parameters for 200-UP-1 Iodine-129 Submodel Hydrostratigraphic Units (HSUs) (Source: CP-47631, Rev. 2)

Layers	Description/Unit	Porosity	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)
1-5	Unit 5: Ringold gravel Units E and C (Lindsey 1995); also includes sand facies of the Upper Ringold Unit where it directly overlies the other E and C units	0.15	5	0.5
1-5	Unit 1: Hanford formation; both the Hanford fine grained unit and coarse grained unit are considered as Unit 1. UP-1 Iodine-129 model consists of coarse grained Hanford formation	0.15	17000	1200
1-5	Unit 3: Cold Creek Unit	0.15	400	20
6	Unit 8: Fine-grained Ringold Lower Mud including Ringold Units B and D (Lindsey 1995)	0.15	0.008	0.0008
7	Unit 9: Ringold Unit A (Lindsey 1995), a gravel and sand facies	0.15	4.8	0.48

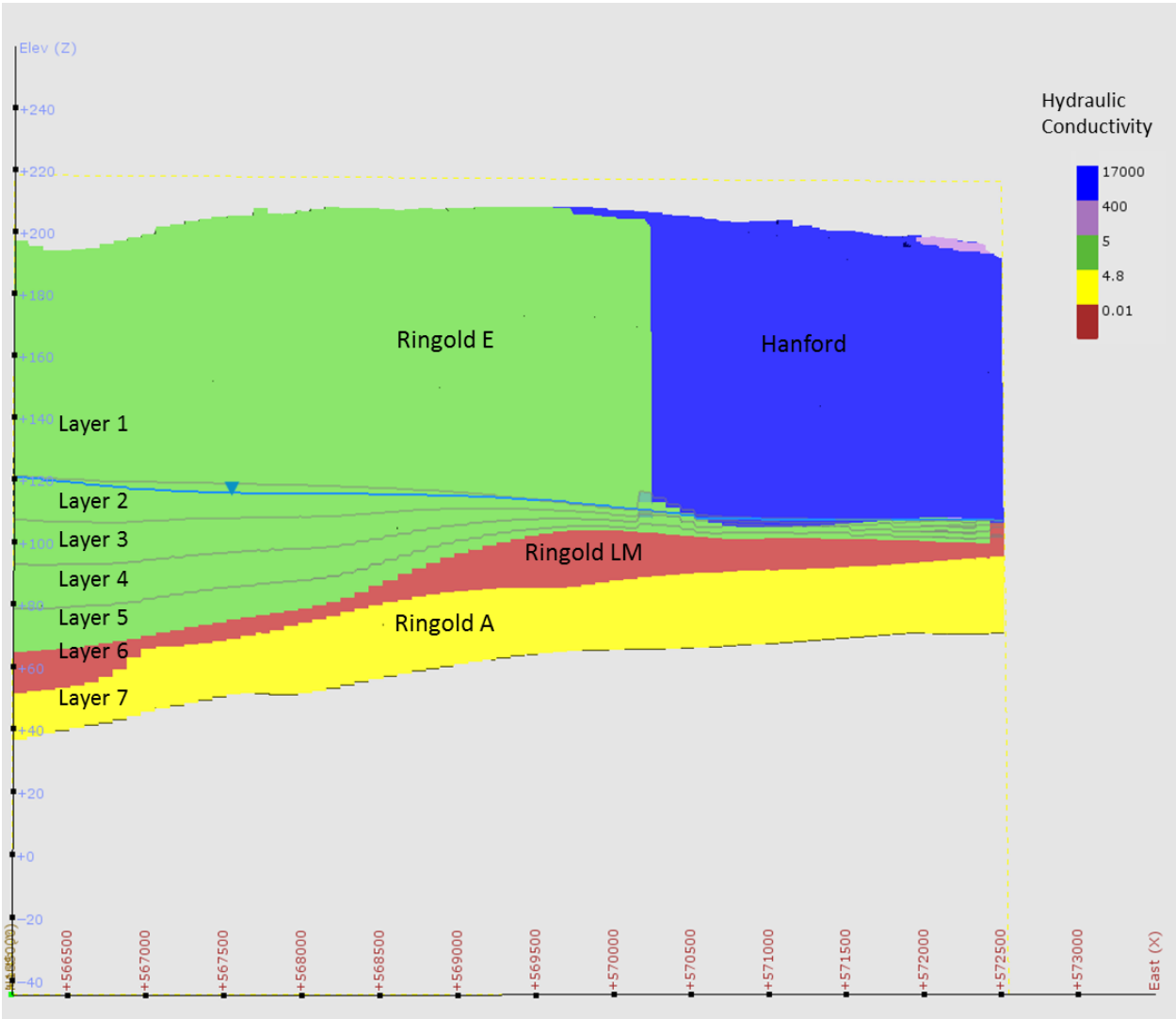

Figure 5. Vertical Numerical Grid Discretization for The UP-1 Iodine-129 Submodel

4.2 Boundary and Initial Conditions

The Central Plateau Groundwater Model version 6.3.3 and model result from ECF-200UP1-14-0053 provided the basis for the boundary and initial conditions of the 200-UP-1 Iodine-129 submodel. Hydraulic head results from along the identified submodel boundary and concurrent with the timeframe of the remedial action were extracted from the CPGW Model. These results, interpolated to the refined grid of the submodel, were adopted as prescribed head boundary conditions. These heads changed through time, depending on the results of the stress periods in the CPGW Model that coincide with the timeframe of the remedial action. Initial conditions for the submodel domain were extracted from the results of the CPGW Model for the time representing 2014.

4.3 Wells

The location and injection rates for the three injection wells were obtained from ECF-200UP1-14-0053 (Containment System for 200-UP-1 Iodine, Rev. 0). According to the ECF-200UP1-14-0053, Well 299-E20-1 (Easting 570503 and Northing 135200), 299-E20-2 (Easting 570899 and Northing 134896), and 299-E11-1 (Easting 571006 and Northing 134507) will be installed at the end of calendar year 2015. The predictive results in ECF-200UP1-14-0053 showed that 50 gpm (272.50 m^3/day) at each well would be the optimized injection rate to achieve the remedial action goals. Figure 6, details their injection rates and locations under the Base Case condition. All three injection wells are screened across Layer 2 through Layer 5 in the model which resulted in 19.2 m screen for 299-E11-1, 15.6 m screen for 299-E20-2, and 14.4 m screen for 299-E20-1.

