ECF-Hanford-14-0053
Revision 0

Containment System for 200-UP-1 Iodine

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company
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Approved for Public Release;
Further Dissemination Unlimited

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INTERA, Inc.

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Environmental Calculation File
Containment System for 200-UP-1 Iodine

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1 Purpose

The purpose of this environmental calculation file (ECF) is to document the design of a containment system for the Iodine (I-129) plume at the 200-UP-1 Groundwater Operable Unit (OU) in the U.S. Department of Energy's (DOE's) Hanford Site (Figure B-1). This calculation involves hydraulic modeling to define hydraulic containment requirements for injection well locations (plan and screened interval) and injection rates to achieve remedial action objectives as described in the in DOE/RL-2013-07, 200-UP-1 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan (RD/RAWP). The results of the calculation documented in the ECF will be used to support the conceptual (30%) design of the hydraulic containment system and function as design input for the subsequent design phases.

Hydraulic containment of the I-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 I-129 plume. Treated water from the 200 West Groundwater Treatment Facility will be pumped to the injection wells. It was initially estimated in the RD/RAWP that three injection wells with a flow rate of 50 gpm per well (150 gpm total) will be needed to hydraulically control the plume.

Groundwater modeling was performed to provide a basis for the design of injection well locations, operating flow rates, and anticipated operating durations using the Central Plateau Groundwater (CPGW) model. The contaminant plume geometry used as an input to the model was based on data available in the 2013 Hanford Site annual groundwater monitoring report (DOE/RL-2014-32, Rev. 0, *Hanford Site Groundwater Monitoring Report for 2013*, Rev. 0).

The system included three injection wells (IWs) to contain the leading edge of the plume. These locations were determined using a heuristic method. I-129 was considered the contaminant of interest (COI).

This ECF was completed in three steps.

1. The heuristic evolution of the containment system for the I-129 plume is discussed. An initial selection of system was evolved to the final selection for containing the plume.
2. The effectiveness of the system in containing the plume was assessed.
3. A sensitivity analysis (SA) was conducted to assess the sensitivity of the final selection to additional conditions at the OU.

2 Methodology

2.1 History

A set of scenarios to remediate the contaminant plumes at the 200-UP-1 OU was presented in ECF-200UP1-10-0374, 2012, *Development and Evaluation of Pumping Scenarios for Iodine, Uranium, Nitrate, Technetium-99, Tritium, and Chromium Plumes in the 200-UP-1 Operable Unit Using Central Plateau Groundwater Model Version 3*, Rev. 2. In all these scenarios, a containment system was included to contain the I-129 plume at the OU. The system included three IWs. Each of these IWs was operated at 50 gpm. However, the system needed to be revised as the plume evolved over time. In this ECF, the containment system is revised. Primarily, the system is assessed using particle tracking method. Secondarily, the system is assessed summarizing the evolution of the plume over time using statistical analysis. A cut-off level (CL) was needed to separate the plume from the clean water practically. The CL was selected as 1% of the

drinking water standard (DWS) (ECF-200UP1-14-0031, 2014, *Optimization of 200-UP-1 Uranium Pump-and-Treat Well Locations with Resultant Contaminant Effluent Concentrations*, Rev. 0).

2.2 Containment System

A heuristic method was used to select the containment system with three IWs (Section 1). Below, the method is discussed (Section 2.3). In summary, the method evolved an initial selection through a heuristic path of improved selections to the final selection. Groundwater modeling was conducted for the evolution (Section 2.4). In this ECF, the heuristic method itself is not documented. Only, the final selection is documented (Table A-1). In addition, the sensitivity of this selection to additional conditions is documented.

2.3 Heuristic Method

Optimization may refer to efforts for improving the effectiveness, efficiency, and speed of a remedy (USEPA 2007). Simulation (groundwater modeling) optimization is a tool to support the effort (ECF-200UP1-14-0031, 2014). The optimization attempts to minimize cost or time in achieving a remedial objective using mathematical models of subsurface processes. One primary approach is groundwater flow (hydraulic) optimization. In general, this approach is applicable to plume containment. Given the approach, simulation optimization is conducted running one combination of well locations and flow rates at a time. The simulation is repeated using a trial-and-error method until a combination meeting the objective acceptably is found. This method is labor intensive. A few combinations may be tried in a given time, leading to less mature termination of the approach. Theoretically, the method could be terminated at a sub-optimal solution. As the optimal solution remains unknown, this sub-optimal solution is tentative. The solutions (from the initial to the sub-optimal) found along the heuristic path are studied to assess the acceptability.

In this ECF, the heuristic method was implemented using the trial-and-error method. The method evolved an initial selection to the final selection along a heuristic path scenario-by-scenario. The first scenario included an initial selection: the containment system taken from 200UP1-10-0374 (2012). The selection included three IWs to contain the plume in 200UP1-10-0374 (2012). The wells were screened given the initial concentration (IC) of the plume (Section 5.2.3). They were screened in Layers 2 through 5. Each well was assigned an injection rate (50 gpm). The rate was distributed to the screens of the well based on the transmissivities of the layers. These wells, together with other wells in the model domain, formed a configuration. Groundwater modeling was conducted to assess containment of the present plume over time given the configuration. The next scenario included a revised configuration. The knowledge from previous scenario was used to relocate the wells for the revised configuration. Groundwater modeling was conducted to assess the revised configuration. Repeating, the knowledge from previous scenarios was used over a series of scenarios. The final scenario included IW locations to contain the present plume acceptably (Table A-1). Given the above discussion and this scenario, the design is considered to be sub-optimal (workable), not optimal.

2.4 Groundwater Modeling

Given a selection of the containment system, groundwater flow was simulated using the CPGW model (CP-47631, 2014, *Model Package Report: Central Plateau Groundwater Model Version 6.3.3*, Rev. 2). The simulation began from an initial head (IH) of the groundwater (Section 5.2.1). The hydraulic head and groundwater flow over time were predicted by the simulation. Given the flow, groundwater particle tracks from IWs and plume boundary were simulated re-using the CPGW model. The simulation began from an initial location (IL) of the particles (Section 5.2.2). The simulation helped to assess the effectiveness of the selection in containing the plume and, hence, mass containment of the COI. Finally, contaminant transport

of the COI was simulated re-using the CPGW model. The simulation began from an IC of the COI (Section 5.2.3). The predictions helped to assess the system effectiveness further.

The CPGW model was used for the groundwater modeling. The model was implemented using the MODFLOW-2000-MST, MODPATH-MST, and MT3DMS-MST software packages for the flow and transport, respectively. A description of the model is provided in CP-47631 (2011) and CP-47631 (2014). The key features are presented in Section 4.

2.5 Summary Statistics

Given the final selection (containment system), groundwater modeling was conducted over a simulation period. The selection was operated over a part of the simulation period. The summary statistics were predicted.

1. 90th percentile concentration (C_{90}) of the plume was predicted (200UP1-14-0031, 2014). The prediction was compared with the DWS.
2. Maximum concentration (C_{max}) of the plume was predicted (200UP1-14-0031, 2014). The prediction was compared with DWS.

C_{90} is sensitive to CL (200UP1-14-0031, 2014). C_{90}, based on the CL (Section 2.1), provided a tentative bound. C_{max} provided the upper bound. Together, these bounds provided a workable knowledge for plume management.

2.6 Sensitivity Analysis

A SA was conducted to assess the sensitivity of the final selection to additional conditions.

3 Assumptions and Limitations

3.1 Assumptions

The assumptions of this ECF are the same as those of the CPGW model (CP-47631, 2014; ECF-200BP5-10-0351, 2010, *200-BP-5 Remedial Investigation Report - Groundwater Fate and Transport Modeling*, Rev. 0; ECF-200UP1-10-0373, 2010, *200-UP-1 Remedial Investigation Report; Groundwater Contaminant Fate and Transport Model*, Rev. 0). The groundwater flow solution of this model is implemented in the MODFLOW-2000 software (USGS, 2000, *MODFLOW-2000, the U.S. Geological Survey Modular Ground-water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*). The groundwater particle tracks are implemented in the MODPATH software (USGS, 1994, *User's Guide for MODPATH/MODPATH-PLOT, Version 3: A Particle Tracking Post-processing Package for MODFLOW, Open-File Report 94-464, the U.S. Geological Survey Finite-difference Ground-water Flow Model*). The contaminant transport solution is implemented in the MT3DMS software (SERDP-99-1, 1999, *MT3DMS: A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Groundwater Systems, Documentation and User's Guide*). Thus, these approved software packages together with certain assumptions are used for groundwater modeling. The key assumptions are discussed in ECF-200UP1-14-0031 (2014).

3.2 Limitations

The limitations of this ECF are those arising from the use of the CPGW model (CP-47631, 2014; ECF-200BP5-10-0351, 2010; ECF-200UP1-10-0373, 2010). The flow model is limited in intent and purpose to

the simulation of saturated flow in the unconsolidated aquifer above the underlying basalts (CP-47631, 2014). The model is suitable for predicting water levels, hydraulic gradients, and groundwater flow directions and rates throughout the Central Plateau. The key limitations are discussed in ECF-200UP1-14-0031 (2014). Similarly, the particle-tracking and transport models are limited to the simulation of particle tracks and contaminant transport, respectively, in the same aquifer (ECF-200BP5-10-0351, 2010; ECF-200UP1-10-0373, 2010). The predictions of the flow model were used to predict particle tracks (advection without sorption) using the MODPATH software and contaminant transport (advection-dispersion-reaction with sorption) using the MT3DMS software. Thus, the model was considered suitable for this analysis: the containment system design.

4 Key Features

4.1 Domain

- Shape (Rectangular, **Figure B-2**)
  - Length (east-west extent): 25.6 km
  - Width (north-south extent): 13.4 km
- Datum
  - Horizontal: Washington State Plane, NAD 1983
  - Vertical: NAVD 1988
- Origin (lower-left corner)
  - Easting: 555650 m
  - Northing: 129850 m
- Coordinate System
  - x-axis: horizontal (east-west) direction
  - y-axis: horizontal (north-south) direction
  - z-axis: vertical direction

4.2 Discretization

- Domain: 134 rows, 256 columns, and 7 layers
  - Each cell: 100 m by 100 m
  - Each layer: non-uniform thickness

4.3 Hydrostratigraphic Units

HSUs are used to define the model domain. They are:

1. Hanford coarse-grained
2. Hanford fine-grained
3. Cold Creek
4. Ringold E
5. Ringold mud
6. Ringold A

The key properties of the HSUs are presented in **Table A-2** and **Figure B-2** to **Figure B-4**. Each HSU is tagged to a distinct hydraulic conductivity (K) value (**Table A-2**). Thus, the delineation of the HSU in Layer 3 may be conceived from the distribution of K in the layer (**Figure B-2**). A discussion of the HSUs is provided in CP-47631 (2014).

