Appendix B
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 2 Results and Recommendations

Final Report

Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 2 Results and Recommendations

Prepared for

The Montana Environmental Trust Group, LLC
Trustee of the Montana Environmental Custodial Trust

May 2015

CH2MHILL®

7 West 6th Avenue Suite 519
Helena, Montana 59601

Acknowledgements

This report was prepared by CH2M HILL with contributing support and technical documents provided by Hydrometrics and NewFields.

Contents

Figures (located at the end of text, following the tables)

Acronyms and Abbreviations

AACE	Association for the Advancement of Cost Engineering
bgs	below ground surface
CMS	Corrective Measures Study
COPC	constituent of potential concern
CSM	conceptual site model
Custodial Trust	Montana Environmental Custodial Trust
ET	evapotranspiration
ICS	Interim Cover System
ICS 1	Interim Cover System 1 completed in November 2014
IM	interim measure
kg	kilogram
MCL	maximum contaminant level
MDEQ	Montana Department of Environmental Quality
mg/L	milligram(s) per liter
PPC	Prickly Pear Creek
PRB	permeable reactive barrier
RCRA	Resource Conservation and Recovery Act
ROM	rough order of magnitude
SPHC	South Plant Hydraulic Control
TPA	Tito Park Area
USEPA	U.S. Environmental Protection Agency
ZVI	zero-valent iron

Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 2 Results and Recommendations

1.0 Introduction

The Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust (Custodial Trust), has performed this Tier II remedy evaluation as part of the Corrective Measures Study (CMS) at the East Helena Facility (Facility). The CMS is being performed pursuant to Paragraph VI.10.c of the First Modification to the 1998 Resource Conservation and Recovery Act (RCRA) Consent Decree (First Modification; Dreher et al., 2012). As stated in the First Modification, the purpose of the CMS is to "*…….identify and evaluate alternatives which will prevent or mitigate the continuing migration of or future release of hazardous waste or hazardous constituents at and/or from the ASARCO Properties, and to restore contaminated media to standards acceptable to EPA.*" The framework for the CMS was presented in the *Draft Former Asarco East Helena Facility Corrective Measures Study Work Plan* (CMS Work Plan) (CH2M HILL, 2014a).

The Custodial Trust is implementing three interrelated, interdependent interim measures (IMs) at the Facility, referred to as "Tier I" alternatives because they form the foundation of final remedy. The primary purpose of the Tier I IMs is to protect human health and the environment by reducing the migration of contaminants to or into groundwater from the operating area of the former ASARCO Smelter (former Smelter site) and eliminating direct contact with contaminants in soils by humans and ecological receptors and stormwater. The IMs were conceptually approved in 2012 by the U.S. Environmental Protection Agency (USEPA) with the approval of the *Former ASARCO East Helena Facility Interim Measures Work Plan–Conceptual Overview of Proposed Interim Measures and Details of 2012 Activities* (CH2M HILL, 2012). The approved IMs are (1) South Plant Hydraulic Control (SPHC), (2) Source Removal, and (3) Evapotranspiration Cover System. In this document, the three approved IMs are called Tier I corrective action measures. Implementation of the Tier I measures started in 2012 and is scheduled for completion in 2016.

1.1 Purpose and Objectives of the Tier II Evaluation

As an integral part of the CMS, the primary purpose of the Tier II evaluation is to assess the potential effects of select source control remedies for the West Selenium and North Plant areas on groundwater quality and estimate associated implementation costs.

The Tier II evaluation process was conducted in two phases. The Phase 1 work was completed in November 2014 (Appendix A) and included a team kickoff meeting, a team workshop to establish and discuss key source areas and potential source control measures, and a screening evaluation of the potential source control measures to evaluate effectiveness, implementability, and cost. Results of the Phase 1 screening evaluation were presented at a meeting with the groundwater technical work group on November 20, 2014. The Phase 2 evaluation was initiated in December 2014 and includes a more detailed costing approach (actual rough order of magnitude [ROM] Class 4 [Association for the Advancement of Cost Engineering [AACE], 2005]) and effectiveness evaluations performed on the alternatives selected from the Phase 1 screening evaluation. This Tier II evaluation summarizes information compiled for both Phase 1 and Phase 2.

The objectives of the Tier II evaluation being performed under the CMS process are as follows:

- Identify, screen, and evaluate source control remedy components to meet the remedy performance standards and remedial action objectives identified in the draft CMS Work Plan.
- Provide technical information to support a comparison of the cost-to-environmental-benefit of the selected source control measures.

- Develop recommendations based on the results of remedy selection and supplemental evaluations for path forward decision making.

1.2 Resource Conservation and Recovery Act Cleanup Framework

The Tier II evaluation was conducted as part of the CMS underway at the Facility in accordance with the elements of the First Modification. The purpose of the CMS is to identify and evaluate cleanup alternatives for releases to soil and groundwater at the Facility.

Pursuant to Paragraph 39 of the First Modification, the final CMS task is to prepare a draft CMS report. This report will document information from the CMS evaluations, including this Tier II evaluation, and present the recommended final remedies with supporting technical justification. Formal public comment on the CMS report will be solicited after USEPA approves the CMS report and has preliminarily selected the final site remedies.

1.3 Related Work

The Tier II evaluation builds on and references the following additional, site-specific documents:

- *Draft Former Asarco East Helena Facility Corrective Measures Study Work Plan* (CMS Work Plan) (CH2M HILL, 2014a). This document addresses the site-specific remedy performance standards.
- *Former Asarco East Helena Facility Interim Measures Work Plan – 2015 and 2016* (IMWP) (CH2M HILL, 2015a). This document provides a summary of completed and approved IMs (to date).
- *2014 Supplemental Contaminant Source Area Investigation at the Former East Helena Smelter* (Hydrometrics, 2014a) (hereinafter the 2014 SAI Report). This document provides a summary of supplemental source area investigation results completed in 2014, in part, to support the Tier II evaluation process.
- *Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations* (CH2M HILL, 2015b). This document (Appendix A) provides the Phase 1 screening evaluation and summary of the recommended alternatives selected for more detailed Tier II evaluation (presented herein).
- *FINAL Fate and Transport Model Design and Calibration, East Helena Site Technical Memorandum* (NewFields, 2015). Update to the groundwater flow model and predictive analysis to support selection and implementation of corrective actions. The model refinements included flow and particle tracking based on data collected before, during, and after PPC bypass, comparison to Upper Lake drawdown test results, and complete evaluations to support potential effectiveness of the IMs and provide a basis for fate and transport model analyses.
- *FINAL Predictive Fate and Transport Modeling, Interim Measures and Tier II Corrective Actions, East Helena Site* (NewFields, 2015). Fate and transport simulations and sensitivity analysis results specific to 2011 conditions, Tier I IM conditions, and Tier II alternatives.

1.4 Document Organization

This document is organized into the following sections:

- Section 1.0 – Provides the document purpose and objectives, RCRA applicability, related work, and document organization.
- Section 2.0 – Describes the site-specific remedy performance standards, completed or approved Tier I IMs, the Phase 1 screening evaluation process for selection of Tier II alternatives, a description of the Tier II alternatives, a delineation of source areas with definition of current and predicted conditions, and a description of balancing criteria and their application to the Tier II evaluation process.