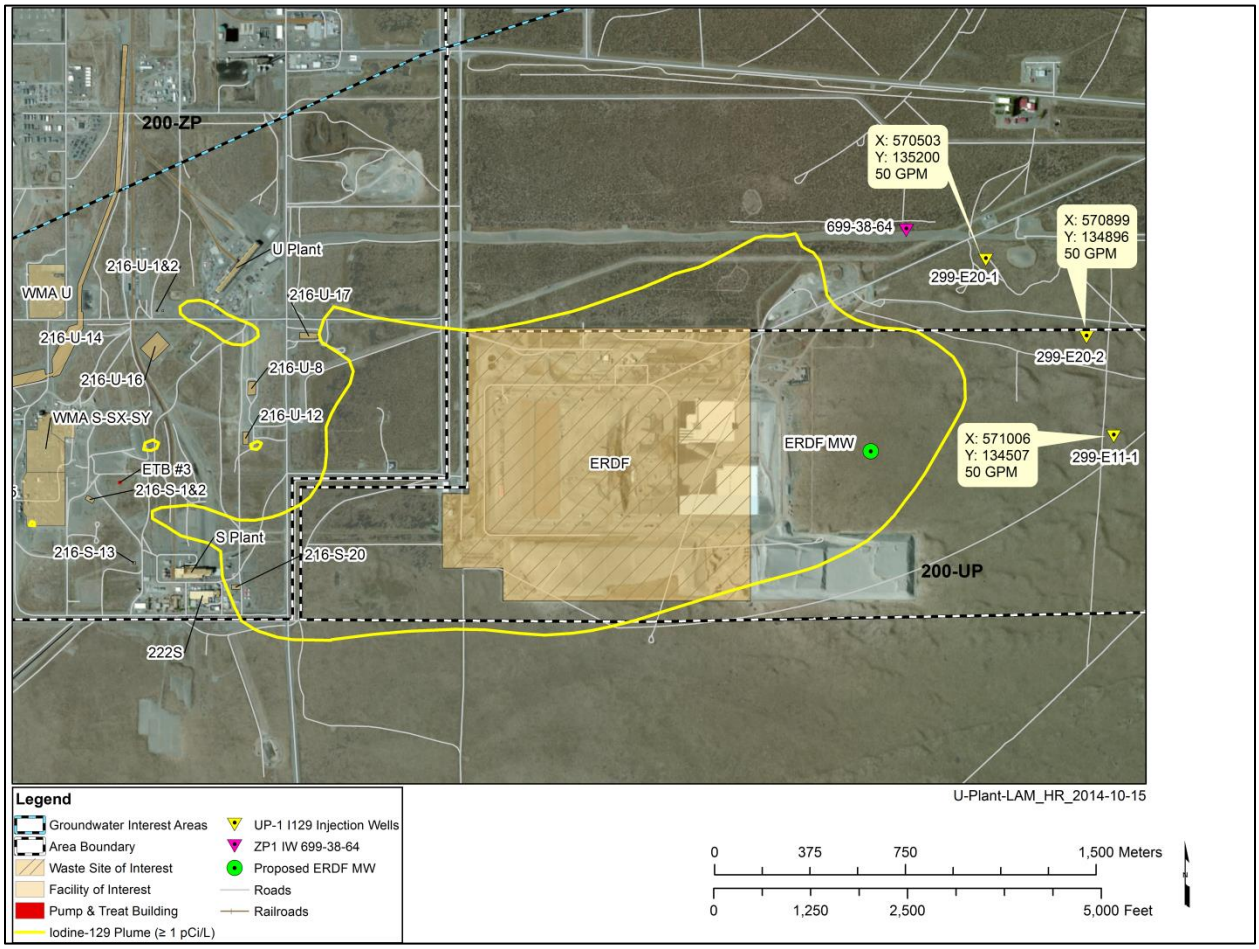

Figure 6. Injection Well Locations and Injection Rates under Base Case Scenario

5 Software Applications

MODFLOW-2000-MST, MODPATH-MST, and Groundwater Vistas™[1] software programs were used for this environmental calculation. These are CH2M HILL Plateau Remediation Company (CHPRC) approved software, managed and used in compliance with the requirements of PRC-PRO-IRM-309, Controlled Software Management. The following supporting information is provided.

5.1 Approved Software

For Approved Software used in this calculation, the required description is provided.

5.1.1 Description

MODFLOW

- Software Title: MODFLOW-2000-MST
- Software Version: CHPRC Build 0006 (mf2k-mst-chprc06dp.exe)
- Hanford Information System Inventory (HISI) Identification Number: 2517 (Safety Software, Level C)
- Authorized Workstation type and property number: Personal Computer, PSC-Lithium
- Authorized User: H Rashid
- CHPRC Software Control Documents:
    - CHPRC-00257 Rev 1, MODFLOW and Related Codes Functional Requirements Document
    - CHPRC-00258 Rev 2, MODFLOW and Related Codes Software Management Plan
    - CHPRC-00259 Rev 2, MODFLOW and Related Codes Software Test Plan
    - CHPRC-00260 Rev 5, MODFLOW and Related Codes Requirements Traceability Matrix
    - CHPRC-00261 Rev 5, MODFLOW and Related Codes Acceptance Test Report

MODPATH

- Software Title: MODPATH-MST
- Software Version: CHPRC Build 0006 (modpath-mst-chprc06sp.exe)
- HISI Identification Number: N/A (Support Software; see CHPRC-00258 Rev. 2)
- Authorized Workstation type and property number: N/A
- Authorized User: N/A
- CHPRC Software Control Documents:
    - CHPRC-00258 Rev 2, MODFLOW and Related Codes Software Management Plan

Groundwater Vistas™

- Software Title: Groundwater Vistas™
- Software Version: 5.51 Build 18b
- HISI Identification Number: N/A (Support Software; see CHPRC-00258 Rev. 2)

[1] Groundwater Vistas is a trademark of Environmental Systems, Inc.

- Authorized Workstation type and property number: N/A
- Authorized User: N/A
- CHPRC Software Control Document:
    - CHPRC-00258 Rev 2, MODFLOW and Related Codes Software Management Plan

5.1.2 Software Installation and Checkout

Approved Safety Software packages (MODFLOW) and the controlled version of the support software (MODPATH) were checked out in accordance with procedures specified in CHPRC-00258 Rev. 2. Executable files were obtained from the Software Owner who maintains the configuration-managed copies in MKS Integrity™[2], installation tests identified in CHPRC-00259 Rev. 2 performed and successful installation confirmed, and Software Installation and Checkout Forms were completed and approved for installations used to perform model runs reported in this calculation. Copies of the Software Installation and Checkout Forms for approved users and installations used to perform this calculation are provided in Attachment A.

5.1.3 Statement of Valid Software Application

The preparers of this ECF attest that the software identified above, and used for the calculations described in this calculation brief, is appropriate for the application and used within the range of intended uses for which it was tested and accepted by CHPRC.

Because MODFLOW is graded as Level C software, use of this software is required to be logged in the HISI. Accordingly, this environmental calculation has been logged by the software owner in the HISI under Identification Number 2517.

[2] MKS Integrity™ is a trademark of MKS, Incorporated.

6 Calculation

Two MODFLOW runs, one with Iodine-129 injection wells injecting at 50 gpm per well (i.e., the Base Case scenario) and one with no Iodine-129 injection wells (i.e., No Action scenario), were performed. The flow simulations were performed for 12 years where start of the simulation represents calendar year 2014. The injection at the Iodine-129 injection wells commence at simulation year three (i.e., at the beginning of calendar year 2016) and continues for rest of simulation periods. The hydraulic head distribution at the end of the simulation period for model run with no Iodine-129 injection wells and for model run with three Iodine-129 injection wells (i.e., Base Case) are shown in Figure 7 and Figure 8, respectively. The simulated hydraulic gradient for model run with no Iodine-129 injection wells (Figure 7) indicates that groundwater is flowing towards northeast side of the model domain, which is consistent with the CPGW model analysis and shows the submodel is functioning properly. As groundwater flows towards north-east direction, the Iodine-129 plume is also expected to migrate in the direction (i.e., along the flow direction). Three Iodine-129 injection wells were placed to the east of Iodine-129 plume footprint to prevent the migration of the plume in the north-east direction. The simulated hydraulic head for model run with three Iodine-129 injection wells (Figure 8 shows layer 2 that has the maximum mounding) indicates that mounding of water occurs at and near the Iodine-129 injection wells in layers 2 through 5. The maximum height of the groundwater mounds created in each well for the Base Case (as well as for the sensitivity cases discussed in Section 7) are shown in Table 2. In no case, does the height of the groundwater mound in any well rise above land surface.

The increase in hydraulic head created by injection creates a reverse hydraulic gradient from north-east towards west side of the Iodine-129 plume footprint. MODPATH runs with forward particle tracking option were performed to see the migration of the plume footprint for corresponding flow conditions. The particles were placed along the edges of the Iodine-129 plume in Layer 3 (at the center of saturated thickness of Layer 3). As the plume is expected to migrate toward north-east side of the model, the particles were placed only at the eastern half of the plume. The resulting migration of the plume for the no Iodine-129 injection well (i.e., No action scenario) and for three Iodine-129 injection wells (i.e., Base Case scenario) are shown in Figure 9 and Figure 10, respectively. Vertical movement of the particle with time is indicated by different color for each layer (e.g., green color indicates that the particle is in Layer 3) and each arrow indicates the horizontal distance travelled in every two years; there is no vertical migration outside of layer 3.

In the No Action scenario, none of the particles released on the edge of the plume leave the OU, traveling a maximum distance of approximately 400 m toward the OU boundary (Figure 9). As in the No Action scenario, no particles leave the OU in the Base Case scenario, with the maximum distance traveled of approximately 160 m (Figure 10). Thus, the Base Case scenario injection well design provides containment of the I-129 plume, retarding movement of particles without redirecting them beyond the boundaries the plume would follow in the No Action scenario.

Table 2. Injection Well Mounding Heights

Injection Well	Mound Height (m)		
	Base Case (50 gpm per well)	Sensitivity Run 1 (100 gpm per well)	Sensitivity Run 2 (150 gpm per well)
299-E20-1	3.67	7.56	11.35
299-E20-2	4.62	9.32	13.86
299-E11-1	4.59	9.45	14.17

Another MODPATH run with forward particle tracking option were performed to see the migration of the plume footprint in vertical direction. The particles were placed along the edges of the Iodine-129 plume in Layer 5 (at the center of saturated thickness of Layer 5). The particle track results for Layer 3 (Figure 10) and Layer 5 (Figure 11) show similar behavior. Flat contour of the particles in Figure 10 and Figure 11 clearly indicates that Iodine-129 plume is moving very slowly in horizontal direction and practically stays stable in vertical direction.