4.4 Initial Time

- Beginning of 2014 (**Table A-3**)

5 Inputs

This section specifies the model inputs used for the groundwater modeling. Inputs include boundary conditions, initial conditions, model parameter, and simulation period. Flow inputs were mostly obtained from CP-47631 (2014). Transport inputs were mostly obtained from the CPGW model CP-47631 (2011 and 2013) and ECF-200UP1-14-0019, 2014, *Initial Groundwater Plume Development (Uranium, Technetium-99, Nitrate, and Iodine-129) to Support Fate and Transport Modeling for Remedial Design in the 200-UP-1 Groundwater Operable Unit*.

5.1 Boundary Conditions

5.1.1 Flow Boundary Condition

The key boundary conditions are discussed in ECF-200UP1-14-0031 (2014). They were kept same throughout the simulation period in this analysis.

5.1.2 Transport Boundary Condition

The key boundary condition is discussed in ECF-200UP1-14-0031 (2014). They were kept same throughout the simulation period in this analysis.

5.2 Initial Conditions

5.2.1 Initial Head

The IH is the predicted head for the initial time (the beginning of 2014, Section 4.4) at the beginning of the simulation. This head delineates the hydraulic head and groundwater flow distribution at the said time. The head is set to the predicted head at the end of the historic model simulation (CP-47631, 2014).

5.2.2 Initial Location

The IL is the selected locations for groundwater particle release at a specified time (the beginning of 2016 or 2 years after the initial time, Section 5.2.1). The particles were released at the beginning of the containment system operation. They were tracked till the termination of the operation.

5.2.3 Initial Concentration

The initial condition is the concentration of the COI (I-129) for the initial time (Section 5.2.1). The IC development is presented in ECF-200UP1-14-0019. The development is based on data collected through 2013. The concentration was revised for this ECF, insofar as the concentration (from ECF-200UP1-14-0019) above a CL was selected (**Table A-4**), leading to the plume geometry shown in **Figure B-5**. The vertical extents of the plume are presented in **Table A-4**. The extension is from Layer 2 to Layer 5.

5.3 Model Parameters

5.3.1 Flow Parameter

The hydraulic conductivity (K) for the HSUs is presented in **Table A-2**. The hydraulic conductivity along the x-, y-, and z-axis in Layer 3 is presented in **Figure B-2** (Section 4.1).

5.3.2 Transport Parameter

The bulk density of soil is presented in **Table A-2**. The distribution coefficient, half-life, and decay rate of the COI are presented in **Table A-5**.

5.4 Containment System

The initial time of the CPGW model is set to the beginning of 2014 (Section 4.4). The containment system is expected to become operational in the beginning of 2016. Thereafter, the system is expected to remain operational for 10 years.

5.5 Simulation Period

Given the expectation for the containment system operation (Section 5.4), the simulation period is selected to be 12-year long. The system begins operation after 2 years since the beginning of the period. The system continues operation for 10 years till the end of the period. Given the stress periods in the CPGW model, the simulation period is discretized using five stress periods (**Table A-3**):

1. The first period is 1 year for 2014. This period presents the present condition (PT1).
2. The second period is 1 year for 2015. This period continues the present condition (PT1).
3. The third period is 4 years from 2016 to 2019. This period includes the operation of the containment system (PT2). At the beginning of this period, the system begins operation.
4. The fourth period is 5 years from 2020 to 2024. This period continues the operation of the system (PT2).
5. The fifth period is 1 year from 2025 to 2025. This period continues the operation of the system (PT2).

6 Software Application

Software is used in accordance with PRC-PRO-IRM-309, 2013, *Controlled Software Management*.

6.1 Approved Software

Approved software used is managed under the following software quality assurance documents of CH2M HILL Plateau Remediation Company (CHPRC) consistent with the requirements in PRC-PRO-IRM-309:

- CHPRC-00257, *MODFLOW and Related Codes Functional Requirements Document*
- CHPRC-00258, *MODFLOW and Related Codes Software Management Plan*
- CHPRC-00259, *MODFLOW and Related Codes Software Test Plan*
- CHPRC-00260, *MODFLOW and Related Codes Acceptance Test Report*

- CHPRC-00261, *MODFLOW and Related Codes Requirements Traceability Matrix*

The safety software and support software are distinguished in CHPRC-00259. Safety software predicts reportable results. Support software supports run, visualization, or similar functions.

6.2 Description

Approved software packages were used.

1. **MODFLOW-2000-MST** (USGS, 2000)
    - HISI Entry: #2157
    - Rated: Safety Software (Graded Level C)
    - Function: Simulate groundwater flow under saturated conditions
    - Application: Solve the three-dimensional groundwater flow equation using the finite difference method for both steady state and transient systems in the CPGW model
    - Vendor: U.S. Geological Survey, with modifications by S. S. Papadopoulos and Associates
    - Version: Build 6 with Minimum Saturated Thickness (MST)
    - CHPRC approved executable file: mf2k-mst-chprc06dp.exe (CHPRC Build 6)
2. **MODPATH-2000-MST** (USGS Open-File Report 94-464)
    - Rated: Support Software
    - HISI Entry: N/A (CHPRC-00259 Rev. 2)
    - Function: Particle Tracking
    - Application: Used to provide graphical depictions of three-dimensional flow paths from the groundwater heads and fluxes calculated by MODFLOW
    - Vendor: U.S. Geological Survey, with modifications by S.S. Papadopoulos and Associates
    - Version: Build 6 with MST
    - CHPRC approved executable file: modpath-mst-0006sp.exe (CHPRC Build 6)
3. **MT3DMS-2000-MST** (SERDP-99-1)
    - Rated: Safety Software (Graded Level C)
    - HISI Entry: #2158
    - Function: Simulate contaminant transport under saturated conditions
    - Application: Solves the three-dimensional transient advection dispersion equations using the several different methods.
    - Vendor: U.S. Environmental Protection Agency, with modifications by S. S. Papadopoulos and Associates

- Version: Build 6 with MST
- CHPRC approved executable file: mt3d-mst-chprc06dp.exe (CHPRC Build 6)

4. **Groundwater Vistas™[1]**
   - Rated: Support Software
   - HISI Entry: N/A
   - Function: Provides a graphical user interface to construct, run, and depict MODFLOW and MT3DMS model and results
   - Application: Construct, run, and depict CPGW model
   - Vendor: Environmental Simulations, Inc. (Rumbaugh and Rumbaugh, 2011)
   - Version: 6

6.3 Software Installation and Checkout

Approved Safety Software (MODFLOW and MT3DMS) packages were checked out in accordance with procedures specified in CHPRC-00258. Executable files were obtained from the Software Owner who maintains the configuration-managed copies in MKS Integrity™[2]. Installation tests identified in CHPRC-00259 were performed, and successful installation was confirmed. Software Installation and Checkout Forms were completed and approved. Copies of the Software Installation and Checkout Forms for approved users and installations are provided in Appendix C.

6.4 Statement of Valid Software Application

The software is used consistent with its intended use for the CHPRC. The use is identified in CHPRC-00257. The use is valid.

7 Prediction

7.1 Containment System

A heuristic method was used to select the containment system. Discussed earlier, the method evolved from an initial system of three IWs to the final system of three IWs. During the evolution, the well locations were varied. The injection rates were not varied. In this ECF, the final system is documented only. The system includes the three IW locations presented in **Table A-1** and **Figure B-1**. The system injects 150 gpm, where each well contributes 50 gpm.

7.2 Effectiveness of Containment System

The effectiveness of the containment system in containing the COI (I-129) plume was assessed. Flow simulation with these wells was conducted. Then, particle tracking simulation was conducted. The predicted

[1] Groundwater Vistas™ is a trademark of Environmental Simulations Incorporated (ESI).

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

tracks helped assess the plume containment. Finally, transport simulation of the COI plume was conducted. The predicted concentration of the COI was used to predict C_{90} and C_{max} over time.

8 Result

8.1 Particle Tracking

The containment system, together with the initial plume, is shown in **Figure B-5**. Groundwater particles were released around the IWs of the system. Additional particles were released near the plume boundary (defined by DWS contour). All particles were released in Layer 3 at the beginning of its operation and tracked through the operational period (Section 5.4). Their tracks are shown in **Figure B-6**. Different colors show the tracks through different layers. The system is expected to contain the leading edge of the plume within 200 m approximately over the operational period.

8.2 Contaminant Transport

Given the system operation, the plume after 2 years is shown in **Figure B-7**. The same after 12 years is shown in **Figure B-8**. These figures support the system expectation obtained from particle tracking.

8.3 Summary Statistics

1. C_{90} is presented in **Figure B-9**. C_{90} remains constant approximately throughout the simulation period. The concentration distribution with the plume is expected to remain constant statistically. These figures support the system expectation obtained from particle tracking.

2. C_{max} is presented in **Figure B-10**. C_{max} remains constant approximately throughout the simulation period. The hot-spot of the plume is expected to remain constant approximately. The plume is expected not to disperse significantly. These figures support the system expectation obtained from particle tracking.

8.4 Sensitivity Analysis

1. The sensitivity of the system to increased injection rate was analyzed. The containment system was operated at 2-times and 3-times the base rate (150 gpm). First, the plume after 12 years for the 2-times rate (300 gpm) is shown in **Figure B-11**. A small portion of the leading edge is expected to be pushed back 150 m approximately into the plume. Second, the plume after 12 years for the 3-times rate (450 gpm) is shown in **Figure B-12**. A large portion of edge is expected to be pushed back 300 m approximately into the plume.

2. The sensitivity of the system to revised/future conditions was analyzed (**Figure B-13**). The conditions considered were:

   a. The S-SX wells with rates from CP-47631 (2014) were included in developing the containment system. These rates were revised recently.

   b. The U-Plant wells (ECF-200UP1-14-0031, 2014) were not included in developing the system. The wells were expected to be installed in late 2014. They were expected to operate in the beginning of 2015.