- Section 3.0 – Presents the individual evaluation of alternatives and scoring for the two source areas and respective alternatives.
- Section 4.0 – Presents the comparative evaluation of alternatives and scoring with supporting discussion and rationale.
- Section 5.0 – Presents the recommended alternatives with supplemental discussion and recommendations pertaining to additional verification data needs, alternative benefits, risk factors, cost, implementability, and schedule.
- Section 6.0 – Contains a bibliography of references cited in text.

Supporting information is provided in a series of figures and in three appendixes, as follows:

- Figure 2-1 shows the primary source areas. Figure 2-2 shows the current extent of arsenic and selenium plumes. Figures 2-3 through 2-6 show the West Selenium alternative dimensions in plan view, and Figures 2-7 through 2-9 show the North Plant alternative dimensions in plan view. Figures 2-10 and 2-11 provide charted analyses of West Selenium and North Plant effectiveness and cost. Figures 2-12 through 2-18 show the various plume geometries via model simulations at steady-state conditions after implementation of the potential Tier II alternatives. Figure 5-1 provides an implementation timeline for additional investigations, evaluations, and verification of recommendations of the Tier II process.
- Appendix A contains the Phase 1 screening evaluation technical memorandum titled *Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations* (CH2M HILL, 2015b). Appendix B contains model simulation results and backup documentation generated from the predictive groundwater contaminant fate and transport model. Appendix C contains supporting ROM Class 4 cost details.

2.0 Method of Evaluation

Section 2.0 describes the framework and assumptions that form the basis for the Tier II evaluation process. Included in this section is a summary of the remedy performance standards, Tier I IMs completed or approved to date, baseline conditions assumed for comparison to the potential/estimated benefits from the various alternatives, the preliminary screening process used to select the Tier II alternatives, a description of the Tier II alternatives, and the site-specific application of the RCRA balancing criteria to the Tier II evaluation.

2.1 Remedy Performance Standards

Final remedies under RCRA corrective action should achieve three performance standards: (1) protection of human health and the environment, (2) achievement of media cleanup levels, and (3) remediation of the sources of releases. The CMS Work Plan (CH2M HILL, 2014a) defines the performance standards specific to groundwater at the Facility as follows:

- Return usable groundwater to maximum beneficial uses wherever practicable, within a time that is reasonable considering all property-specific conditions.
- Reduce constituent of potential concern (COPC) concentrations in groundwater within the operating facility boundary such that the Montana Numeric Water Quality Standards (as defined in Circular DEQ-7, and hereafter referred to as DEQ-7; Montana Department of Environmental Quality [MDEQ], 2012) are met at the points of compliance established by USEPA.
- Achieve stability and attenuation of offsite plumes downgradient of the former Smelter site such that COPC concentrations in groundwater can be expected to meet DEQ-7 standards within a reasonable time.
  - The DEQ-7 maximum concentration level (MCL) in groundwater for selenium is 0.05 milligrams per liter (mg/L).

  – The DEQ-7 MCL in groundwater for arsenic is 0.01 mg/L.

- During the timeframe when attainment of the DEQ-7 standards has not been achieved, minimize further migration of the plumes, prevent exposure to the contaminated groundwater, and evaluate further risk reduction approaches. To the extent practicable, control or eliminate other surface water and subsurface sources of contamination to groundwater within control of the Custodial Trust.

The Tier II approach assumes that the alternatives were selected to support progress toward future achievement of these performance standards with the intent to (1) stabilize, control, and (if possible) reduce the plume size, (2) reduce plume contaminant mass, and (3) reduce groundwater concentrations (i.e., decreasing trends) to support future achievement of DEQ-7 standards at the points of compliance to be established by USEPA. The Tier II alternatives may be implemented as IMs and in the short-term are not expected to achieve onsite or offsite DEQ-7 standards. However, the Tier II alternatives have been selected to be consistent and compatible with the anticipated successful final remedy, or to serve as a component of the final remedy, to the extent practicable.

2.2 Tier I Interim Measures

The purpose of this section is to describe the Tier I IMs which provide a comparative condition to evaluate the effectiveness of the predicted Tier II alternatives. The three interrelated, interdependent Tier I IMs were proposed in concept in the IM Work Plan 2012 (CH2M HILL, 2012) and subsequently approved by USEPA on August 28, 2012. Components of these IMs have been completed as described in the IM Work Plan 2013 (CH2M HILL, 2013) and IM Work Plan 2014 (CH2M HILL, 2014b) approved by USEPA on January 21, 2013, and April 28, 2014, respectively. The three IMs are summarized as follows:

- **South Plant Hydraulic Control IM (SPHC IM).** The SPHC IM was implemented to reduce the migration of inorganic contaminants in groundwater by changing the hydrogeologic conditions at the southern end of the former Smelter site.
- **Source Removal IM (Tito Park Area Removal)**. The Tito Park removal actions were implemented to reduce the mass loading of contaminants to groundwater by reducing the volume of soil with high concentrations of inorganic contaminants that are subject to infiltration or flow-through and subsequent leaching to groundwater.
- **Evapotranspiration Cover System IM (ET Cover System IM)**. The ET Cover System IM work is currently in process and is designed to further reduce the potential for inorganic soil contaminants to leach to groundwater by eliminating or substantially reducing the amount of infiltration through contaminated materials and providing a clean surface for runoff. The ET Cover System IM will also eliminate human and ecological receptor exposure to inorganic-contaminated soil.

Implementation of the three Tier I IMs will occur in phases over a number of years. The following is a summary of their implementation since 2012:

- **SPHC IM**: Relocation of utilities and subsequent construction of the Temporary Bypass for Prickly Pear Creek (PPC) (PPC Temporary Bypass) was completed to route PPC flow around Smelter Dam. The groundwater levels in the South Plant area was lowered substantially, enabling removal of the Tito Park Area (TPA) (see discussion under Source Removal IM below), and potentially enabling construction of the new PPC channel (also referred to as PPC Realignment) in mostly dry conditions. Construction of the PPC Temporary Bypass began in July 2013 and was completed in October 2013.
- **Source Removal IM—Tito Park Area Removal**: Removal of contaminated soil, debris, and other material from the TPA, which consists of Tito Park, Upper Ore Storage Area, Acid Plant Sediment Drying Area, and Lower Lake. The soil was removed to eliminate the potential for inundation and erosion from potential PPC flooding, meet the functional needs of the PPC Realignment, support the development of wetland habitat in the PPC floodplain, and reduce the overall footprint of the ET Cover System. The final design of the TPA removal provides flexibility in the construction and ultimate performance of the PPC

Realignment, which is critical to the implementation of the SPHC IM. Removal of contaminated material from the TPA was completed in October 2014.

- **ET Cover System IM**: Phase 1 and Phase 2 demolition of the buildings and infrastructure on the former Smelter site and subsequent construction of the first phase of the ET Cover System (Interim Cover System 1 [ICS 1]) to serve as the foundation layer of the western portion of the ET Cover (referred to as ET Cover West). Phase 1 demolition was completed in July 2013 and Phase 2 demolition was completed in October 2013. The ICS 1 was completed in November 2014.

Final Tier I IM implementation is planned for 2015 and 2016 with the completion of the PPC Realignment and ET cover systems over the Facility area. These IM projects will be completed in two phases to allow for coordination and timing of the work between the two major construction projects, and potential implementation of recommended Tier II alternatives as determined appropriate. Further discussion of the implementation of recommended Tier II alternatives relative to current Tier I IM construction activities is presented in Section 5.0.