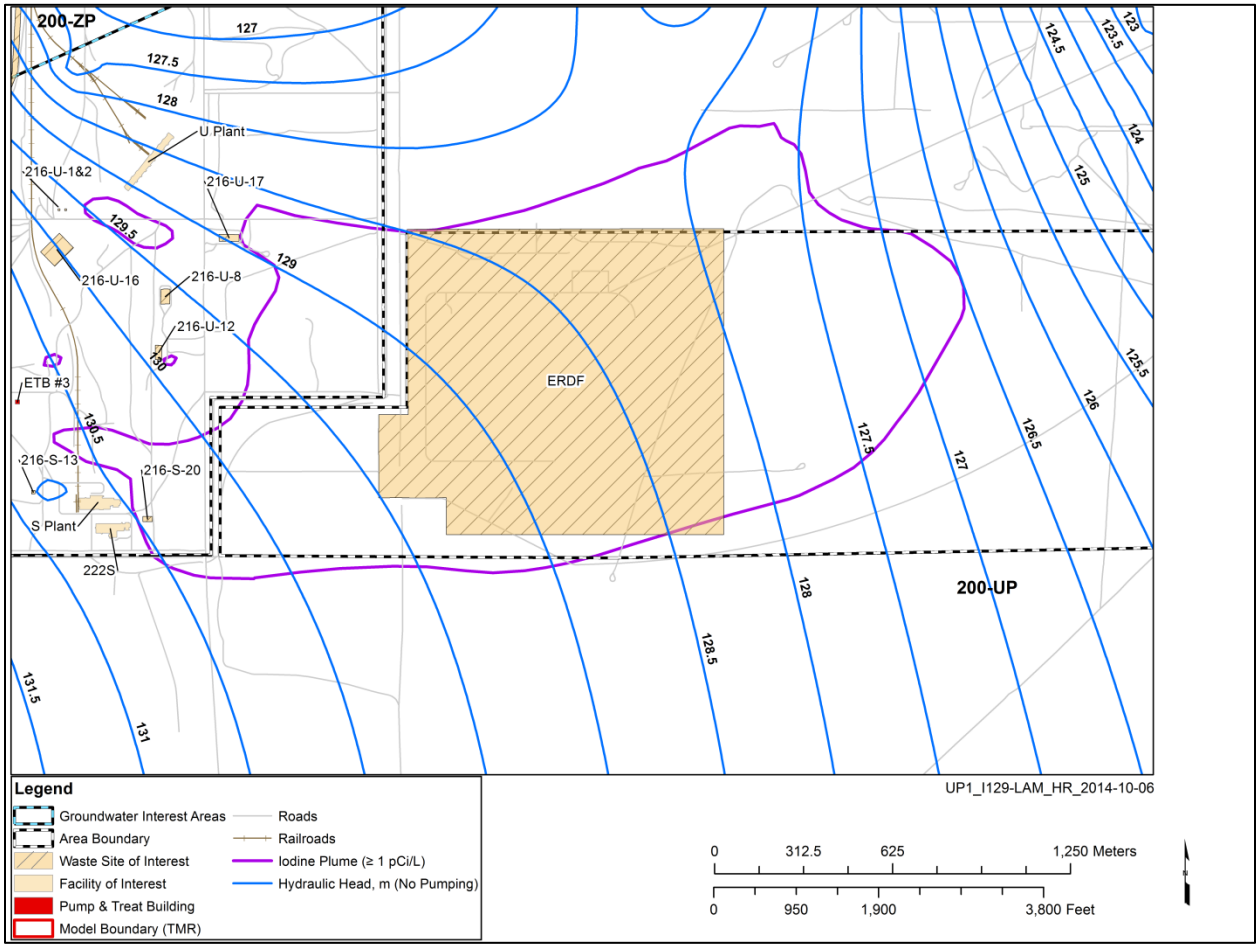

Figure 7. Hydraulic Head Distribution After Twelve Years of Simulation at Layer 2 for No Injection at The Iodine-129 Injection Wells (0.5 m Contour Interval)

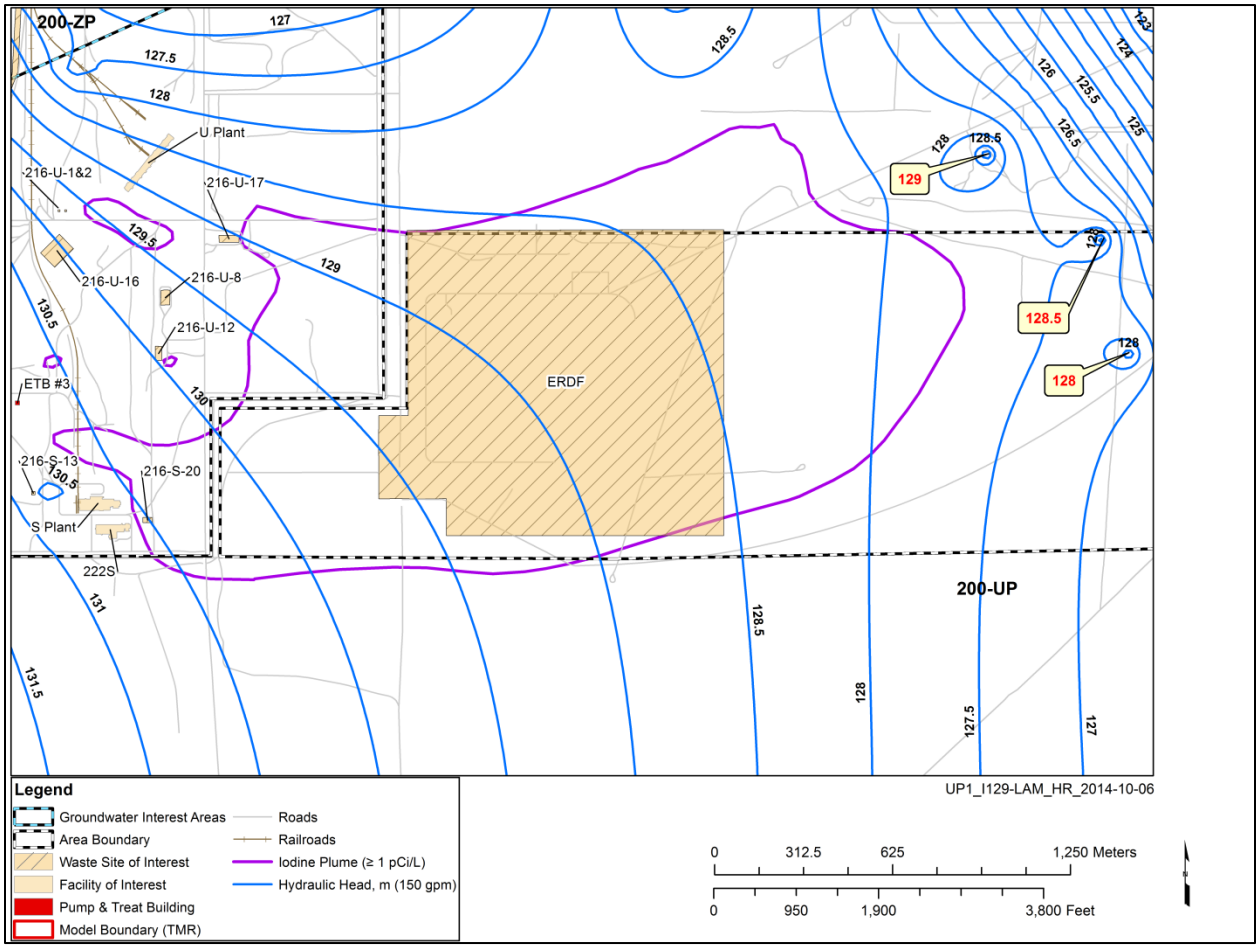

Figure 8. Hydraulic Head Distribution after Twelve Years of Simulation at Layer 2 for Base Case (0.5 m Contour Interval)