   Thus, the system performance in the presence of the revised S-SX wells and the future U-Plant wells was assessed. The system was re-run in the presence of these wells. The plume after

12 years is shown in **Figure B-14**. Comparing **Figure B-8** and **Figure B-14**, these wells are expected to have insignificant effect on the system performance in containing the leading edge of the plume.

3. The sensitivity of a future monitoring well (MW) for the Environmental Restoration Disposal Facility (ERDF) to the hydraulic containment system was analyzed (**Figure B-15**). This MW was sited down-gradient of ERDF prior to the hydraulic containment system design described here. It is thus necessary to determine what, if any, effect the hydraulic containment system will have on the efficacy of the MW.

   The MW was screened in all the layers of the CPGW model. C_{max} at a time is the maximum of these screen concentrations at the time. The simulation with the system was reconsidered. Another simulation without the system was performed. The sensitivity was analyzed comparing the C_{max} plots with and without the system (**Figure B-16**). The plots are identical visually. They differ insignificantly. The containment system is expected not to impact the C_{max}-based function of the MW.

   In addition, particle tracks around the MW were studied. The backward (reverse) tracks were simulated for three configurations. They were:

   i. No-Pumping : no containment (**Figure B-17**)

   ii. Specified-Pumping : containment at 150 gpm (**Figure B-18**)

   iii. Higher-Pumping : containment at 300 gpm (**Figure B-19**)

   Given a configuration, the particles were released around the MW at the end of Stress Period 5 (2025). Then, they were tracked backward to the beginning of Stress Period 3 (2016). Thus, they were tracked over a 10-year period. The resulting tracks delineated groundwater that the MW is expected to receive over the period. The resulting observations are:

   i. East of ERDF, groundwater flow is towards north-east direction under No-Pumping configuration. The direction changes towards east under Specified-Pumping configuration. Finally, the direction changes towards south-east under Higher-Pumping configuration.

   ii. Over the 10-year period, the MW receives particle from about 300 m (west of it) under No-Pumping configuration. The distance is smaller for the other configurations. Given the east-most side of ERDF is about 650 m west of the MW, no groundwater release from ERDF will be received by the MW over the period.

   iii. The particles were released arranged in a circle with a radius of 45 m for visualization. In reality, the MW radius will be significantly smaller than the circle radius. Thus, only a middle track through the middle of the tracks shown should be associated to the MW in interpreting the results at the scale shown.

   iv. Given Observation (iii), a leak in a fraction of the east side of ERDF may be detected by the MW based on particle track alone. The fraction may be increased based on transport simulation. To increase the fraction appropriately, a series of MWs will be needed.

   v. Given Observation (iv), additional groundwater modeling effort is recommended to design the MW itself or the MW series. The effort may include ERDF boundary properties (and others) in the model given a conceptual failure configuration.

The operation of the containment system affects hydraulic gradients in the vicinity of the MW. As the purpose of the MW is to provide observations of groundwater down-gradient of the ERDF facility, it may be necessary to re-evaluate the location of this well once the hydraulic containment system begins operation.

9 Conclusion

Based on the numerical flow and transport modeling documented above, an optimal configuration of three injection wells was developed to contain the I-129 plume. The well locations are:

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

These results were based on constant injection over a 10-year period. It was assumed that a total injection rate of 150 gpm for all three wells (50 gpm per well), sustained over the said period, would be the base case (minimum necessary). In addition, total injection rates of 300 gpm (100 gpm per well) and 450 gpm (150 gpm per well) were studied as sensitivity cases. Thus, the conclusions reached were:

1. A total injection rate of 150 gpm (50 gpm per well) is expected to provide containment of the leading edge of the I-129 plume (Section 7.1).
2. The containment system is expected to arrest movement of the leading edge of the plume with higher injection rate. Tentatively, an upper limit to the injection rates may be considered to be 300 gpm.
3. An injection rate of 450 gpm was observed to create a local reversal of flow, redirecting the leading edge of the I-129 plume and (possibly) compromising containment of the plume by forcing it around the vicinity of the injection wells rather than holding it in place.
4. Hydraulic gradients in the vicinity of the proposed ERDF monitoring well are altered by operation of the containment system (Section 8.4). Given that, it may be necessary to evaluate the hydrologic conditions brought about by operation of the containment system and re-evaluate the most effective location for this well.

In all particle tracking simulations, particles were released in model layer 3, representing the full saturated thickness of the aquifer. The screened intervals for these wells will be analyzed within the higher resolution local sub-area model documented in this ECF's follow-on report, ECF-200UP1-14-0052, Local-Scale Simulation of Iodine-129 Plume Containment for the Proposed Injection Wells at the 200-UP-1 Operable Unit.

10 Reference

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Appendix A

Tables

Table A-1. Grid Coordinates of I-129 Extraction Wells

Well (Field Name)	Well (Model Name)	Row (#)	Column (#)	Top Layer (#)	Bottom Layer (#)
299-E11-1	IW-1-I	88	154	2	5
299-E20-2	IW-2-I	84	153	2	5
299-E20-1	IW-3-I	81	149	2	5

Table A-2. Hydrogeological Properties (CP-47631, 2014)

CP (Order)	HSU (Name)	PNNL (Name)	K_x (m/day)	K_y (m/day)	K_z (m/day)	ρ_b (kg/L)
1	Hanford coarse-grained	HSU 1	17000	17000	1200	1.93
2	Hanford fine-grained	HSU 1	40	40	5	1.93
3	Cold Creek	HSU 3	400	400	20	1.93
4	Ringold E	HSU 5	5	5	0.5	1.90
5	Ringold mud	HSU 8	0.008	0.008	0.0008	1.90
6	Ringold A	HSU 9	4.8	4.8	0.48	1.90

HSU : Hydrostratigraphic unit
CP : Listing order in Section 4.3
PNNL : HSU number in PNNL-14898 (CP-47631)
K_i : Hydraulic conductivity along i-th direction
x-axis : Horizontal (east-west) direction
y-axis : Horizontal (north-south) direction
z-axis : Vertical direction
ρ_b : Bulk density of soil

Table A-3. Design of Stress Periods

Stress Period (#)	Period Length (yr)	Begin (Year)	End (Year)	Condition (Type)
1	1	2014	2014	PT1
2	1	2015	2015	PT1
3	4	2016	2019	PT2
4	5	2020	2024	PT2
5	1	2025	2025	PT2

PT1 : Pump-and-treat with present condition
PT2 : Pump-and-treat with the selected injection wells (IWs) turned-on

Table A-4. Vertical Extent and Cut-Off Levels for Initial Concentration

Contaminant	VE Top Layer (#)	VE Bottom Layer (#)	CL (pCi/L)
Iodine-129	2	5	0.2

VE : Vertical extent
CL : Cut-off level

Table A-5. Transport Properties (ECF-200BP5-10-0351, 2010)

Contaminant	Longitudinal Dispersivity (m)	Transverse Dispersivity (m)	Vertical Dispersivity (m)	Molecular Diffusion Coefficient (m^2/day)
Iodine-129	3.5	0.7	0	0
	Distribution Coefficient (L/kg)	**Half-Life (yr)**	**Half-Life (day)**	**Decay Rate (1/day)**
	0.1	1.57E+07	5.73E+09	1.21E-10

Distribution coefficient : K_d
Vertical dispersivity : ECF-200UP1-10-0373 (2010)

Table A-6. Cut-Off Levels for Summary Statistics

Contaminant	DWS (pCi/L)	Fraction	CL (pCi/L)
Iodine-129	1	0.01	0.01

DWS : Drinking water standard
CL : Cut-off level

Table A-7. Grid Coordinates of Future Monitoring Well

Well (Field Name)	Well (Model Name)	Row (#)	Column (#)	Top Layer (#)	Bottom Layer (#)
Future MW	MW_new	89	144	1	7

MW: Monitoring well

Appendix B

Figures

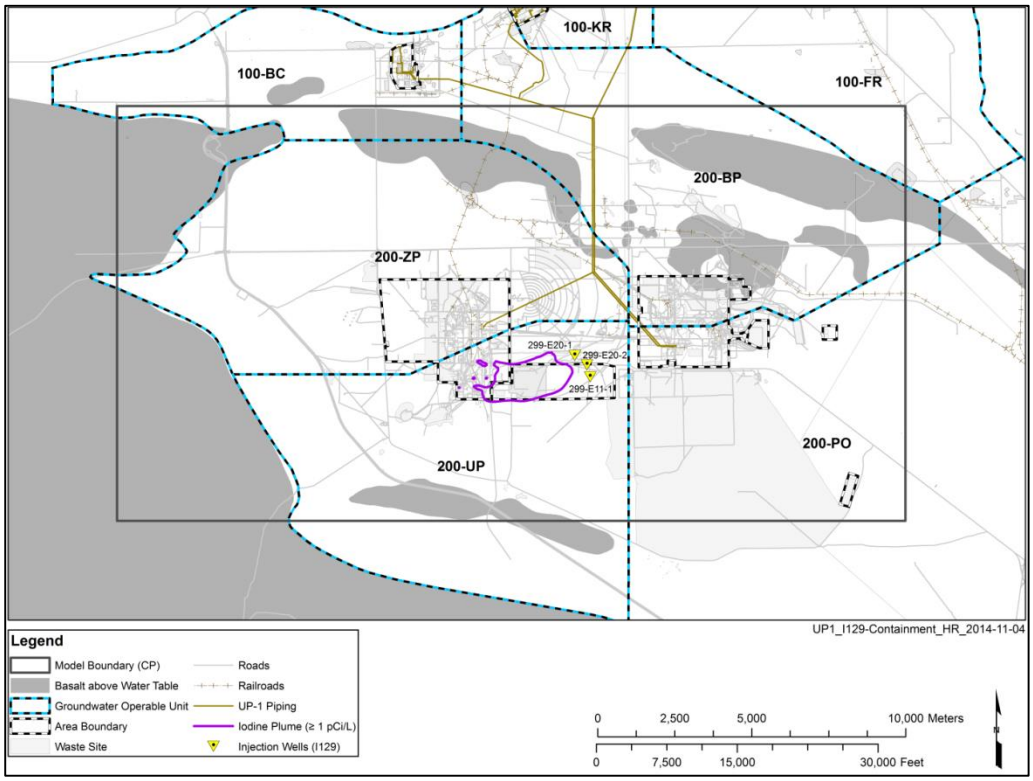

Figure B-1: I-129 Plume (2013) (ECF-200UP1-14-0052, 2014)