The Tier II alternatives have been evaluated as remedial actions to supplement the following activities:

- Completion of the three planned Tier I IMs described above
- Long-term administration of institutional controls, including a Controlled Groundwater Area
- Long-term, monitored natural attenuation

2.3 Phase 1 Screening Evaluation Process to Select Tier II Alternatives

This section summarizes the preliminary, Phase 1 screening Tier II evaluation process followed to identify the seven alternatives recommended for more detailed evaluation. Details of the screening evaluation are provided in Appendix A; a summary of the screening approach, results and rationale, and retained alternatives is provided in the following subsections.

2.3.1 Summary of Screening Approach

The screening evaluation focused on the following primary source areas of concern:

- Affected Area—the term “affected area” refers to impacted groundwater above MCL, encompassing both onsite sources/groundwater plumes and offsite groundwater plumes
- West Selenium
- North Plant
- Former Speiss/Dross Area

The *Source Area Inventory* (Hydrometrics, 2014b) identified West Selenium, North Plant, former Acid Plant Area, Slag Pile, and former Speiss/Dross Area as the primary source areas needing additional evaluation. (The Former Thornock Lake Area and the Monier Flue were also identified as source areas but were not recommended for further assessment because of their location and limited size.) The primary source areas were prioritized based on their process history and observed substantive impacts on existing soil and groundwater conditions on and around the former Smelter site. The screening evaluation identified Affected Area, West Selenium, North Plant, and Former Speiss/Dross areas for Tier II evaluation of potential alternatives. The two other primary areas, the Slag Pile and Former Acid Plant, identified in the Source Area Inventory have been excluded from the Tier II evaluation and deferred to a later date for the reasons described below.

The Slag Pile and Former Acid Plant areas are discussed in the Source Area Inventory in terms of their contribution to the overall site conditions, potential impacts of the planned IMs on their ongoing contribution to site contamination, and accessibility once the planned IMs are in place. An evaluation of these areas will be conducted at a later date, based on the outcome of the Phase 2 evaluations of the primary source areas of concern and groundwater quality conditions observed during ongoing site monitoring events. A summary of the two deferred source areas is presented as follows:

- Former Acid Plant Area—Groundwater quality at the former Acid Plant Area is showing improvement as a result of the lowering of groundwater in the South Plant associated with the SPHC IM. The SPHC IM is predicted to have the biggest impact to reducing groundwater levels and therefore reducing contact with impacted soils for this area of the Facility. In addition, several thousand cubic yards of speiss material was removed just upgradient of the Acid Plant Area as part of source removal actions in the Tito Park area. This removal may also positively impact groundwater quality from this area of the site. Consequently, no additional remedy elements over the IMs may be necessary for this area. Continued monitoring for the time being is recommended to validate the predictions. Upcoming performance groundwater fate and transport modeling of the IMs will help to support this determination.
- Slag Pile—Groundwater quality changes beneath the Slag Pile will be monitored to observe the effects of the SPHC and Source Removal IMs. Any corrective measure found to be necessary to address the Slag Pile as an ongoing source of contamination to groundwater is expected to be implemented as a final corrective measure. Continued groundwater monitoring and upcoming performance modeling of the IMs will help to determine if additional evaluations in this area are appropriate, as well.

A team workshop was held in August 2014 with technical leadership group members from Hydrometrics, NewFields, CH2M HILL, and the Custodial Trust to identify the potential source control remedies and technologies that might be suitable for the selected source areas. As detailed in Appendix A, a Phase 1 screening evaluation was then performed for each primary source area and the potential source control measures/groundwater remedies against the following three broad criteria selected in accordance with USEPA guidance (USEPA, 1994; USEPA, 2000):

1. **Effectiveness**: For the purpose of the Phase 1 screening evaluation, three criteria were combined: (1) long-term effectiveness and permanence, (2) toxicity, mobility, and volume reduction, and (3) short-term effectiveness for the specific corrective action measure proposed. The effectiveness of a corrective action measure was evaluated against arsenic or selenium, the key contaminants of primary concern in groundwater.
2. **Implementability:** For the purpose of the Phase 1 screening evaluation, focused on: (1) construction and operation requirements, (2) technology reliability, (3) suitability to site conditions, and (4) onsite treatment options.
3. **Cost**: For the purpose of the Phase 1 screening evaluation, considered: (1) capital costs that are fixed, one-time expenses incurred as a result of implementation or construction in 2014 dollars, and (2) net present worth (NPW) of capital costs, and annual operations and maintenance and site control costs. The NPW was estimated assuming a fixed 30-year period at 5 percent discount.

The Phase 1 screening costs followed ROM Class 5 guidance (AACE, 2005). The Class 5 costs are estimated at -50 percent to +100 percent accuracy and are intended for concept-level screening with 0 to 2 percent design assumptions. Phase 1 costs rely on professional judgment, analogies from other projects, and published literature for unit costs. The Phase 2 costs (presented in Section 3.0 and Appendix C herein) follow ROM Class 4 guidance (AACE, 2005). The costs are estimated at -30 percent to +50 percent accuracy and are intended for studies that assume 1 to 15 percent design. Phase 2 costs are built from site-specific elements including mobilization, health and safety components, labor hours, equipment/equipment rental, construction/materials, services, site survey, documentation/as-built reports, and demobilization.

2.3.2 Results and Rationale

Results and rationale from the Phase 1 screening process are summarized as follows:

- Affected Area:

  - No additional or specific alternatives were recommended beyond the approved Tier I IMs, administration of the Controlled Groundwater Area Petition (institutional controls), potential Tier II groundwater components (if implemented), and Monitored Natural Attenuation. The various pump and treat alternatives were excluded from Phase 2 evaluations because of the high cost (estimates ranging from $21 to $120 million) and the complexities associated with implementation of the Pump and Treat option at the affected area scale.

- West Selenium (Selenium Plume):
  - **Source Removal**. Retained for reasons of high effectiveness combined with moderate cost.
  - **PRB for Selenium**. Retained for reasons of favorable effectiveness and implementability with low cost.
  - **Slurry Wall Enclosure**. Retained for reasons of favorable effectiveness and implementability with low cost.
  - **Focused Pump and Treat**. Retained for reasons of favorable effectiveness and implementability of semipassive and low-flow volume treatment with potential low cost.
- North Plant (Arsenic Plume):
  - Source Removal**.** Excluded for reasons of moderate effectiveness and implementability, and relatively high cost.
  - **PRB for Arsenic**. Retained for reasons of favorable effectiveness and implementability and considering low cost.
  - **Slurry Wall Enclosure**. Retained for reasons of favorable effectiveness and implementability score with low cost.
  - **In-Situ Injections**. Retained for reasons of moderate effectiveness and implementability combined with low cost.
- Former Speiss/Dross Area:
  - Nothing supplemental beyond the existing slurry wall.

2.3.3 Retained Alternatives

The seven alternatives shown as retained in Section 2.3.2 (bold font above) were recommended for retention as an outcome of the Phase 1 screening process to address the West Selenium and North Plant plumes; details of the screening evaluation are included in Appendix A. Results from the Phase 1 screening evaluation were presented in a meeting on November 20, 2014, attended by the groundwater technical work group, which is made up of representatives from USEPA, MDEQ, the Montana Department of Justice, Lewis and Clark County, the Custodial Trust, Hydrometrics, NewFields, and CH2M HILL. A description of the retained Tier II alternatives is provided in Section 2.4; the technical balancing criteria evaluation is provided in Sections 3 and 4.

2.4 Description of Tier II Alternatives

This section describes the retained Tier II alternatives for West Selenium and North Plant, respectively.