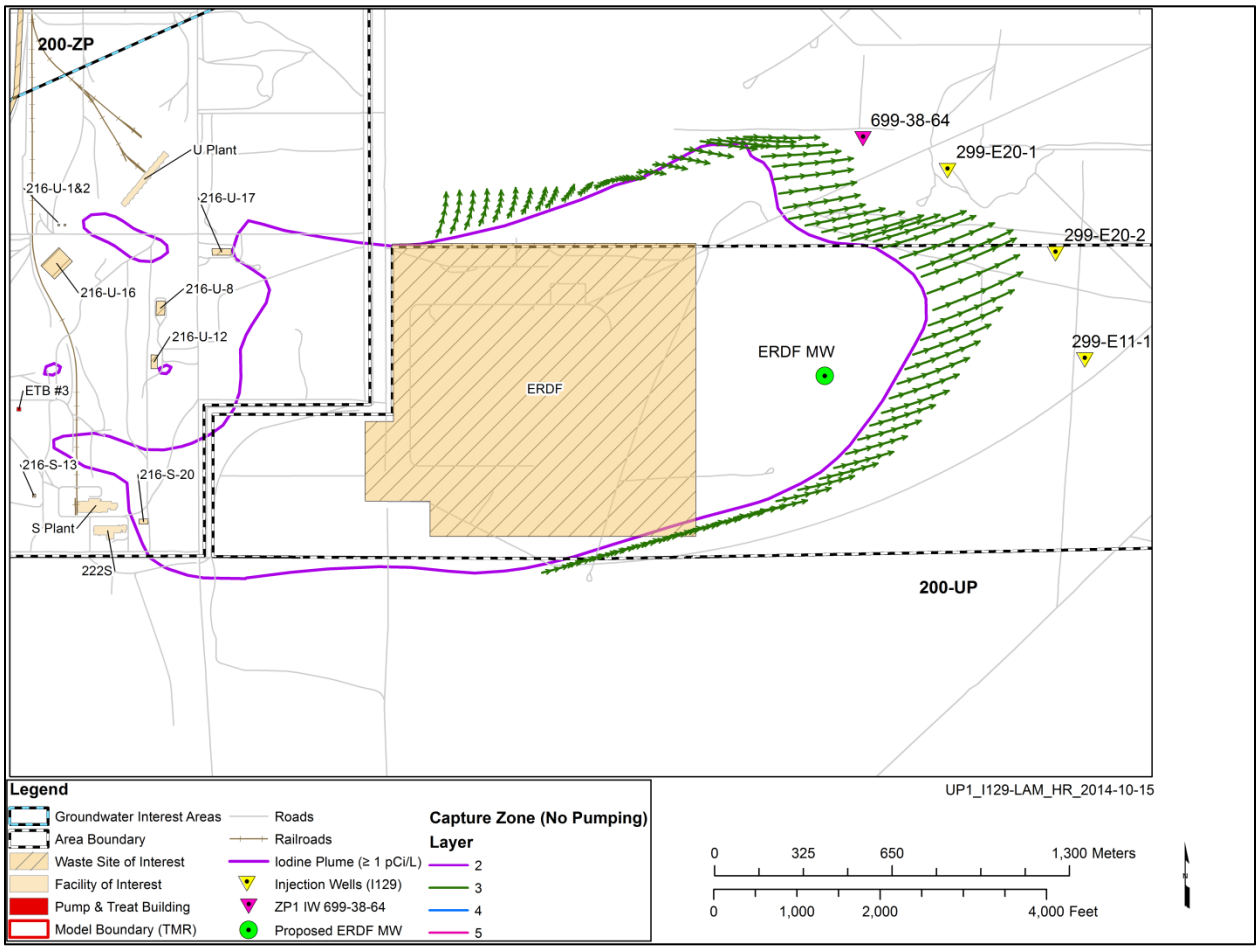

Figure 9. Predicted Hydraulic Containment in Layer 3 at 2-Year Intervals for No Injection at Iodine-129 Injection Wells (Forward Particle Tracking)

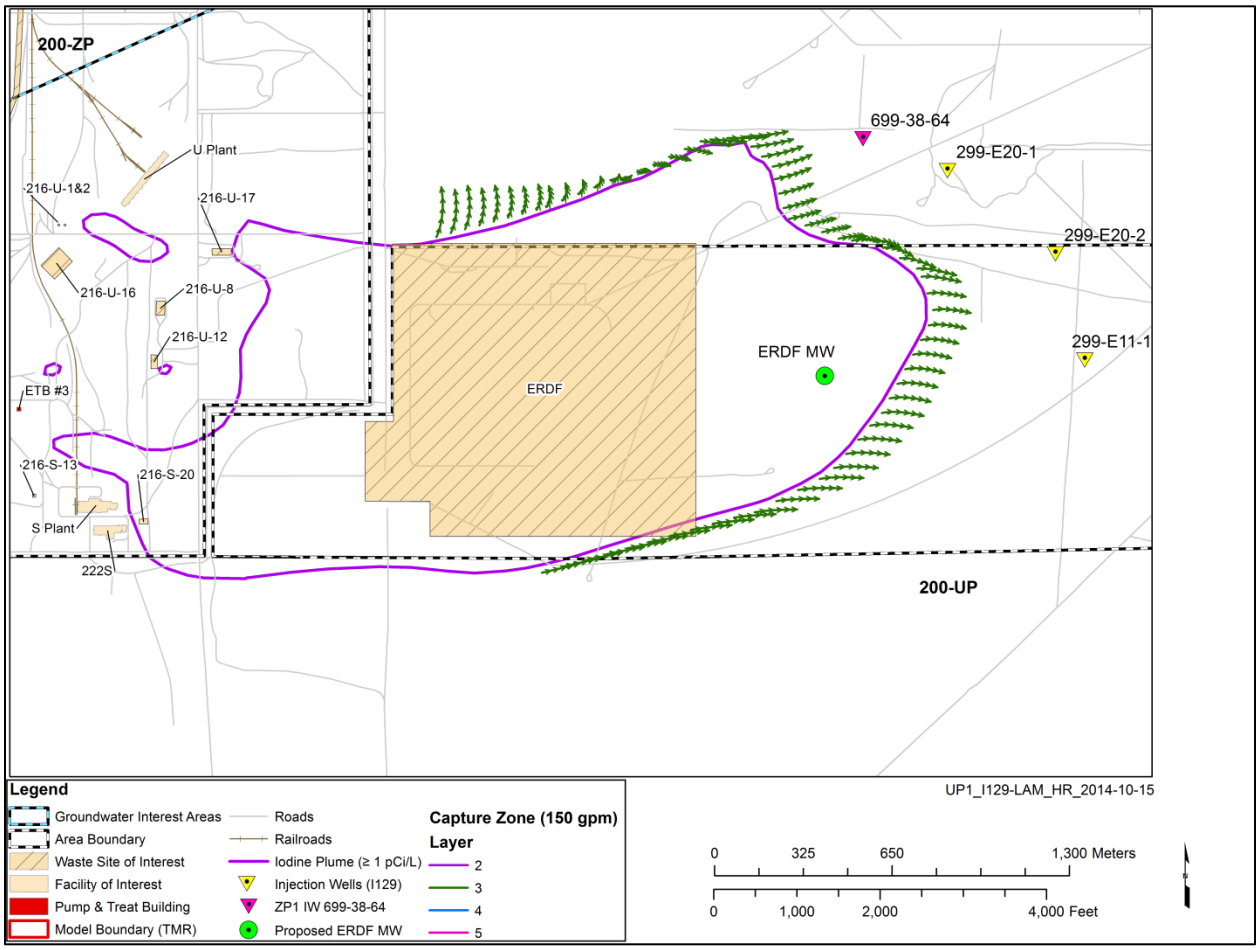

Figure 10. Predicted Hydraulic Containment in Layer 3 at 2-Year Intervals for Base Case (Forward Particle Tracking)