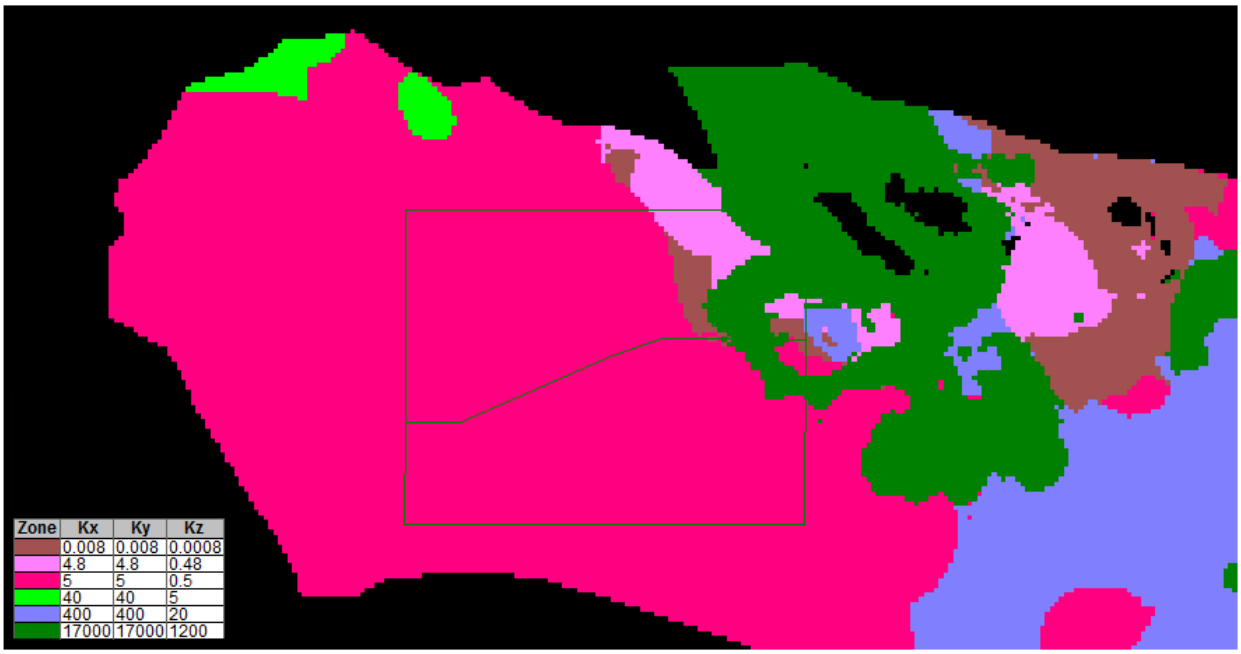

Figure B-2: Hydraulic Conductivity (K: m/day) of Soil in Layer 3 (CP-47631, 2014)

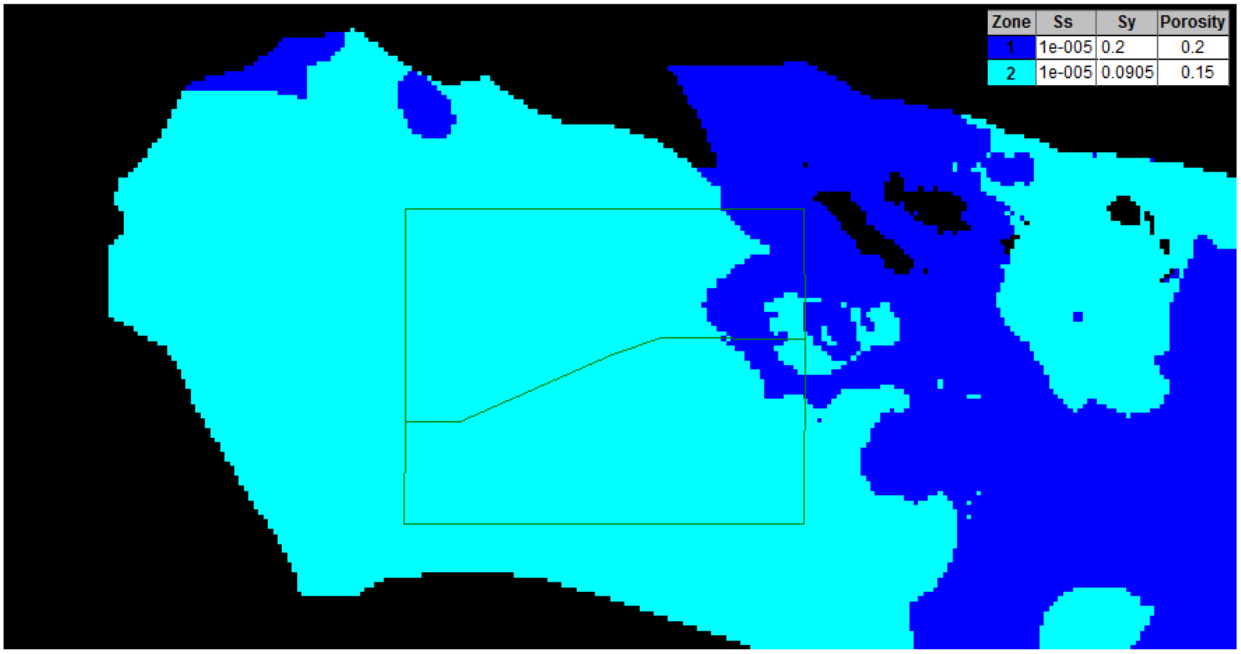

Figure B-3: Specific Storage (S_s: 1/m), Specific yield (S_y: m^3/m^3), and Porosity (m^3/m^3) of Soil in Layer 3 (CP-47631, 2014)

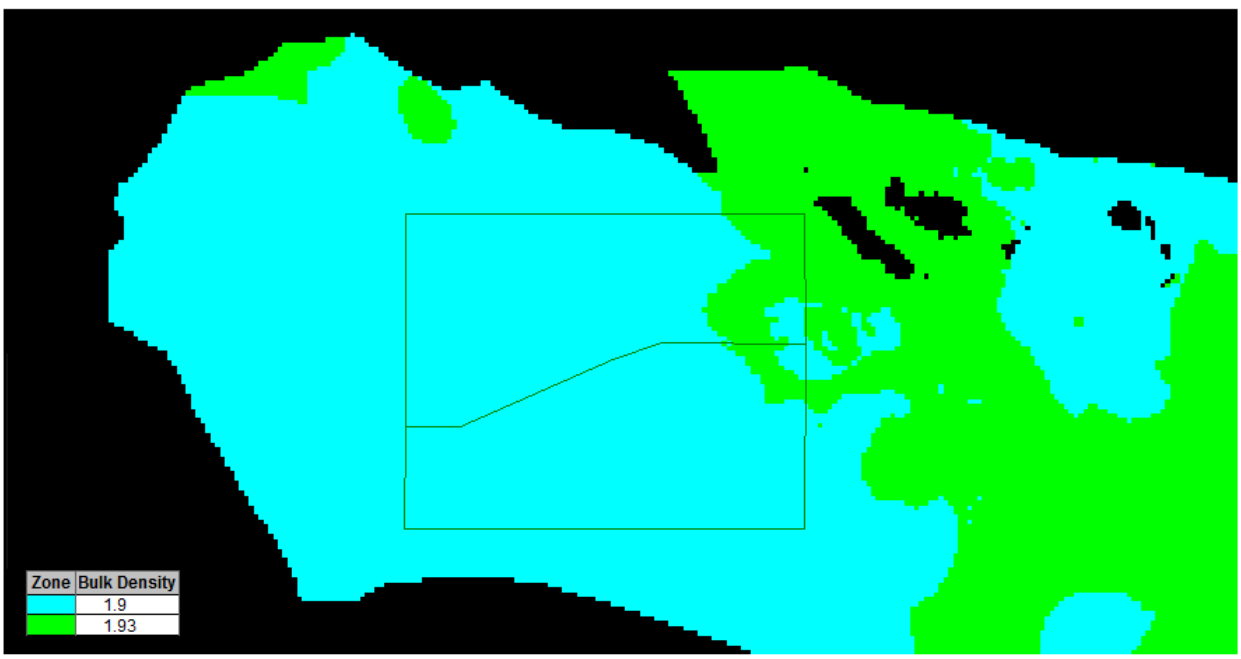

Figure B-4: Bulk Density (kg/L) of Soil in Layer 3 (CP-47631, 2014)

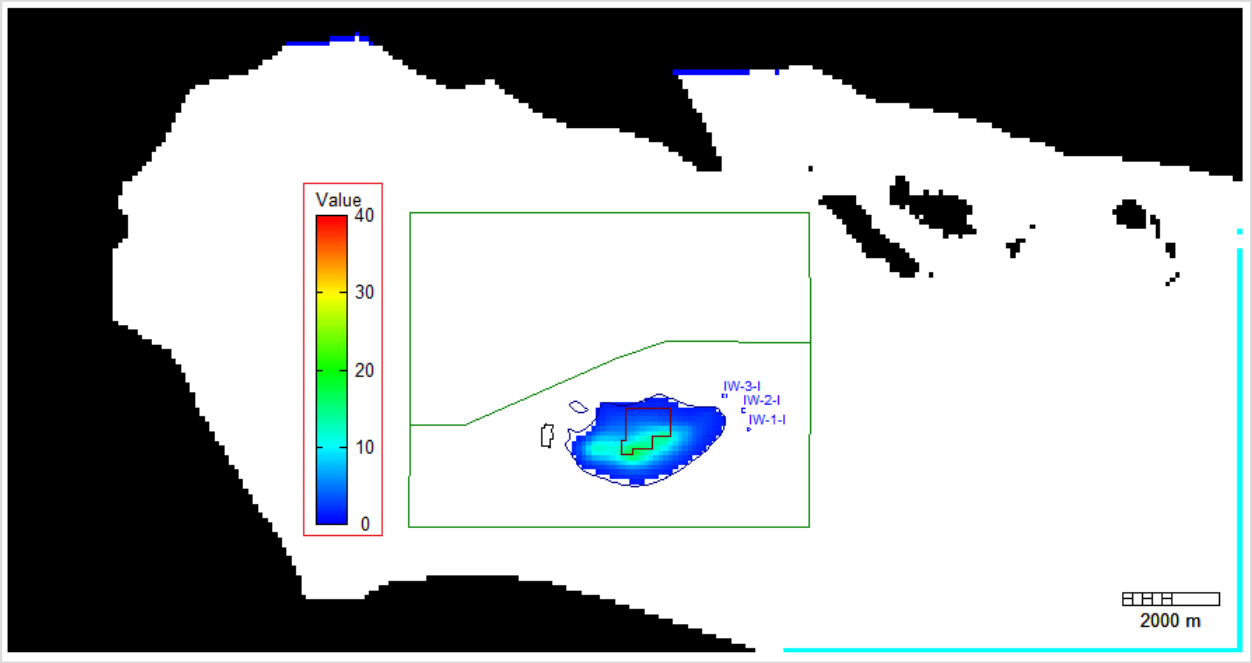

Figure B-5: Initial Concentration (pCi/L) of Iodine-129 in Layer 3 (2013)