2.4.1 West Selenium Alternatives

Table 2-1 provides a summary of the following four alternatives for West Selenium:

- Alternative 1: Source Removal
- Alternative 2: PRB for Selenium
- Alternative 3: Slurry Wall Enclosure
- Alternative 4: Focused Pump and Treat

Figures 2-3 through 2-6 illustrate the alternative dimensions in plan view, and (when applicable), the conceptual cross-sectional design and key assumptions used in the evaluation. The layouts for the various alternatives are based on the West Selenium plume dimensions described in Section 2.5.

2.4.2 North Plant Alternatives

Table 2-1 provides a summary of the three alternatives for North Plant, which are numbered as follows:

- Alternative 5: PRB for Arsenic
- Alternative 6: Slurry Wall Enclosure
- Alternative 7: Slurry Wall Enclosure with In-situ Injections

Figures 2-7 through 2-9 illustrate the alternative dimensions in plan view, and (when applicable), the conceptual cross-sectional design and key assumptions used in the evaluation. The layouts for the various alternatives are based on the North Plant plume dimensions, as described in Section 2.3.

Note that for North Plant, there are two primary alternatives (PRB designed for Arsenic and Slurry Wall Enclosure [Alternatives 5 and 6, respectively]). Should Alternative 6 be selected for more detailed evaluation and final implementation, it is assumed that injections (Alternative 7) within the slurry wall would be considered following construction of the slurry wall. Accordingly, Alternative 7 is included in the evaluation as a potential follow-on measure. The concept and approach for Alternative 7 originated from team discussions during the August 2014 workshop (discussed in Section 2.3.1). Given this assumption, Alternative 7 is not considered an independent or stand-alone evaluation, but rather linked to the outcome of the evaluation results for Alternative 6.

2.5 Delineation of Source Areas and Definition of Current and Predicted Conditions

This section establishes and defines two overarching components needed with reasonable confidence to support the Tier II evaluation: (1) delineating the primary source area(s) respective of the selenium [West Selenium] and arsenic [North Plant] plumes in groundwater, and (2) establishing and defining the current and predicted Tier I conditions in groundwater as a comparative (baseline) condition to quantify the predicted conditions in groundwater as a result of implementing the Tier II alternatives. A reasonable understanding of both components is important for a qualitative and quantitative assessment of the five balancing criteria. For example, a reasonable delineation of the source area dimensions or plume geometry is needed to evaluate factors such as implementability and cost, whereas the effectiveness and mass/volume reductions for a given alternative are estimated by comparing the current base case (current and Tier I conditions) to some estimated or predicted condition (i.e., predicted Tier II conditions via model simulation). The assumptions for both components are described in Section 2.5.1.

2.5.1 Source Areas and Plume Characteristics

Recent field investigation efforts as described in the 2014 SAI Report (Hydrometrics, 2014a) helped to refine the current understanding of the primary source areas and plume characteristics respective of the West Selenium (selenium plume) and North Plant (arsenic plume). The key assumptions for the Tier II evaluation are provided below.

West Selenium (selenium plume). Figure 2-1 illustrates the West Selenium primary source area and related selenium plume map, as modified from Figure 1-1 of the 2014 SAI Report. For the Tier II evaluation, the primary source area dimensions for selenium in plan view are estimated at approximately 100 feet wide across the plume width (northeast-southwest), and roughly 200 feet along plume axis parallel to groundwater flow (northwest-southeast). This area does not represent 100 percent of the source mass, but given current understanding of site conditions and plume geometry, is believed to represent conservatively about 70 percent of the current mass contributing to the selenium plume in this area. Recent investigation data demonstrate the depth to groundwater in this primary source area at roughly 39 feet below ground surface (bgs), and depth to underlying fine-grained ash/clay layer (defining the base of unconfined aquifer) of approximately 45 feet bgs; thus, the saturated interval in the primary West Selenium area is estimated at 6 feet thick. Based on the 2014 SAI results (via soil sampling and leach test results), the primary source of selenium is believed to be found within the saturated zone in this area and not (leaching) from unsaturated zone sources above.

Figure 2-2 illustrates the selenium plume as depicted in Figure 1-2 in the 2014 SAI Report. Downgradient of the primary source area, the highest selenium concentrations (1- to 3-mg/L concentrations) develop a relatively narrow plume width in plan view at roughly 100 feet. The length of the selenium plume extends north to Lamping Field, with concentrations ranging from 0.1 to 0.5 mg/L, and the farthest extent of the plume (concentrations 0.05 to 0.1 mg/L) reaching several thousand feet beyond/north of Lamping Field.

North Plant (arsenic plume). Figure 2-1 illustrates the North Plant and related arsenic plume map, as depicted in Figure 1-1 of the 2014 SAI Report. For the Tier II evaluation, the dimensions of the primary source area for arsenic in plan view are estimated at roughly 200 feet by 200 feet. This area does not represent 100 percent of the source mass, but given the current understanding of site conditions and of plume geometry, is believed to represent the primary source mass that is contributing to the arsenic plume in this area. Recent investigation data demonstrate the depth to groundwater at roughly 35 feet bgs, and depth to underlying fine-grained ash/clay layer (defining the base of unconfined aquifer) of approximately 48 feet bgs; thus, the saturated interval in the primary North Plant source area is estimated at 13 feet thick.

Figure 2-2 illustrates the arsenic plume as depicted in Figure 1-2 in the 2014 SAI Report. Downgradient of the primary source area the highest arsenic concentrations (20-mg/L concentrations) develop a plume width in plan view at roughly 200 feet. The length of the arsenic plume extends north just past Highway 12 with moderate concentrations (10- to 20-mg/L concentrations), and the farthest downgradient extent just south of Lamping Field and encroaching into East Helena (0.1-mg/L concentrations).

2.5.2 Current and Predicted Conditions

This section uses the steady-state groundwater fate and transport model results (NewFields, 2015) to simulate and compare the groundwater conditions which existed in 2011 (prior to implementation of the Tier I IMs), the predicted model conditions as a result of implementing the approved Tier I IMs (described in Section 2.2), and each of the Tier II alternatives . The “pre-IM” conditions were estimated using the groundwater model and calibrating it to average flow conditions from 2011 and groundwater contaminant plumes for selenium and arsenic (Appendix B) prior to implementation of Tier I IMs. Steady-state predictive simulations were used to evaluate groundwater plume geometry and mass after implementation of each Tier I IMs. An additional simulation was run for each Tier II alternative, including sensitivity runs simulating varying effectiveness, to establish conservative but reasonable estimates of the effectiveness of each alternative on the downgradient groundwater plume. The predictive modeling was used to determine the lateral plume extent, plume volume, and plume mass for each Tier I IM, and then for each Tier II alternative in the Section 3.0 evaluation.