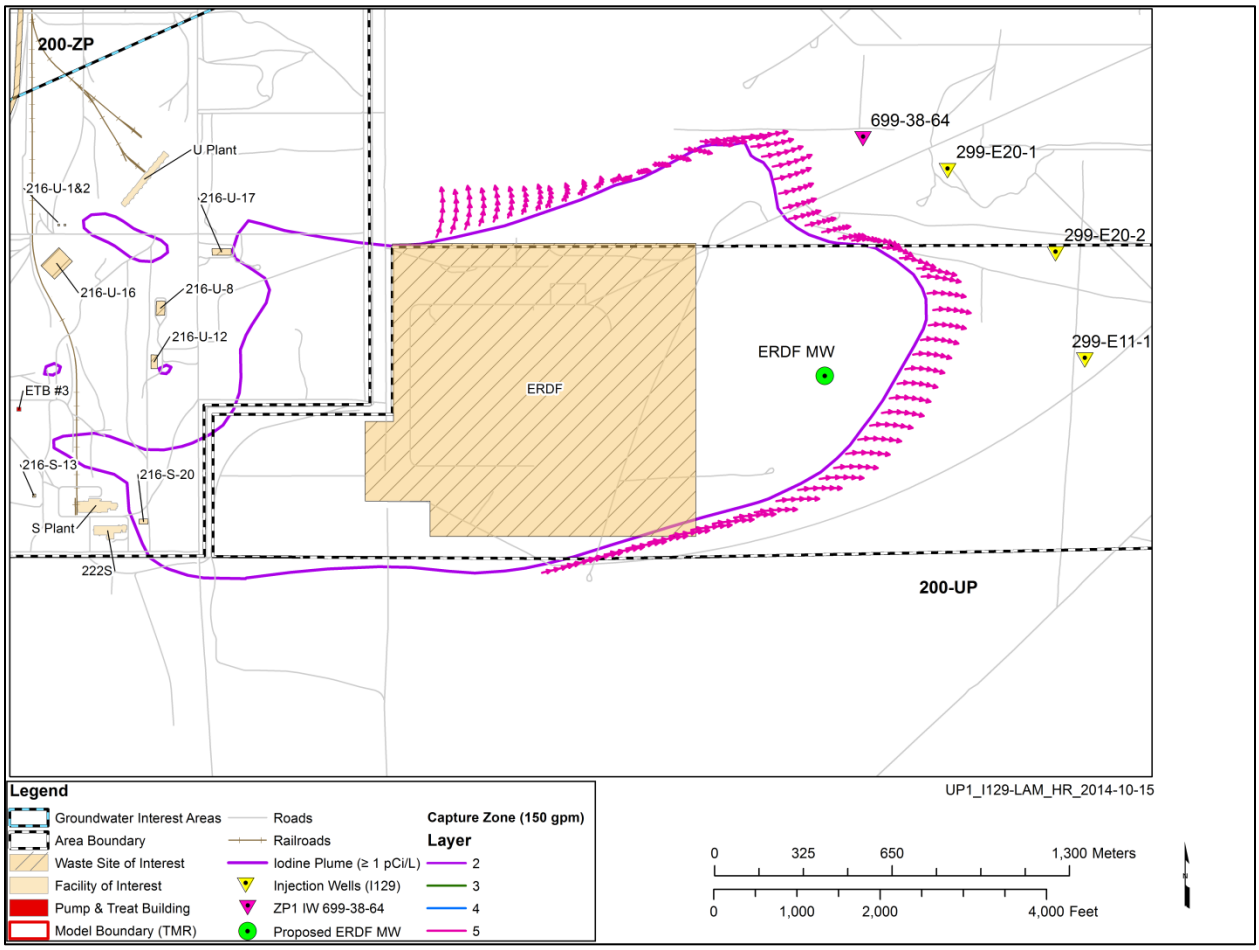

Figure 11. Predicted Hydraulic Containment in Layer 5 at 2-Year Intervals for Base Case (Forward Particle Tracking)

7 Sensitivity analysis

MODPATH model results of the local area submodel showed that the well configuration (i.e., location, injection rate, and well screen) for the Base Case is capable of reducing the maximum migration distance of a particle released at the northeast edge of the Iodine-129 plume footprint to approximately 160 m from approximately 400 m in the No Action scenario. Several sensitivity runs were performed to understand the effect on the plume containment due to higher injection rate at the Iodine-129 injection wells. The detail description of the sensitivity runs are tabulated in Table 2.

Table 3. Comparison of Sensitivity Scenarios with Base Case Scenario

No.	Description
No injection	No injection at the Iodine-129 injection wells (i.e., No action scenario)
Base Case	Each Iodine-129 injection well is injecting at 50 gpm
Sensitivity Run 1	Each Iodine-129 injection well is injecting at 100 gpm
Sensitivity Run 2	Each Iodine-129 injection well is injecting at 150 gpm

The hydraulic head distribution at the end of the simulation period for Sensitivity Run 1 and Sensitivity Run 2 are showed in Figure 12 and Figure 13, respectively. The figures clearly show that mounding of water at and near the Iodine-129 injection wells would increase as the injection rate increases at the Iodine-129 injection wells (see Table 2). As a result, the simulated hydraulic gradient from the well locations towards the Iodine-129 plume footprint would be steeper as the injection rate increases. MODPATH runs were performed for both sensitivity runs where particles are placed at the same location as the Base Case simulation.

The mounding at the Iodine-129 injection wells for all the scenarios are showed in Figure 16 through Figure 18. Negative drawdown value indicates that mounding occurs at the injection wells if injection is on.

The resulting migration of the plumes for Sensitivity Run 1 and Sensitivity Run 2 are shown in Figure 14 and Figure 15, respectively. The figures indicate that the north-east front of the plume will push back to the south-west direction due the steeper reverse gradient. On the other hand, the south-east front of the plume starts to migrate towards south side of the model because the higher injection rates more strongly deflect the overall north-east gradient. Overall, while both of these scenarios reverse the movement of particles along the northeastern edge of the plume, with no particles escaping the OU, they also cause particles along the north and south edge of the plume to migrate laterally beyond the footprint the plume would occupy in the No Action scenario. Given that, these scenarios may not properly be considered to provide containment of the plume.

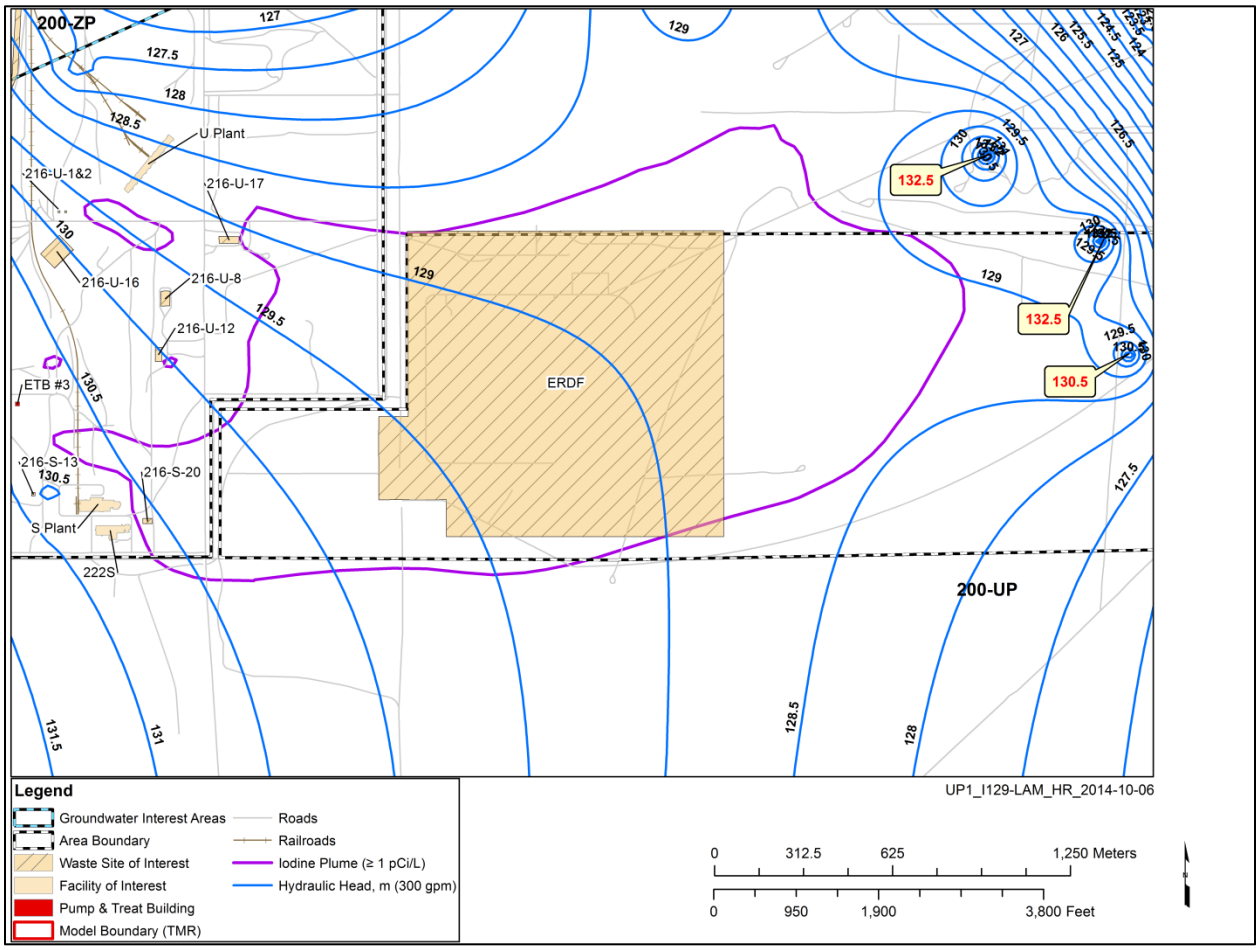

Figure 12. Hydraulic Head Distribution After Twelve Years of Simulation at Layer 2 for Sensitivity Run 1 (0.5 m Contour Interval)