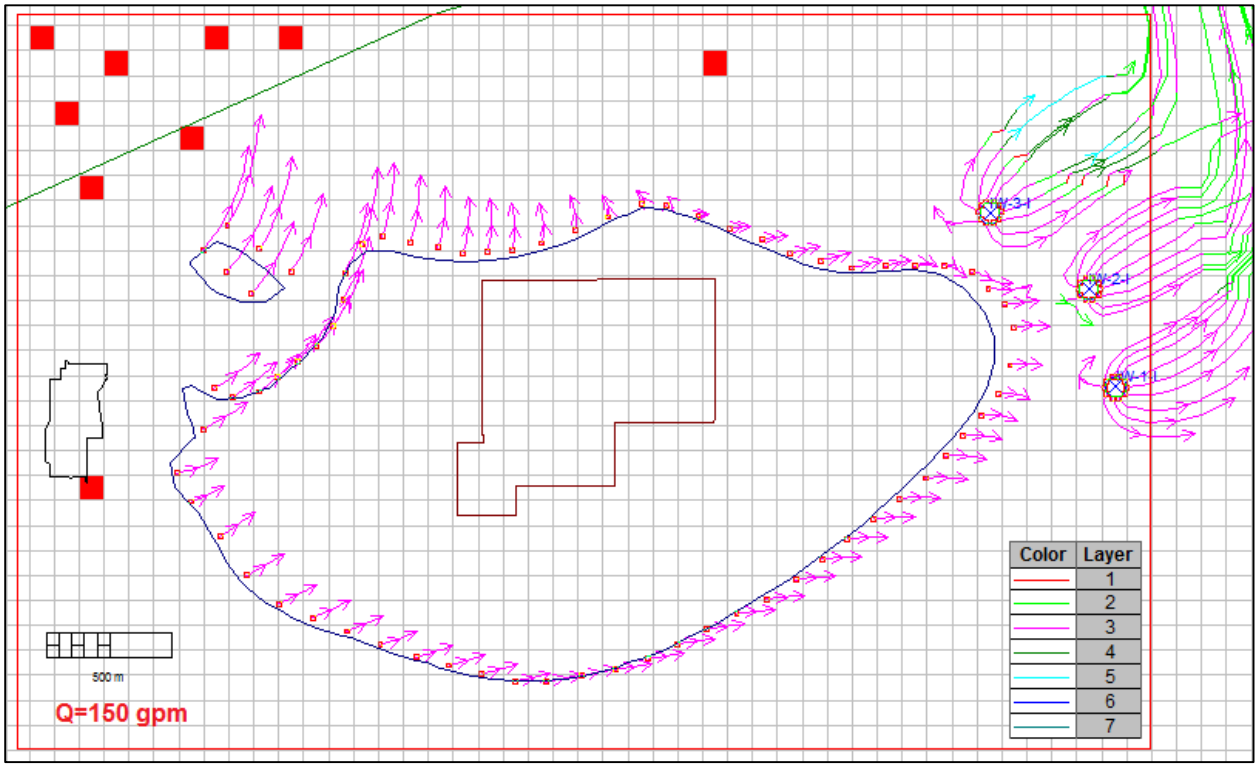

Figure B-6: Particle Track for the Specified Configuration (150 gpm)

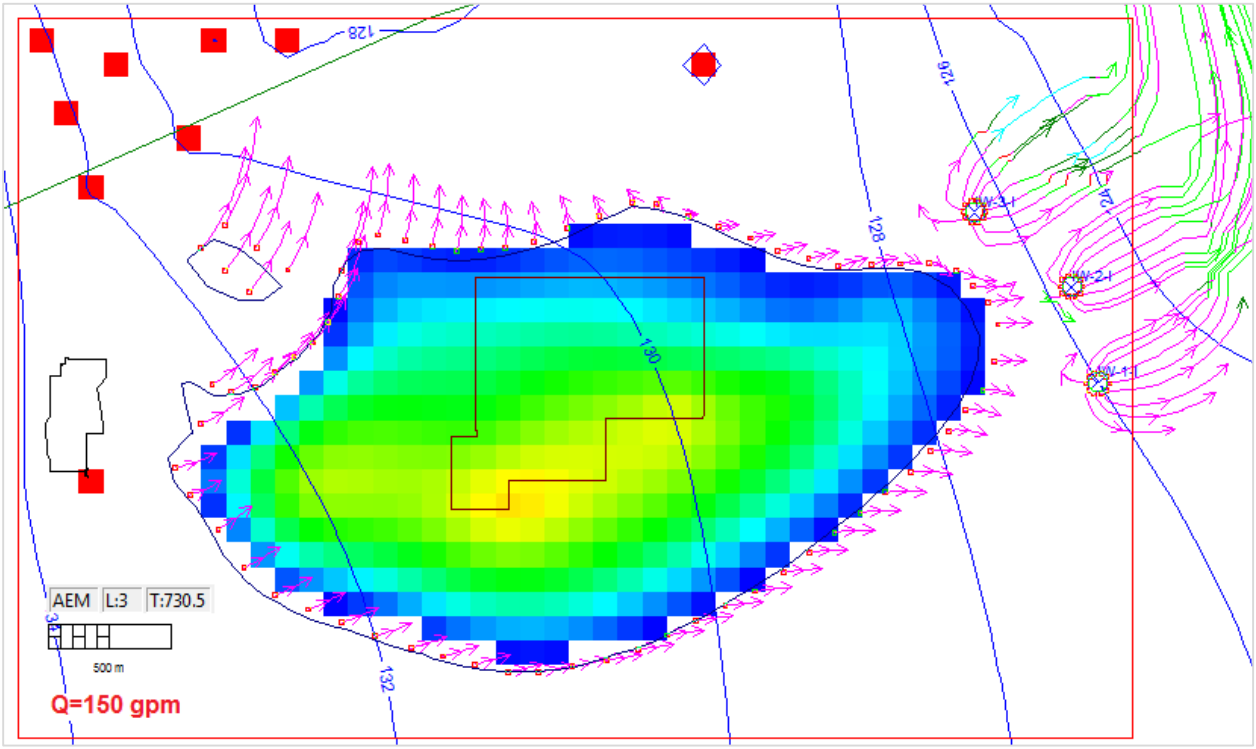

Figure B-7: I-129 Plume after 2 years (150 gpm)

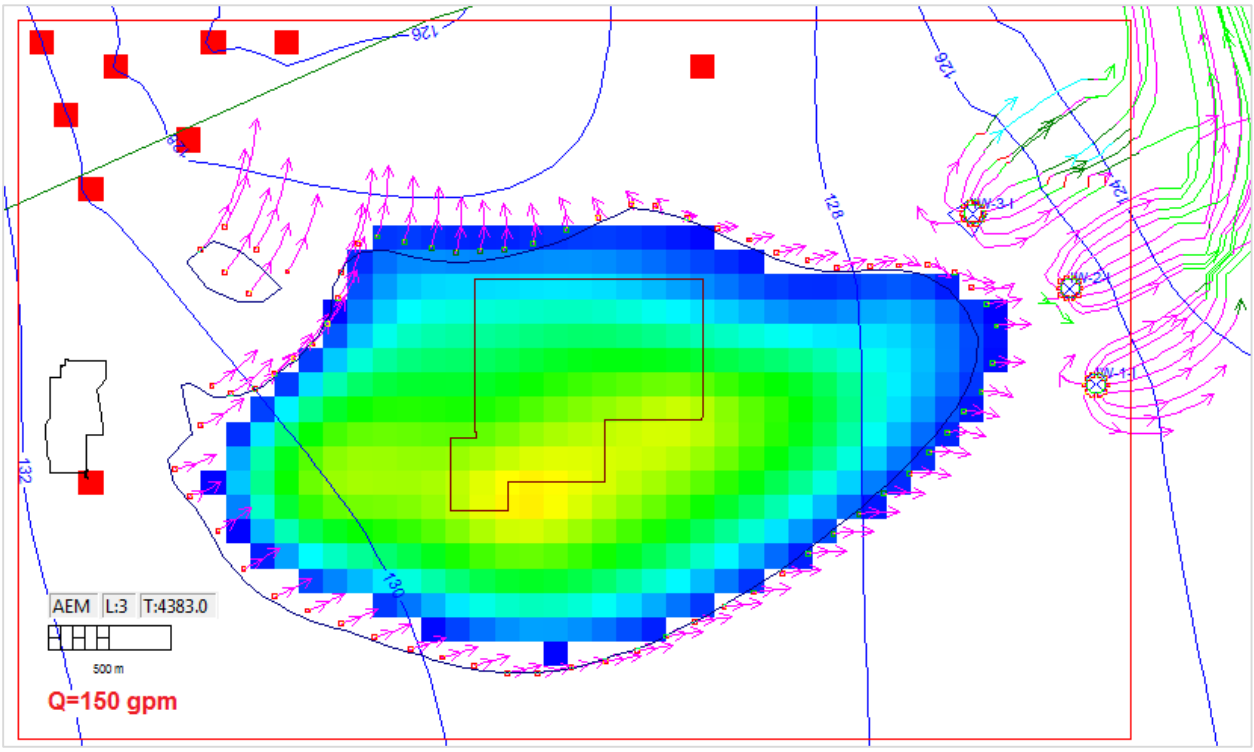

Figure B-8: I-129 Plume after 12 years (150 gpm)