Table 2-2 provides an effectiveness summary for selenium plume alternatives versus current conditions and Tier I IMs; Figure 2-10 shows a graphical representation (bar chart) of the effectiveness to compare current conditions against the predicted Tier I IMs and potential Tier II alternatives. As shown in Table 2-2, the modeled effectiveness of implementing the approved Tier I IMs (PPC realignment with ET cover) predicts a resulting downgradient plume mass of 61 percent remaining of the 2011 plume conditions (for example, assuming the 2011 conditions represent 100 percent of selenium mass the model predicts 61 percent remaining mass after implementation of Tier I IMs). Similarly, the model predicts 58 percent remaining downgradient plume volume of groundwater above the MCL for selenium after implementation of the Tier I IMs. The Section 3 effectiveness evaluations follow the same logic by comparing the differences in mass and volume between the West Selenium Tier II alternatives to the predicted conditions after implementation of the Tier I IMs. Table 2-3 provides an effectiveness summary for arsenic plume alternatives versus current conditions and Tier I IMs; Figure 2-11 shows a graphical representation (bar chart) of the effectiveness to compare current conditions against the predicted Tier I IMs and the potential Tier II alternatives. As shown in Table 2-3, the modeled effectiveness of implementing the approved Tier I IMs (PPC realignment with ET cover) predicts a resulting downgradient plume mass of 26 percent remaining of the 2011 conditions (for example, assuming the 2011 conditions represent 100 percent of arsenic mass the model predicts 26 percent remaining mass after implementation of Tier I IMs). However, the model predicts virtually no reduction (102 percent remaining) in downgradient plume volume of groundwater above the MCL for arsenic after implementation of the Tier I IMs. The Section 3 effectiveness evaluations follow the same logic by comparing the differences in mass and volume between the North Plant Tier II alternatives to the predicted conditions after implementation of the Tier I IMs.

Figures 2-12 through 2-18 show the various plume geometries at steady-state conditions after implementation of the potential Tier II alternatives. Appendix B provides model simulation results and backup documentation generated from the predictive groundwater contaminant fate and transport model (NewFields, 2015).

2.6 Balancing Criteria and Application to Tier II Evaluation Process

As introduced in Section 1.0, under RCRA corrective action, USEPA recommends that decision-makers use seven attributes (called balancing or evaluation criteria) to select the “best” alternative during the evaluation process.

Table 2-4 summarizes the seven balancing criteria along with a site-specific interpretation of how the five technical criteria are applied to the East Helena site conditions and the Tier II evaluation process. The interpretations follow the substantive intent of RCRA balancing criteria definitions while providing site-specific guidance to facilitate a systematic and consistent evaluation process. A scoring system has been developed with + (positive), 0 (neutral), and – (negative) logic and assumptions. As described in the table, one of the five technical criteria (cost) follows a quantitative scoring approach, while the other four technical criteria rely on qualitative and best professional judgment. Each balancing criterion is weighted equally (i.e., either +, 0, or -) and the overall evaluation approach assumes that a given alternative is considered neutral (0) unless there is substantive quantitative (cost) or qualitative (the others) information to shift the score to either a + (positive) or a – (negative). The narrative descriptions focus on instances where an alternative is given a + or – to substantiate these cases. Section 3.0 provides an independent evaluation for each alternative. Section 4.0 provides a comparative evaluation and discussion of alternatives by area, West Selenium and North Plant.

3.0 Individual Evaluation of Alternatives

This section presents an individual evaluation of each alternative for the two primary source areas using the balancing criteria and logic presented in Section 2.6 and described in Table 2-4.

3.1 West Selenium Evaluation of Alternatives

Tables 3-1 through 3-4 present the balancing criteria evaluation and scoring logic for the four West Selenium area alternatives. The balancing criteria evaluation tables (Tables 3-1 through 3-4 for West Selenium) contain four columns consisting of Criteria (first column) Factors/Assumptions (second column), Evaluation (third column), and Score (fourth column). Information in the second column (Factors/Assumptions) follows the approach described in Table 2-4 and is the basis for the technical evaluation and scoring described in the third column (Evaluation). The overall score, either + (plus), 0 (neutral), or – (negative), is then provided in the fourth column and relies on the information in the Evaluation and Factors/Assumptions columns.

Supporting information for long-term effectiveness (which is one of the five balancing criteria) is presented in Figures 2-12 through 2-15, as well as in Appendix B. Estimated costs have been developed for each alternative using ROM Class 4 guidance (AACE, 2005) with expected accuracy of -30 to +50 percent. Costs reflect both capital and long-term O&M (if applicable) assuming a 30-year period net present worth at 5 percent rate of return (unless specified otherwise). The total cost reflects capital and long-term O&M (if applicable). Costs are based on conceptual designs and are not considered final designs; if an alternative is selected, a final design will be developed before implementation. Supporting ROM Class 4 costing details as summarized in Tables 3-1 through 3-4 are provided in Appendix C.

The independent evaluation for the West Selenium alternatives shown in Tables 3-1 through 3-4 is summarized as follows:

- **Alternative 1**: Source Removal
  - **Long-term Effectiveness and Permanence**. Overall score is + (positive) given that (1) remaining source mass is limited or moderate (or substantively reduced from IM baseline conditions), (2) the action does not require long-term maintenance, (3) there is a limited or minimized need for institutional controls, and (4) there is reasonable long-term reliability of engineering controls and protectiveness from residual source via ET cover system (i.e., ET cover provides barrier from human health contact, and low permeability to reduce infiltration and leaching to groundwater).
  - **Reduction of Toxicity, Mobility, or Volume through Treatment**. Score is + (positive) considering the removal of an assumed 70 percent of saturated zone source and placement within unsaturated zone beneath the ET cover.
  - **Short-term Effectiveness**. Score is 0 (neutral) considering potential risks to workers during construction, moderate short-term increases/releases of contaminants to groundwater related to source removal actions, and moderate timeframe to design, construct, and implement.
  - **Implementability**. Although the administrative elements and availability of services is considered + (positive), the alternative relies largely on construction elements, including deep excavation techniques with deep shoring elements (to support an approximate 50-foot-deep excavation adjacent to the former Ore Storage Building) and dewatering (which will require significant coordination with the existing high-density sludge (HDS) treatment plant for treatment of selenium-contaminated groundwater). As such, the overall score for implementability is considered 'neutral' and is scored a 0.
  - **Cost**. Costs are 'moderate' based on the Tier II cost logic and score 0 (neutral).
- **Alternative 2**: PRB to treat selenium
  - **Long-term Effectiveness and Permanence**. Score is 0 (neutral) considering this alternative would provide long-term effectiveness but not permanence, given that it requires performance evaluation to verify design and effectiveness, and long-term operations and maintenance to replace spent treatment media. In addition, there is limited full-scale/long-term research on passive PRB for selenium performance.
  - **Reduction of Toxicity, Mobility, or Volume through Treatment**. Score is 0 (neutral) considering limited, site-specific, or long-term industry research and/or published data on dissolved phase capture, and also considering the removal/handling/management of residuals (spent media) every 10 to 15 years.
  - **Short-term Effectiveness**. Score is + (positive) considering the limited risks to human health and the environment and relatively short duration to construct.
  - **Implementability**. Considering uncertainty in technology design with respect to long-term full-scale application lends to a 0 (neutral) score.
  - **Cost**. Costs are 'moderate' based on the Tier II cost logic and score 0 (neutral).
- **Alternative 3**: Slurry Wall Enclosure
  - **Long-term Effectiveness and Permanence**. Although a slurry wall is an engineered feature in the subsurface, if installed properly across the saturated zone into ash/clay layer with an effective low

permeability (at or less than $1x10^{-6}$ cm/sec), the slurry wall is considered an equivalent geologic feature and thus permanent. Groundwater concentrations within the wall are expected to remain high; however, the modeling simulations over a 50-year period support that the alternative provides a stable and permanent influence in areas downgradient of the slurry wall. Based on the groundwater chemistry for the West Selenium area, the groundwater quality will not adversely degrade or influence the permeability of the wall over time. In light of these factors, this alternative scores + (positive).