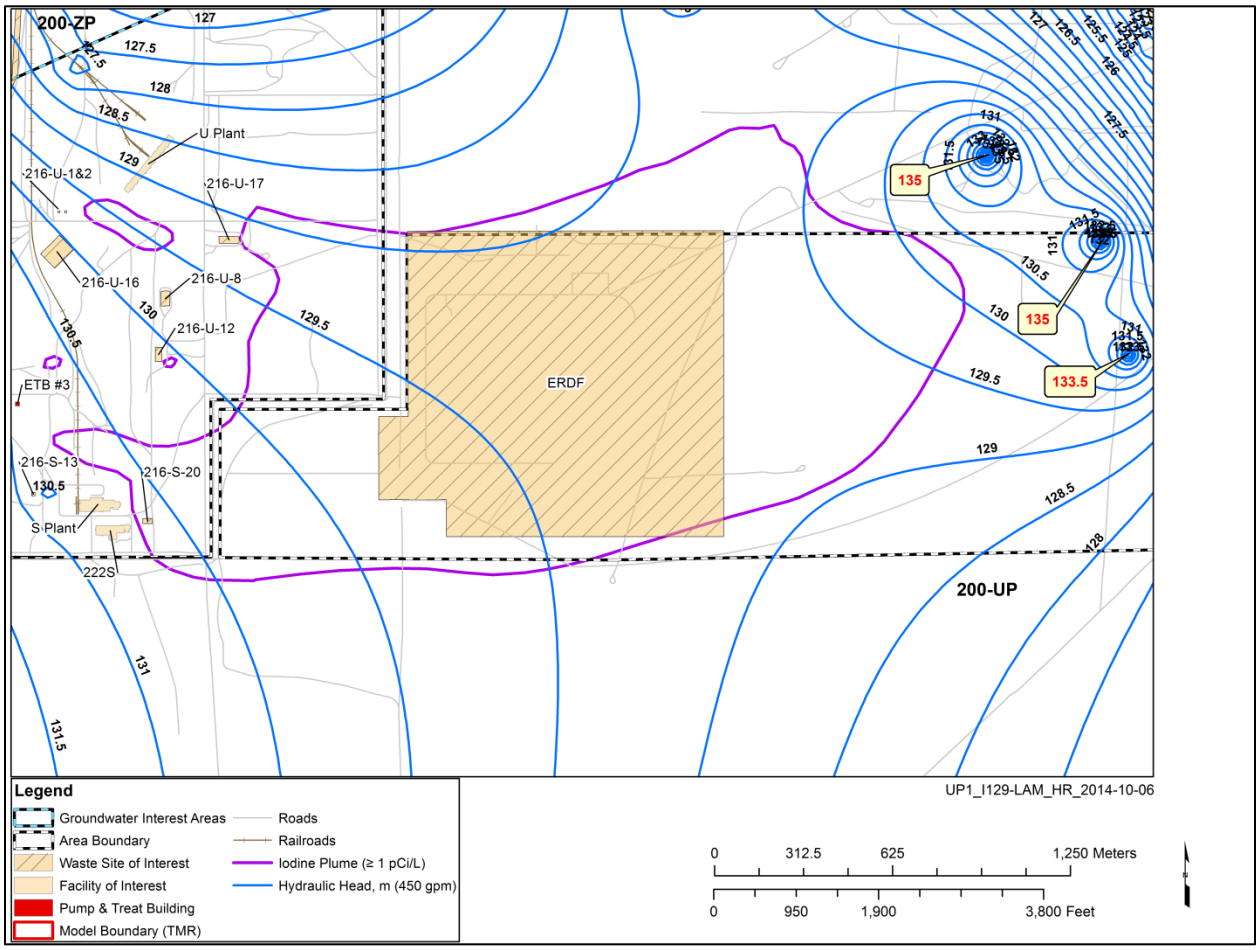

Figure 13. Hydraulic Head Distribution After Twelve Years of Simulation at Layer 2 for Sensitivity Run 2 (0.5 m Contour Interval)

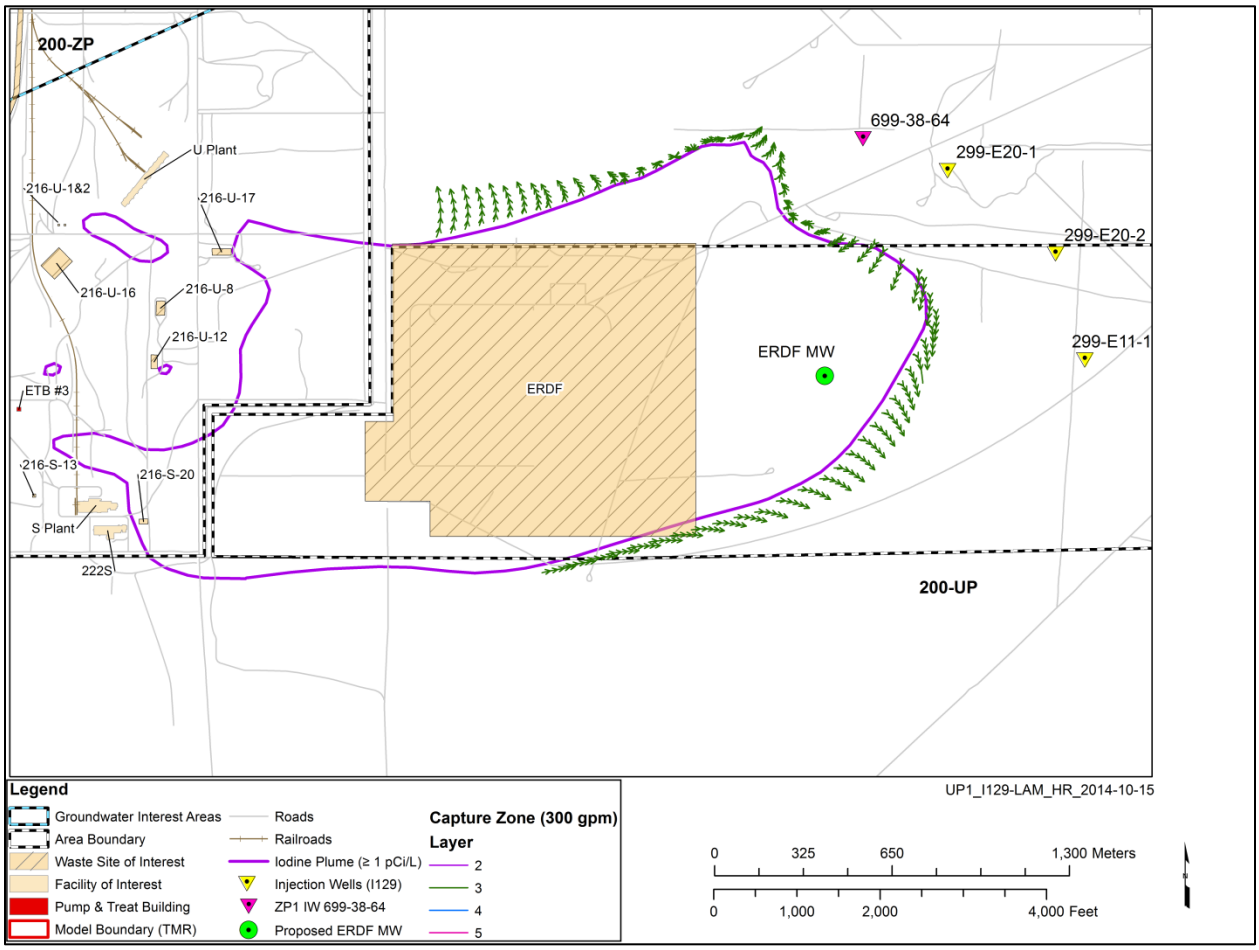

Figure 14. Predicted Hydraulic Capture Zone at 2-Year Intervals for Sensitivity Run 1 (Forward Particle Tracking)