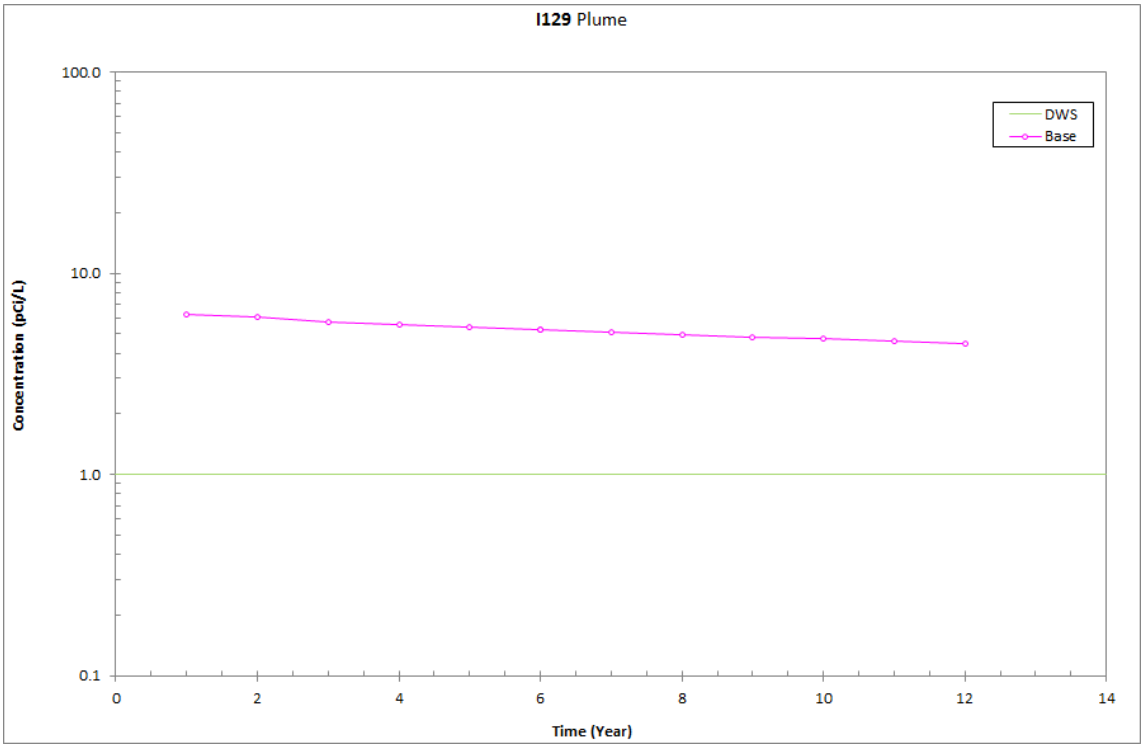

Figure B-9: 90th Percentile Concentration (C_{90}) for Iodine-129 (150 gpm)

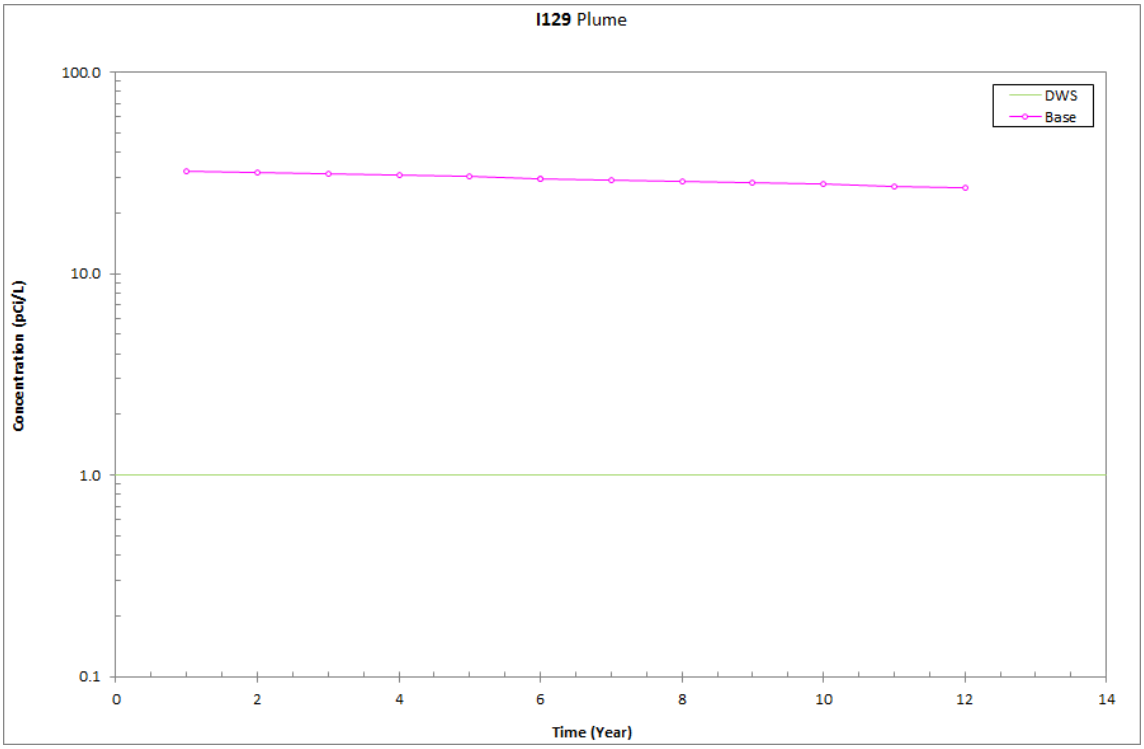

Figure B-10: Maximum Concentration (C_{max}) for Iodine-129 (150 gpm)

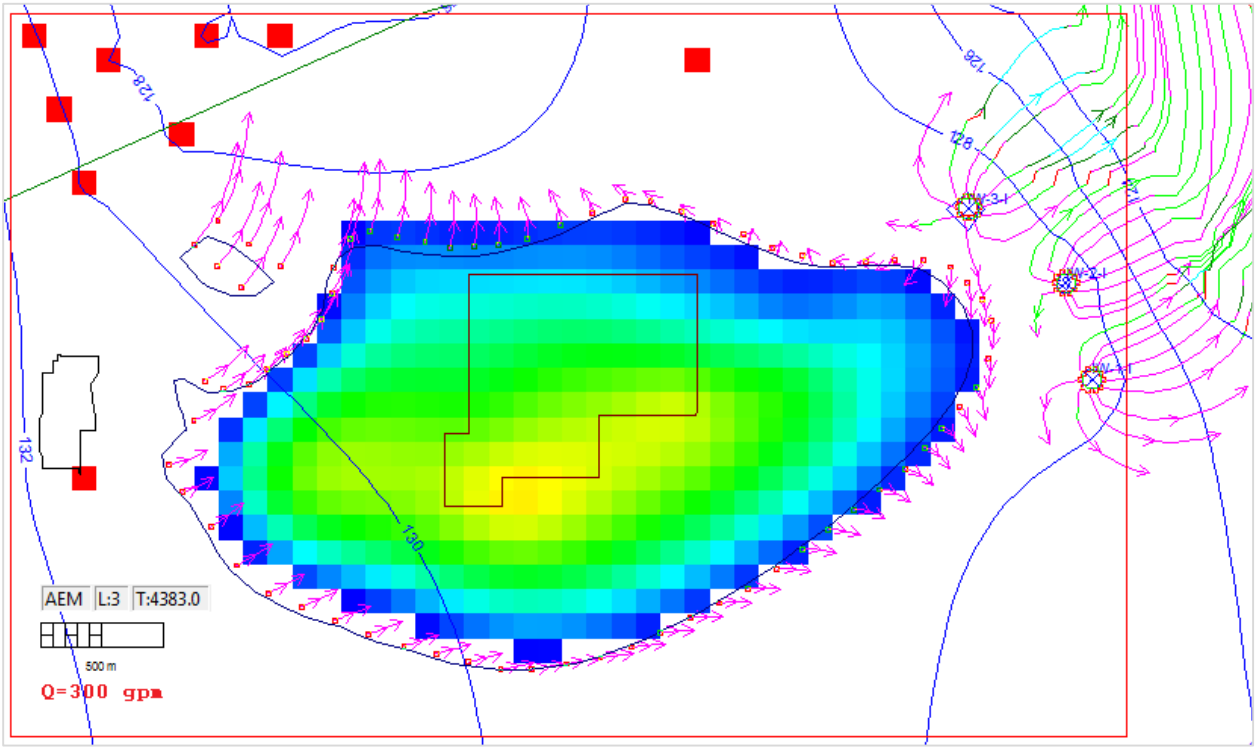

Figure B-11: I-129 Plume after 12 years (300 gpm)