- **Reduction of Toxicity, Mobility, or Volume through Treatment**. Contaminant mass flux to groundwater outside the slurry wall enclosure is predicted to be greatly reduced as the slurry wall will encompass and control a larger contaminant mass volume when compared to source removal. However, the groundwater within the slurry wall enclosure is expected to remain at a high concentration over the long-term. Considering that elevated concentrations remain within the slurry wall enclosure over the long-term lends to a score of 0 (neutral).
- **Short-term Effectiveness**. Score is + (positive) considering the limited risks to human health and the environment and relatively short duration to construct.
- **Implementability**. Score is + (positive) considering limited administrative/agency approvals are needed, relatively simple or basic design of construction elements, and lack of long-term operations/maintenance.
- **Cost**. Costs are 'low' based on the Tier II cost logic and score + (positive).

- **Alternative 4**: Pump and Treat
  - **Long-term Effectiveness and Permanence**. Although this alternative scores favorably for long-term effectiveness, the overall score is 0 (neutral) because the permanence depends on an active/functional extraction system, conveyance system, treatment system, substantive operations/maintenance, and residuals (spent media) removal/handling/management.
  - **Reduction of Toxicity, Mobility, or Volume through Treatment**. Score is 0 (neutral) considering the source remains in place, only extracted groundwater is treated, and spent media results in generation of treatment residuals.
  - **Short-term Effectiveness**. Score is + (positive) considering the limited risks to human health and the environment and moderate duration to construct.
  - **Implementability**. Score is – (negative) considering the need for effluent discharge to surface water, complexity of winterization elements and cold weather operations, substantive operation and maintenance, effluent monitoring, and the need for ongoing operation (estimated 30-plus years considering source remains in place).
  - **Cost.** Costs are 'moderate' based on the Tier II cost logic and score 0 (neutral).

3.2 North Plant Evaluation of Alternatives

Tables 3-5 and 3-6 present the balancing criteria evaluation and scoring logic for the two North Plant primary alternatives, and follow the same evaluation process as described above for West Selenium. Supporting information on long-term effectiveness (which is one of the five balancing criteria) is presented in Figures 2-16 through 2-18, and in Appendix B. Costs follow the same approach as West Selenium (noted above); supporting ROM Class 4 costing details as summarized in these tables is provided in Appendix C.

Below is a summary of the independent evaluation for North Plant alternatives (as shown in Tables 3-5 through 3-6).

- **Alternative 5**: PRB to treat arsenic

  - **Long-term Effectiveness and Permanence**. Score is 0 (neutral) as this alternative would provide limited additional mass removal over IMs and no reduction in plume size above the MCL. This alternative is not considered permanent as it requires performance evaluation and long-term operations and maintenance.
  - **Reduction of Toxicity, Mobility, or Volume through Treatment**. Score is – (negative) considering long-term operations and maintenance, the substantive volume of treatment residuals (volume shown in Table 2-1) and related handling/management every 10 to 15 years, and the limited reductions in plume mobility and toxicity.
  - **Short-term Effectiveness**. Score is + (positive) considering the limited risks to human health and the environment and relatively short duration to construct.
  - **Implementability**. Score is 0 (neutral) considering the long lead-time for procurement/delivery of zero-valent iron (ZVI) media and the need to replace spent media every 10 to 15 years.
  - **Cost**. Costs are 'high' based on the Tier II cost logic and score - (negative).
- **Alternative 6**: Slurry Wall Enclosure
  - **Long-term Effectiveness and Permanence**. In comparison to the Tier I IM base case, this alternative provides a marginal degree of improvement in groundwater source mass reduction and limited/negligible effect on plume geometry concentration above MCL. Considering these predictions in effectiveness, this alternative scores 0 (neutral).
  - **Reduction of Toxicity, Mobility, or Volume through Treatment**. Contaminant mass flux to groundwater outside the slurry wall enclosure is predicted to be reduced. However, the groundwater within the slurry wall enclosure is expected to remain high concentration over the long-term. Considering that elevated concentrations remain within the slurry wall enclosure over the long-term lends to a score of 0 (neutral).
  - **Short-term Effectiveness**. Score is + (positive) considering the limited risks to human health and the environment and relatively short duration to construct.
  - **Implementability**. Score is + (positive) considering limited administrative/agency approvals are needed, relatively simple or basic design of construction elements, and lack of long-term operations/maintenance.
  - **Cost**. Costs are 'moderate' based on the Tier II cost logic and score 0 (neutral).
- **Alternative 7**: Slurry Wall Enclosure with Injections
  - **Long-term Effectiveness and Permanence**. In comparison to the Tier I IM base case, this alternative provides a marginal degree of improvement in groundwater source mass and limited/negligible effect on plume geometry concentration above MCL. Considering these predictions in effectiveness, this alternative scores 0 (neutral).
  - **Reduction of Toxicity, Mobility, or Volume through Treatment**. Contaminant mass flux to groundwater outside the slurry wall enclosure is predicted to be reduced. Assuming the successive injection events are successful at distributing the ZVI nanoslurry into the saturated zone within the slurry wall, the arsenic concentrations in groundwater within the slurry wall enclosure are expected to be significantly reduced and remain relatively low over the long-term. Considering the combined efforts of slurry wall enclosure and injections lends to a + (positive) score with respect to reductions in toxicity, mobility, and volume through treatment.
  - **Short-term Effectiveness**. Score is + (positive) considering the limited risks to human health and the environment and relatively short duration to construct.

- **Implementability**. Score is + (positive) considering limited administrative/agency approvals are needed, relatively simple or basic design of construction elements, and limited long-term operations/maintenance (limited number of injection events).
- **Cost**. Costs are 'moderate' based on the Tier II cost logic and score 0 (neutral).

4.0 Comparative Evaluation of Alternatives

This section presents a comparative evaluation of the alternatives based on the combined scores developed from the individual evaluations presented in Section 3.0.

Table 4-1 summarizes the comparative evaluation results for the various alternatives and tallies up the scores from the five balancing criteria. The scoring approach weighs each of the five criteria equally and as described in Table 2-4, the scores range from positive + (considered +1), to neutral (zero), to negative – (considered -1). The combined scoring process sums up each alternative, and a combined score of "+5" score would be the best/highest possible with all five criteria scored as positive. Conversely, a combined score of "-5" would be the worst/lowest possible with all five criteria scored as negative.

4.1 West Selenium Comparative Evaluation Results

Below is a summary of the combined evaluation for West Selenium alternatives.