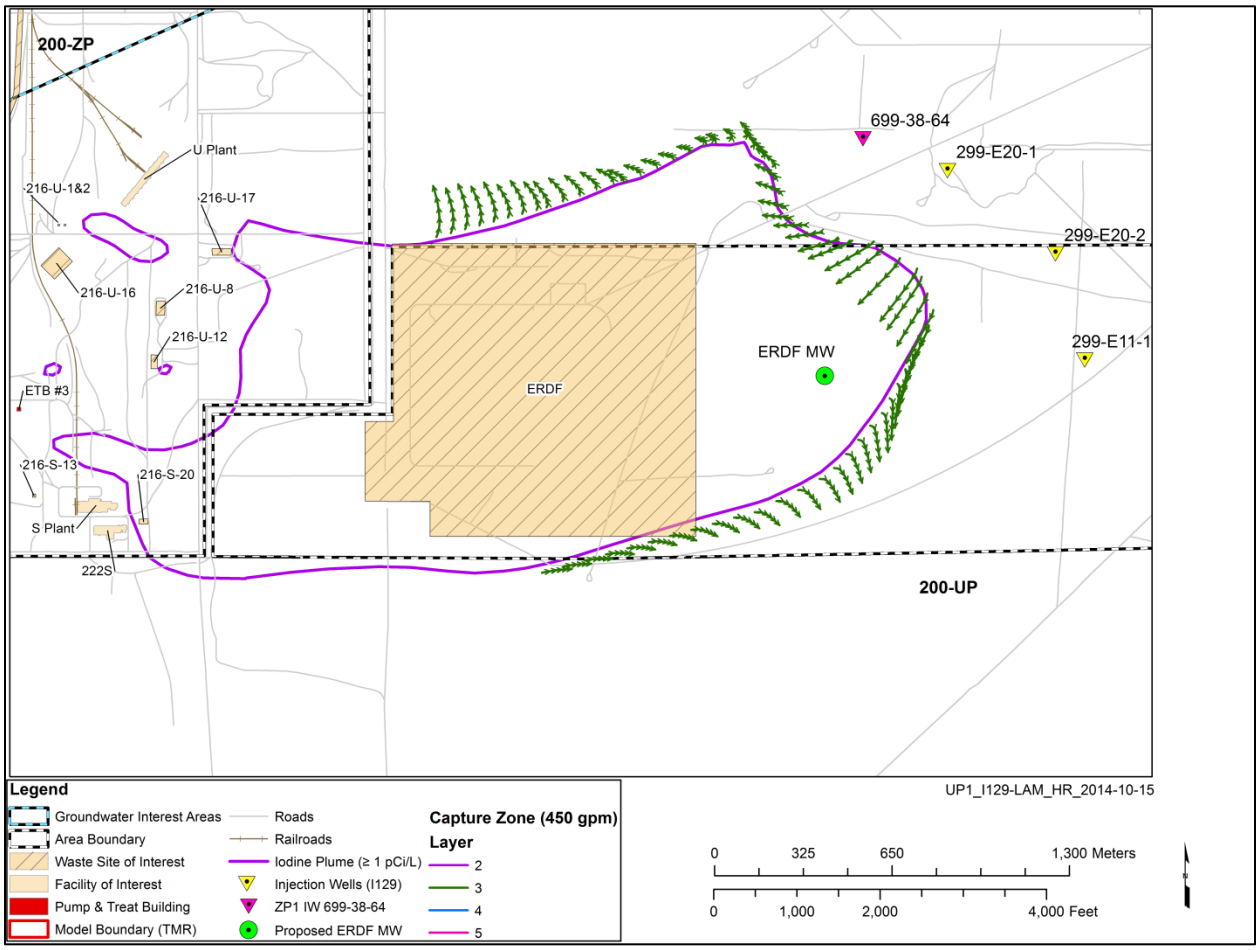

Figure 15. Predicted Hydraulic Capture Zone at 2-Year Intervals for Sensitivity Run 2 (Forward Particle Tracking)