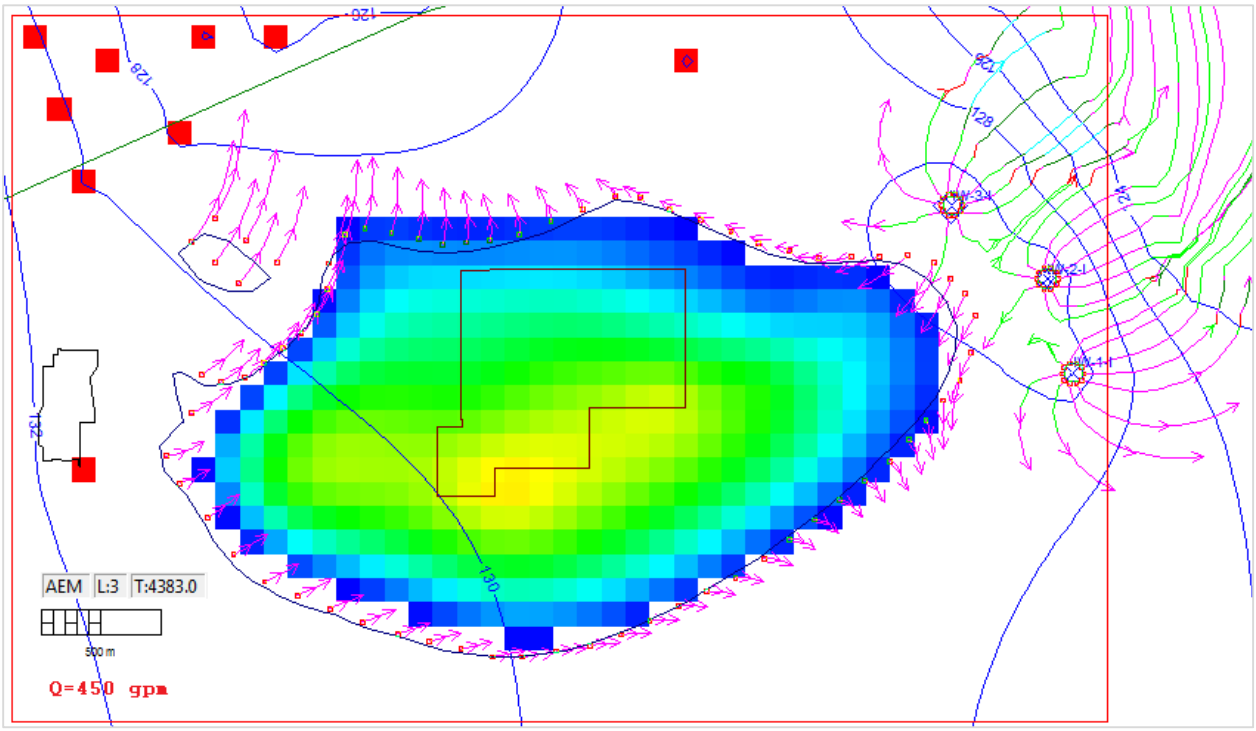

Figure B-12: I-129 Plume after 12 years (450 gpm)

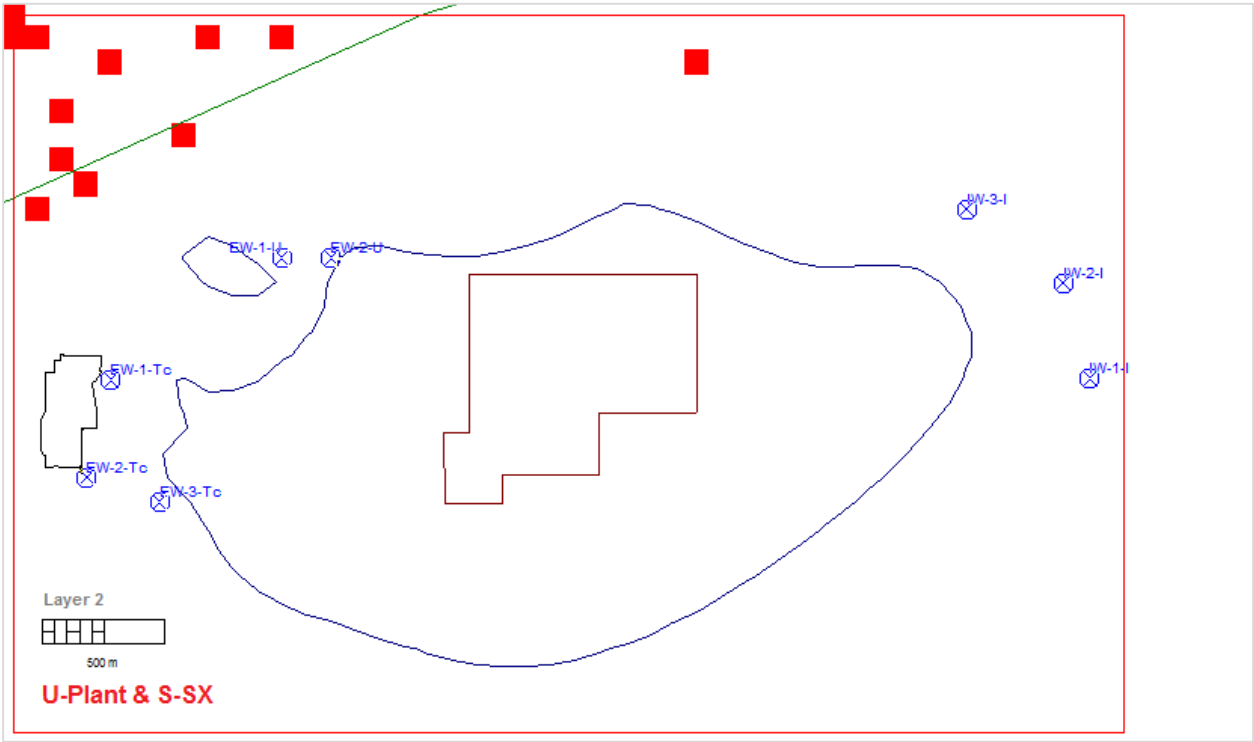

Figure B-13: U-Plant, S-SX, and I-129 Wells

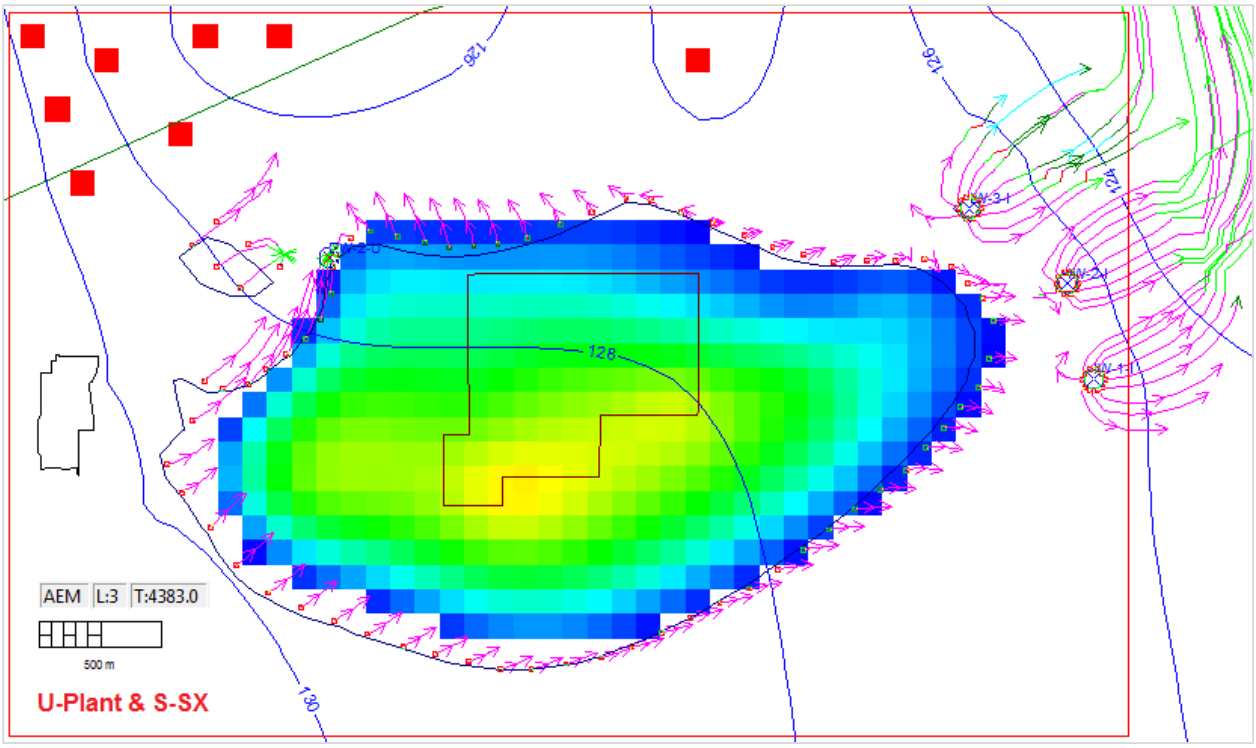

Figure B-14: I-129 Plume after 12 years (300 gpm)