- **Alternative 1**: Source removal is given a combined score of +2 with + (positive) scores for long-term effectiveness and permanence, and reduction in toxicity, mobility, or volume through treatment. The remaining three criteria were scored as 0 (neutral). The estimated cost is $2.8M to excavate/remove saturated source soils in the focused area shown in Figure 2-3; costs assume capital only for source removal activities without any substantive costs related to long-term O&M. The uncertainty of source area capture and the complexity/cost of the excavation process (confined space, deep excavation and shoring, and dewatering) combine to limit the overall score of this alternative.
- **Alternative 2**: PRB for selenium is given a combined score of +1 with a + (positive) score for short-term effectiveness. The remaining four criteria were scored as 0 (neutral). The estimated cost is $2.8M which includes an estimated $1.5M to construct the PRB as shown in Figures 2-4.1 and 2.4.2, and another $1.3M estimated as long-term O&M to excavate/remove spent media and place new media at years 10 and 20 after original installation. The lack of proven selenium PRB examples and need for pilot evaluations for selenium removal effectiveness, coupled with the replacement requirements, combine to limit the overall score of this alternative.
- **Alternative 3**: Slurry Wall Enclosure is given a combined score of +4 with + (positive) scores for all criteria except for reduction in toxicity, mobility, or volume through treatment, which was scored as 0 (neutral). The estimated cost is $1.6M to construct the slurry wall enclosure down to the ash/clay layer with the dimensions shown in Figure 2-5, and no additional costs for long-term O&M. Contaminated groundwater that remains within the slurry wall long-term limits the score for this alternative.
- **Alternative 4**: Pump and treat is given a combined score of 0 (neutral). This alternative scored + (positive) for short-term effectiveness but was considered – (negative) with respect to implementation, considering the elements related to extraction system, conveyance pipe, treatment system, long-term O&M, winter maintenance, and routine monitoring for discharge effluent limits. The remaining three criteria were scored 0 (neutral). The estimated cost is $4.0M, which includes the capital cost construction elements shown in Figures 2-6.1 and 2-6.2 (detailed in Appendix C) estimated at $2.3M, and the long-term O&M items estimated at $1.7M over a 30-year period.

4.2 North Plant Comparative Evaluation Results

Below is a summary of the combined evaluation for North Plant alternatives.

- **Alternative 5**: PRB for arsenic is given a combined score of -1 with + (positive) score for short-term effectiveness, but – (negative) scores on reduction in toxicity, mobility, or volume through treatment and cost. The remaining two criteria were scored 0 (neutral). The estimated cost is $20.3M, which includes an estimated $9.9M to construct the PRB as shown in Figures 2-7.1 and 2-7.2, and another $10.3M estimated as long-term O&M to excavate/remove spent media and place new media at years 20 and 20 after original installation. The lack of significant contaminant mass and plume volume reduction combined with the cost limit the score for this alternative.
- **Alternative 6**: Slurry wall enclosure is given a combined score of +2 with + (positive) scores for short-term effectiveness and implementability. The remaining three criteria were scored 0 (neutral). The estimated cost is $2.0M to construct the slurry wall enclosure down to the ash/clay layer with the dimensions shown in Figure 2-8, and no additional costs for long-term O&M. The lack of significant contaminant mass and plume volume reduction combined with contaminated groundwater that remains within the slurry wall long-term limit the score for this alternative.
- **Alternative 7**: Slurry wall enclosure with injections is given a combined score of +3 with + (positive) scores for reduction in toxicity, mobility, or volume through treatment, short-term effectiveness, and implementability. The remaining two criteria were scored 0 (neutral). The estimated cost is $2.5M, which assumes slurry wall at $2.0M (as shown in Alternative 6), plus the injection wells at $0.2M and four injection events at $0.3M.

5.0 Remedy Alternative Recommendations and Data Needs

This section provides preliminary recommendations and data needs for final selection of remedy alternatives in the West Selenium and North Plant areas. Recommendations include focused field investigations in the West Selenium and North Plant areas with soil and groundwater sample collection and analysis. The field investigation results will be used to refine predictive groundwater modeling assumptions for comparison of IMs and effectiveness of the recommended remedy alternatives in both areas, and support final selection of Tier II groundwater remedies.

Predictive groundwater modeling conducted as part of the Tier II groundwater remedy evaluation process provided estimates of Tier I IM baseline performance and additional benefits of each Tier II alternative. Based on the results from the comparative evaluation, the technical recommendation for West Selenium area is the slurry wall enclosure alternative, while the technical recommendation for North Plant area is the Tier I IMs alone without any supplemental Tier II alternative. However, uncertainties in Tier II evaluation results suggest that if additional information can be obtained and site conditions refined, the balancing criteria might shift toward the second identified remedy alternatives, such as source removal for the West Selenium or a slurry wall enclosure for the North Plant area. The recommended data needs to address data gaps and verify the final recommendations are described by area below.

5.1 West Selenium Area

The slurry wall enclosure was evaluated to have the highest combined balancing criteria score of plus four (+4), followed by source removal at plus two (+2), PRB at plus one (+1), and pump-and-treat at neutral (0). The key considerations for the slurry wall enclosure are long-term effectiveness and permanence, short-term effectiveness, implementability, and cost.

The slurry wall enclosure alternative scores higher than source removal for the short-term effectiveness, implementability, and cost criteria. However, the source removal alternative scores higher than the slurry wall enclosure for the criterion of reduction in toxicity, mobility, or volume through treatment. The source removal advantage recognizes that source removal would provide volume reduction of the source material through excavation and placement under the IM cover system above the saturated zone.

The slurry wall enclosure would address a larger extent of West Selenium in comparison to the source removal alternative, has less uncertainty in application, provides less disturbance with less cost, and provides an effective and permanent remedy similar to the source removal alternative. The implementability of a slurry wall is a relatively straightforward application of proven technology for wall installation, compared with a more complex construction process for source removal, which requires shoring of the 50-foot-deep excavation, temporary support of the excavation adjacent to the former Ore Storage Building, and dewatering of high-concentration selenium groundwater with treatment at the onsite HDS plant, as reflected in the cost estimate balancing criteria. The HDS plant has limited treatment efficiency for selenium, but is assumed to process construction dewatering water without exceeding effluent limits.

In the West Selenium area, low to moderate total concentrations of selenium in soils have been shown to leach high concentrations of selenium, with saturated paste leachate concentrations similar to concentrations currently observed in groundwater. Groundwater and soil selenium data have been used to estimate the location of the potential, high-concentration selenium source (i.e., soils generating groundwater selenium concentrations of >3 to 5 mg/L) geographically. At this time, however, uncertainties to be addressed in the additional investigation are (1) further definition of the lateral and vertical source boundaries in the unsaturated and saturated zones, (2) distribution of concentrations and forms of source materials, (3) better definition of selenium source mass, and (4) characteristics of the top of the ash/clay layer underlying the saturated alluvial unit to support remedy implementation.

Based on currently available data and the conceptual model of selenium loading to groundwater in the inferred source area, saturated soils are the current principal source of selenium loading. Uncertainties exist, however, as the documented total selenium mass in this area is calculated based on previous investigations to date and appears insufficient to generate the observed downgradient selenium plume, suggesting that either (a) the source area is larger than estimated, (b) the highest concentration soils were not encountered in the 2014 soil borings, and/or (c) the conceptual model of the mechanism of selenium loading to groundwater is not fully understood. To address these uncertainties, the following information is needed to support or verify the final alternative recommendation:

- Supplemental soil borings and testing for total and leachable selenium and metals concentrations to address data gaps and increase confidence in source area delineation
- Refined transient groundwater flow simulations to calibrate to post-IM 2014 groundwater conditions and updated fate and transport modeling using the calibrated 2014 conditions for refined predictive analyses

This information will allow the Tier II groundwater alternative selection process to be completed in a thorough fashion and provide the data necessary to verify either source removal or a slurry wall as the recommended technical alternative. In addition, the recommended field investigation in the West Selenium area will provide useful data to support the design phase of the selected groundwater remedy, including either source removal or slurry wall boundaries and locations.