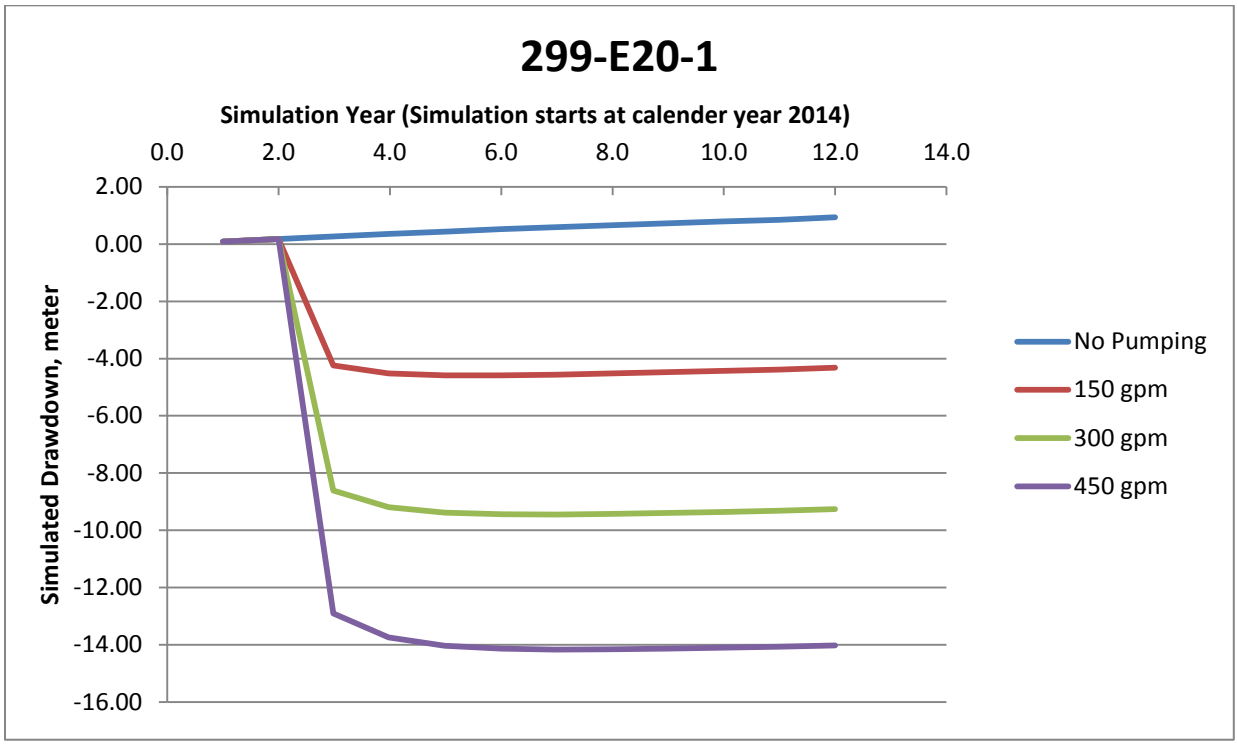

Figure 16. Comparison of Hydraulic Mounding at Well 299-E20-1

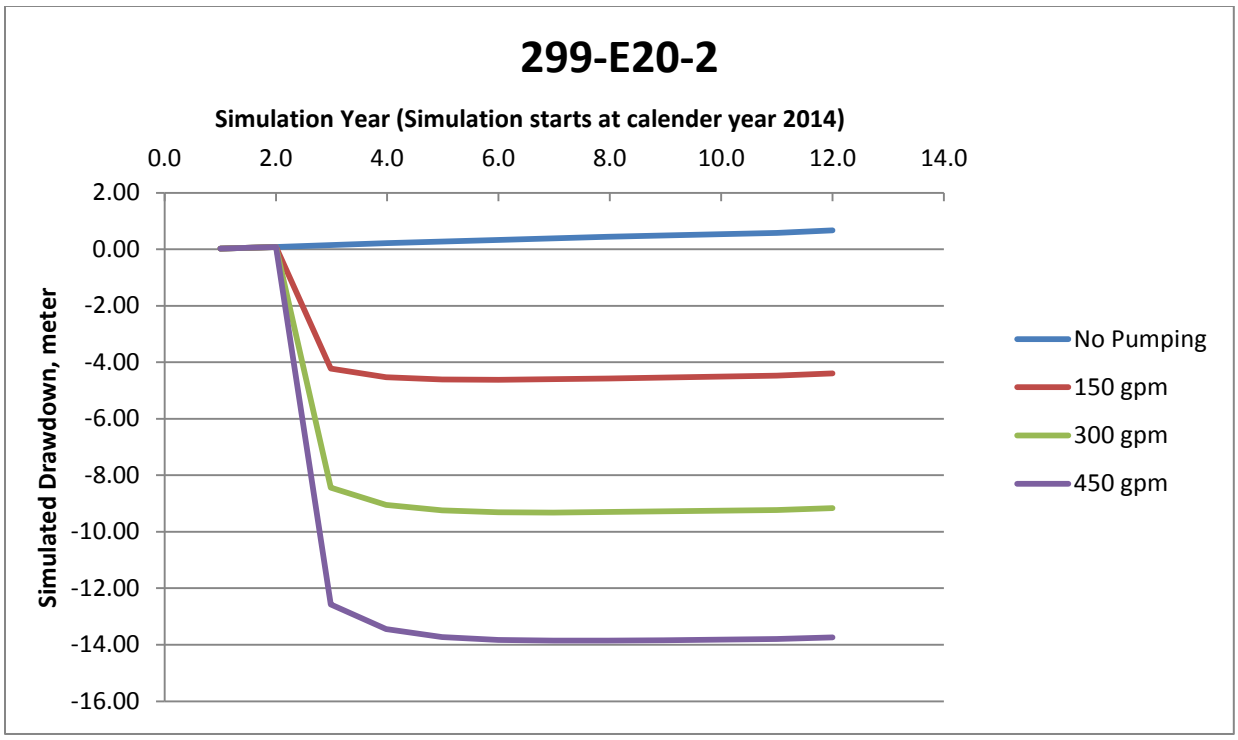

Figure 17. Comparison of Hydraulic Mounding at Well 299-E20-2

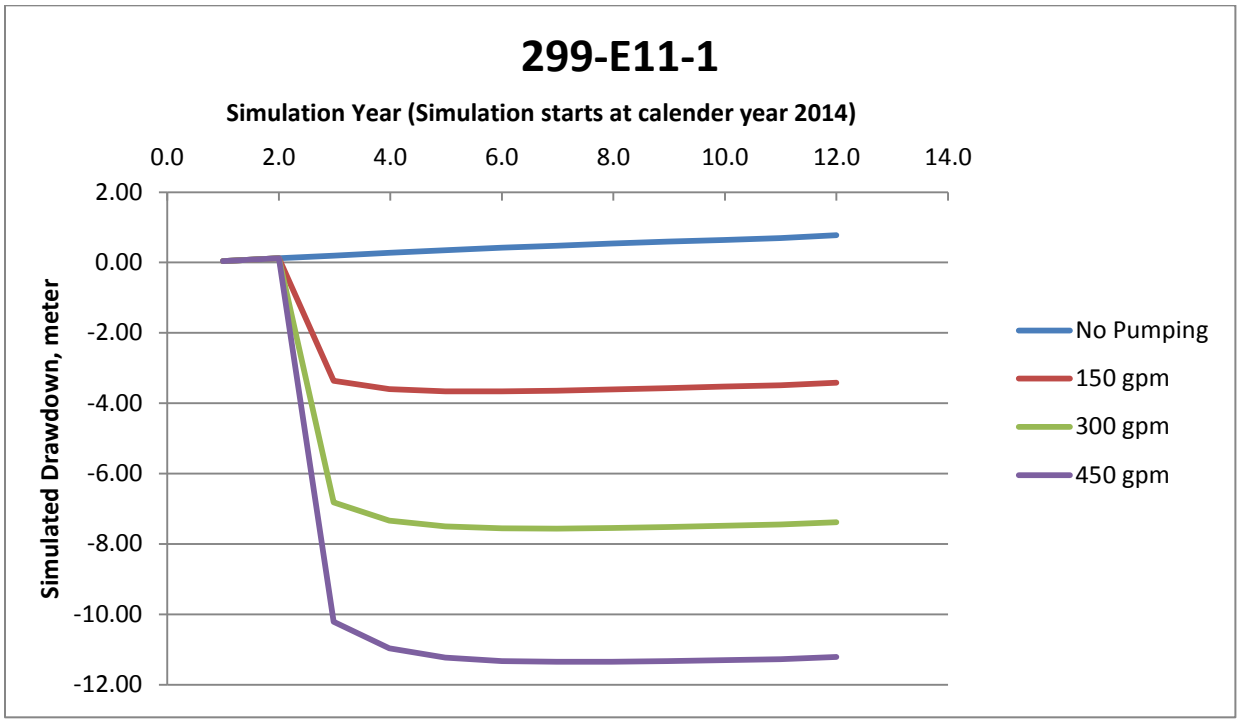

Figure 18. Comparison of Hydraulic Mounding at Well 299-E11-1

8 Results/Conclusions

Four scenarios were simulated: a No Action scenario with no injection of water, a Base Case in which water was injected at 50 gpm per well in each of the three injection well locations, and two sensitivity case scenarios, in which the injection rate was simulated to be 100 gpm per well and 150 gpm per well. The flow simulations were performed for 12 years in which the start of the simulation represents calendar year 2014. The injection at the Iodine-129 injection wells commenced at simulation year three (i.e., at the beginning of calendar year 2016) and continued at a constant rate for rest of simulation periods.

No changes were made to the locations of the injection wells from ECF-200UP1-14-0053, 2014, *Containment System for 200-UP-1 Iodine,* Rev. 0, which were kept at the following coordinates:

- Well 299-E20-1: Easting 570503, Northing 135200;
- Well 299-E20-2: Easting 570899, Northing 134896;
- Well 299-E11-1: Easting 571006, Northing 134507.

All three injection wells are screened across Layer 2 through Layer 5 in the model which resulted in 19.2 m screen for 299-E11-1, 15.6 m screen for 299-E20-2, and 14.4 m screen for 299-E20-1. These intervals correspond to the saturated thickness of the aquifer. It is recommended that the as-built well screened intervals similarly cross the saturated thickness of the aquifer rather than be constructed to match the depths modeled. The height of the groundwater mound above background (i.e No Action) conditions created by injection ranged from 3.67 – 4.62 m for the Base Case (50 gpm per well), 7.56 –

9.45 m for Sensitivity Run 1 (100 gpm per well), and 11.35 – 14.17 m for Sensitivity Run 2 (150 gpm per well).

In the No Action scenario simulation, particles released along the eastern (downgradient) perimeter of the I-129 plume migrate no more than approximately 400 m toward the OU boundary, but do not leave the OU. In the Base Case scenario simulation, in which water is injected at 50 gpm per well, particles released along the eastern perimeter of the plume follow a similar path to those in the No Action scenario, but migrate no more than about 160 m toward the OU boundary, also without leaving the OU. Thus, the Base Case scenario demonstrates hydraulic containment of the plume.

In Sensitivity Runs 1 and 2, in which water is injected at 100 gpm and 150 gpm per well, respectively, the path of particles released along the eastern perimeter of the I-129 plume are reversed on the northeastern portion of that perimeter and are redirected laterally on the northern and southern parts, dispersing the plume beyond the footprint the plume occupies under the No Action scenario.

9 References

CHPRC-00257, 2010, *MODFLOW and Related Codes Functional Requirements Document*, Rev. 1, CH2M-HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00258, 2010, *MODFLOW and Related Codes Software Management Plan*, Rev. 2, CH2M-HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00259, 2012, *MODFLOW and Related Codes Software Test Plan*, Rev. 2, CH2M-HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00260, 2012, *MODFLOW and Related Codes Requirements Traceability Matrix*, Rev. 5, CH2M-HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00261, 2012, *MODFLOW and Related Codes Acceptance Test Report*, Rev. 5, CH2M-HILL Plateau Remediation Company, Richland, Washington.

CP-47631, 2014, *Model Package Report: Central Plateau Groundwater Model Version 6.3.3*, Rev. 2, Central Plateau Groundwater OU RI/FS Projects, CH2M-HILL Plateau Remediation Company, Richland, Washington.

DOE/RL-2011-01, 2011, *Hanford Site Groundwater Monitoring Report for 2010*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2014-32, 2014, *Hanford Site Groundwater Monitoring Report for 2013*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

ECF-200UP1-14-0053, 2014, *Containment System for 200-UO-1 Iodine*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington.

Lindsey, KA, 1995, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*, BHI-00184 Rev 0, Bechtel Hanford, Inc., Richland, Washington.

PRC-PRO-IRM-309, 2013, *Controlled Software Management*, Rev. 4, CH2M-HILL Plateau Remediation Company, Richland, Washington.

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Attachment A

Copy of Software Installation and Checkout Form for MODFLOW & Related Codes Build 0006 Installation to Computer PSC-Lithium (User H Rashid)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

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

Software Subject Matter Expert Instructions:

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

GENERAL INFORMATION:

1. Software Name: MODFLOW and Related Codes Software Version No.: Bld 6

EXECUTABLE INFORMATION:

2. Executable Name (include path):

Following executable files in directory: _____

MD5 Signature (unique ID)	Executable File Name
C3B75ADEBC7F41F15F006A0A3AED2D21	mf2k-chprc06dp.exe
C3141B0D41E084601DC2C8EB746B189F	mf2k-chprc06sp.exe
4F9E3D4A5ECF0360C8247C4279FE25F1	mf2k-mst-chprc06dp.exe
0E38BD210A582EF42CC79145C14F8E69	mf2k-mst-chprc06sp.exe
EE4D6CE61E07E0218F81822CE54499DE	modpath-mst-chprc06dp.exe
F83D1B16B26887A8C9579373D919DF4F	modpath-mst-chprc06sp.exe
D3337D49ED0AAA92E6FE6A6EB027647A	mt3d-mst-chprc06dp.exe
E6A66025170D441389642CC0A7B59749	mt3d-mst-chprc06sp.exe

3. Executable Size (bytes): MD5 signatures listed above uniquely identify executable files

COMPILATION INFORMATION:

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

WC95463; Dell Latitude Laptop

5. Operating System (include version number):

Windows 7 Enterprise Service Pack 1

INSTALLATION AND CHECKOUT INFORMATION:

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

Lenovo Thinkpad W540 (PSC-Lithium)

7. Operating System (include version number):

Windows 8.1 Pro

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

TEST CASE INFORMATION:

9. Directory/Path:

C:\Software test\build-06\test

10. Procedure(s):

CHPRC-00259 Rev 2, MODFLOW and Related Codes Software Test Plan

11. Libraries:

N/A (static linking)

12. Input Files:

MF-ITC-1 and MT-ITC-1 inputs

13. Output Files:

MF-ITC-1 and MT-ITC-1 outputs

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: MODFLOW and Related Codes Software Version No.: Bld 6

14. Test Cases:

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

15. Test Case Results:

All tests returned identical results as base cases

16. Test Performed By: H Rashid

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

18. Disposition (include HISI update): Installation approved, noted in HISI entry. -WEN

Prepared By:

Digitally signed by William E. Nichols
DN: cn=William E. Nichols, o=CHPRC, ou=Risk & Modeling Integration, email=william_e_nichols@chprc.com, c=US
Date: 2014.10.20 06:05:36 -07'00'

19. _____ Software Owner (Signature) | WE Nichols Print | _____ Date

20. Test Personnel:

Sign	Print	Date
S.M. Helalur Rashid	H Rashid	10/17/2014
	N/R (CHPRC-00259 Rev 2)	

Approved By:

21. _____ Software SME (Signature) | _____ Print | _____ Date