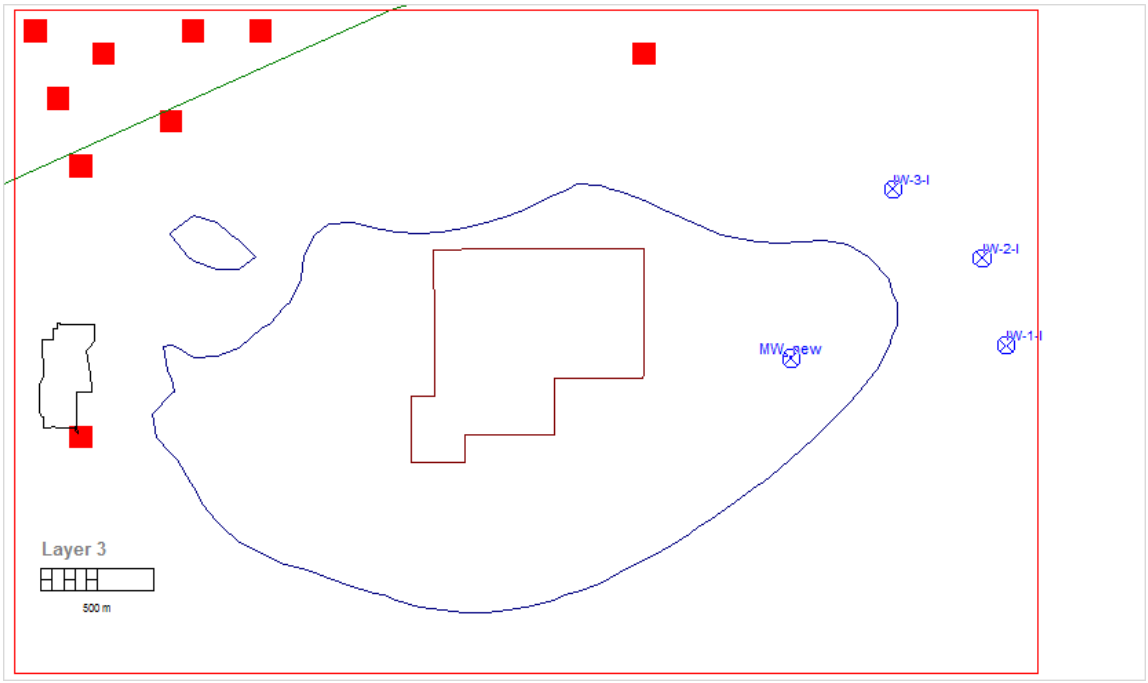

Figure B-15: Future Monitoring Well and I-129 Extraction Wells

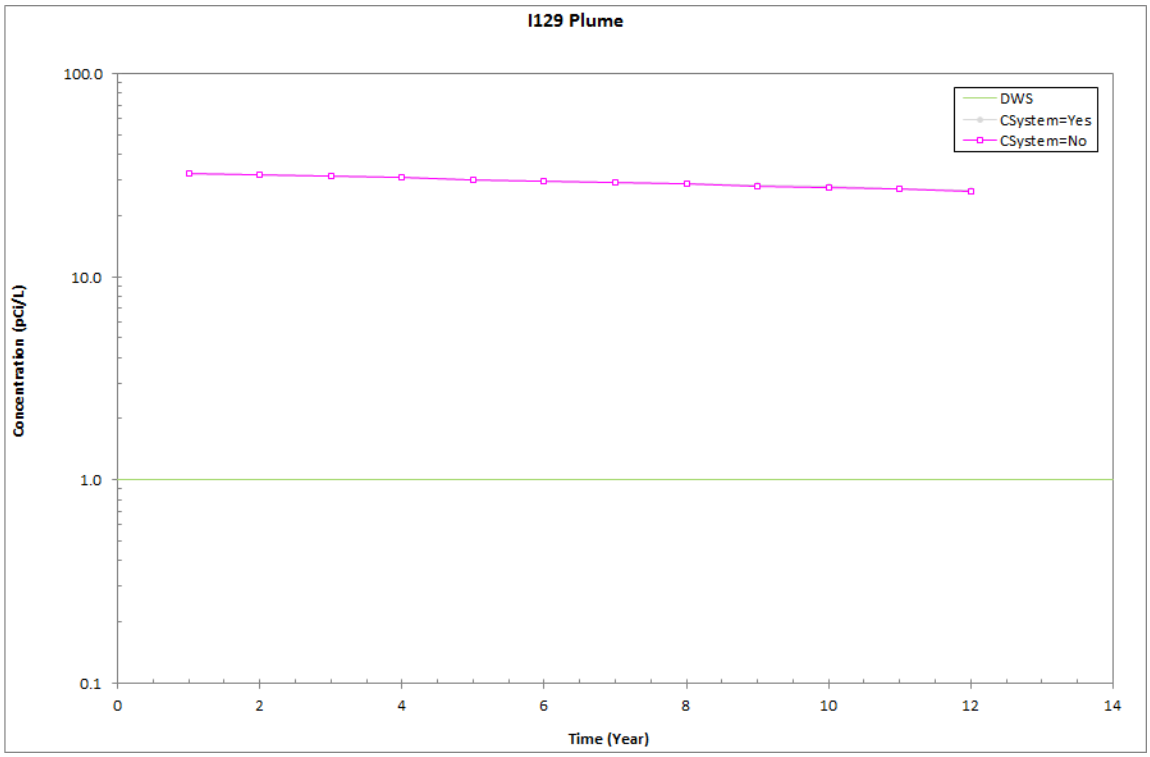

Figure B-16: Maximum Concentration (C_{max}) for Iodine-129 at Future Monitoring Well

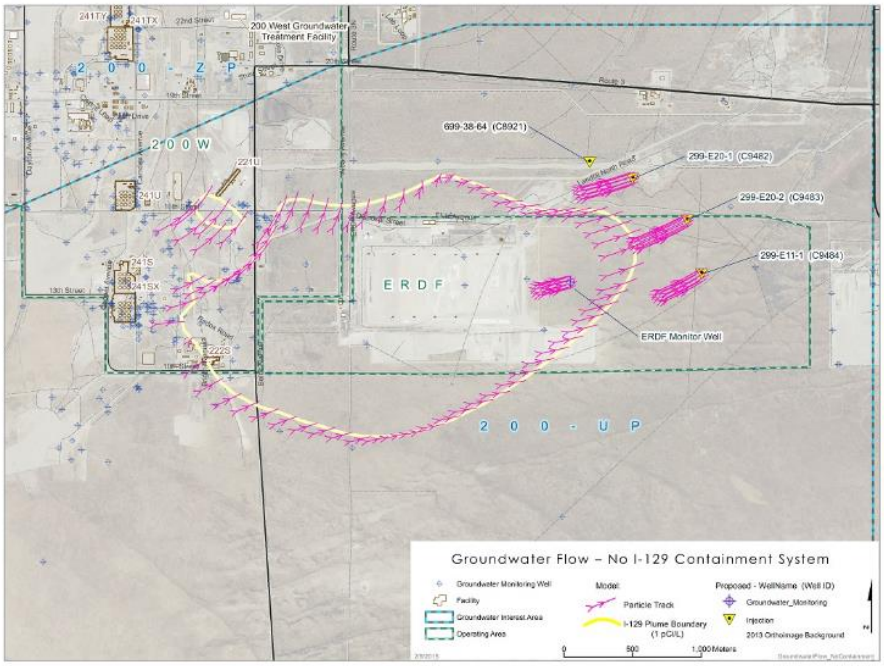

Figure B-17: Particle Track for the No-Pumping Configuration (0 gpm)

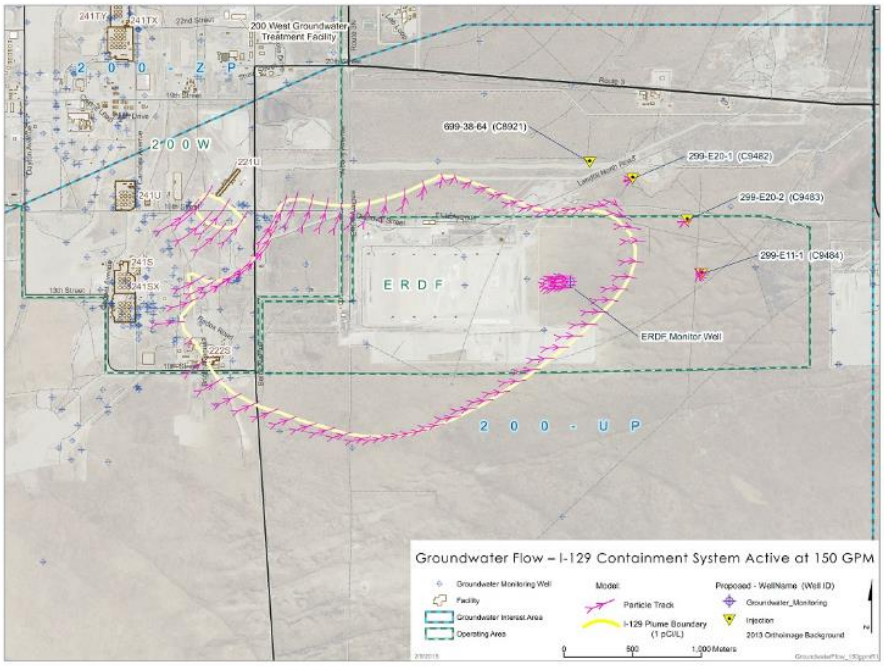

Figure B-18: Particle Track for the Specified-Pumping Configuration (150 gpm)

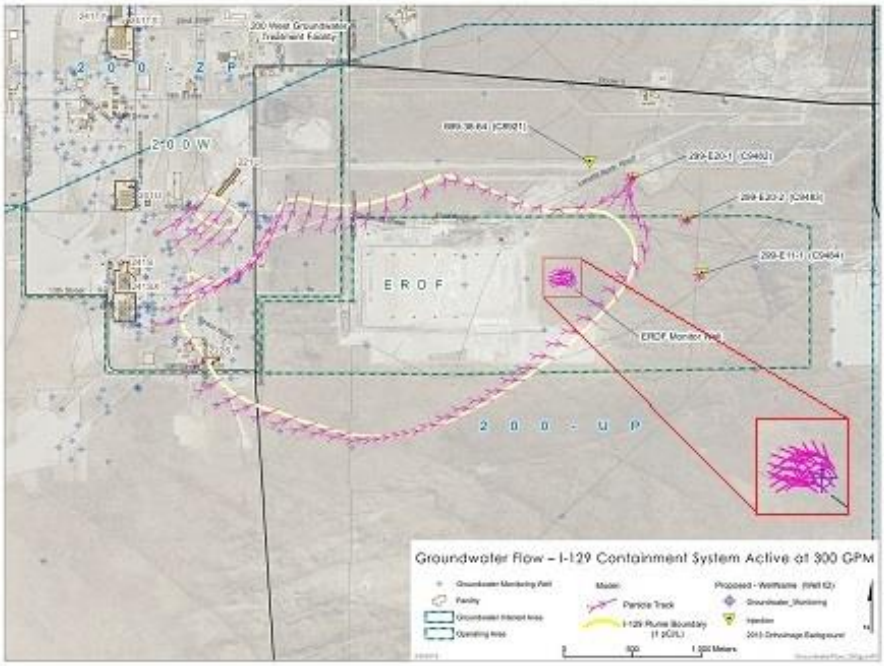

Figure B-19: Particle Track for Higher-Pumping Configuration (300 gpm)

Appendix C

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: 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):

Dell Precision Laptop (INTERA 00590)

7. Operating System (include version number):

Windows 7 Professional Service Pack 1

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

TEST CASE INFORMATION:

9. Directory/Path:

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 return identical result as base cases.

16. Test Performed By: Jahangir Morshed

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

18. Disposition (include HISI update): ADDED TO HISI ENTRIES # 2157 (MODFLOW) + # 2158 (MT3DMS)

Prepared By:

19. [signature]	WE Nichols	20 AUG 2012
Software Owner (Signature)	Print	Date

20. Test Personnel:

J. Morshed	J Morshed	26 · JUL · 12
Sign	Print	Date
Sign	Print	Date
	N/R (CHPRC-00259 Rev 2)	
Sign	Print	Date

Approved By:

21.	N/R (CHPRC-00259 Rev. 2)	
Software SME (Signature)	Print	Date

A-6005-149 (REV 0)