The groundwater model will be used to support additional fieldwork. The model will be refined with transient simulations of flow conditions and results of ongoing IM implementation, refining the groundwater flow within the source areas to support continued Tier II evaluation through predictive simulations of the IMs and remedial alternatives. The existing groundwater flow and transport models use a steady-state flow condition calibrated to pre-IM implementation groundwater conditions (2011) and adjusted to reflect the IM implementation and evaluation of steady-state groundwater plumes. The models will be updated and refined using data collected during the field investigation to reduce uncertainty, test model assumptions, and refine predictive results. The groundwater flow model will be calibrated to average 2014 groundwater elevations and the transient calibration will be extended to include the most recent set of collected groundwater elevations. The transport model will be calibrated to 2014 plume geometry and collected water quality data. The updated models will then be used for further evaluation of IMs and primary remedial alternatives for the slurry wall enclosure and source removal, including transient simulations to assess predicted changes in groundwater quality over time. Revised estimates of effectiveness will be derived from the focused field investigation and used in these predictive simulations.

5.2 North Plant Area

For the North Plant area, the majority of the long-term effectiveness is estimated from implementation of the Tier I IMs. As shown in Table 2-3, the predicted mass reduction in the downgradient plume as a result of the Tier I IMs is from 1,445 kilograms (kg) of arsenic in groundwater to approximately 377 kg, a reduction of approximately 74 percent of the original plume mass. The Tier II alternatives resulted in additional mass reductions ranging from 157 to 250 kg in the downgradient plume, which is an added reduction of about 10 to 17 percent of the original plume mass. The volume of the downgradient groundwater plume above the groundwater MCL for arsenic remains about the same or is slightly increased due to changes in flow through and around the remedy. These estimates reflect site conditions where there is a steep chemical gradient with absorption/precipitation in the downgradient-saturated soils.

Existing data indicate that leachable arsenic in saturated soils throughout a relatively large horizontal area (both within and outside the Facility boundaries) is the current principal source of arsenic loading to groundwater. Arsenic present in saturated zone soils has accumulated in these soils during the active and post-operational life of the Facility, as contaminated groundwater from upgradient process areas moved through the soils and arsenic partitioned to the aquifer materials via adsorption and coprecipitation mechanisms. Given the high concentrations of arsenic in groundwater over many decades, the presence of a high-concentration (>10 mg/L) arsenic plume offsite in East Helena, and the sharp decrease in groundwater arsenic concentrations at the leading edge of the plume, the current conceptual site model indicates that arsenic has been sorbed to aquifer materials offsite for a considerable distance downgradient of the site (hundreds to thousands of feet), and that these soils could continue to function as a secondary source of arsenic loading to groundwater for decades, even after implementation of corrective measures at the former smelter.

If the current conceptual site model is correct, remedial actions taken in the North Plant area can be expected to have minimal benefit to downgradient water quality. To confirm the current understanding, a minimum of two additional soil borings located downgradient of the former smelter are recommended to measure the downgradient saturate soil conditions and verify the predicted plume concentrations resulting from IM implementation.

The soil borings will be advanced and saturated soil samples collected for analysis of total and leachable arsenic, selenium, and metals concentrations. The analysis results would allow for better estimates of the location of the total source mass currently generating the groundwater arsenic plume, as well as better prediction of the potential groundwater quality responses to Tier II IMs through groundwater modeling and analytical calculations. Installation of soil borings near previous boring locations would also allow comparison of changes in soil arsenic concentrations over time to assess net losses or gains in arsenic mass.

The groundwater model will be used to support the additional fieldwork. The model will be refined to reflect current groundwater conditions (2014) and support continued evaluation of the slurry wall enclosure alternative with respect to the refined IM effectiveness model simulations. This will include updating and refining the models using data collected during the field investigation to reduce uncertainty, test model assumptions, and refine predictive results. The groundwater flow model will be calibrated to average 2014 groundwater elevations and the transient calibration will be extended to include the most recent set of collected groundwater elevations. The transport model will be calibrated to 2014 plume geometry and collected water quality data. The updated model will then be used for further evaluation of IMs effectiveness and the slurry wall enclosure.

5.3 Implementation Timeline

Figure 5-1 presents an implementation timeline for additional investigations, evaluations, and verification of recommendations of the Tier II process. Additional field investigation work and reporting is anticipated to occur from June through August 2015 to support the supplemental Tier II evaluation. A concurrent timeline is proposed for the updated groundwater modeling. The timeline was developed to allow sufficient time for completing Tier II evaluations and integrating the results with the ongoing IM construction. In the event that the recommended supplemental phase of Tier II evaluations does not sufficiently reduce the uncertainties, then adjustments to the remedy implementation timeline (and potentially to the IM construction activities in specific areas of the site) will be needed to perform further investigations and evaluations based on the results.

Figure 5-1 also shows the estimated timeline for the development of an addendum to the 2015/2016 IMWP to support the integration of remedy implementation with the construction of IMs scheduled for 2015 and 2016. This timeline assumes implementation of the recommended Tier II slurry wall remedy proposed for the West Selenium area of the site. The timeline for source removal in the West Selenium area would be similar. If supplemental investigations and evaluations indicate that the slurry wall enclosure alternative in the North Arsenic area would be beneficial in addition to the Tier I IMs, then adjustments to this timeline will be needed to accommodate remedy construction in the North Plant area of the site.

6.0 References

Association for the Advancement of Cost Engineering (AACE). 2005. *Recommended Practice No. 18R-97, Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries*.

CH2M HILL. 2012. *Former ASARCO East Helena Facility Interim Measures Work Plan–Conceptual Overview of Proposed Interim Measures and Details of 2012 Activities*. Final. Prepared for The Montana Environmental Trust Group, LLC, and the Montana Environmental Custodial Trust. September 2012.

CH2M HILL. 2013. *Former ASARCO East Helena Facility Interim Measures Work Plan—2013*. Final. Prepared for The Montana Environmental Trust Group, LLC, and the Montana Environmental Custodial Trust. February 2013.

CH2M HILL. 2014a. *Former ASARCO East Helena Facility Corrective Measures Study Work Plan 2013*. Draft. Prepared for The Montana Environmental Trust Group, LLC, and the Montana Environmental Custodial Trust. January 2014.

CH2M HILL. 2014b. *Former ASARCO East Helena Facility Interim Measures Work Plan—2014*. Final. Prepared for The Montana Environmental Trust Group, LLC, and the Montana Environmental Custodial Trust. May 2014.

CH2M HILL. 2015a. *Former Asarco East Helena Facility Interim Measures Work Plan – 2015 and 2016*. Public Review Draft. Prepared for The Montana Environmental Trust Group, LLC, and the Montana Environmental Custodial Trust. February 2015.

CH2M HILL. 2015b. *Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations*. Prepared for The Montana Environmental Trust Group, LLC, and the Montana Environmental Custodial Trust. February 2015.

Dreher, Robert G., E. Rockler, M.W. Cotter, L. Johnson/United States District Court for the District of Montana. 2012. First Modification to the 1998 Consent Decree. Civil Action No. CV 98-H-CCL. Case 6:98-cv-00003-CCL. Document 38. Filed January 17, 2012.

Hydrometrics. 2014a. *2014 Supplemental Contaminant Source Area Investigation at the Former East Helena Smelter*. Draft. Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust.

Hydrometrics. 2014b. *Source Area Inventory* deliverable table titled "Former East Helena Smelter Groundwater Containment Source Inventory." Attachment to email transmittal from Bob Anderson/Hydrometrics to Lauri Gorton/Custodial Trust. August 28, 2014.

Montana Department of Environmental Quality (MDEQ). 2012. *Circular DEQ-7, Montana Numeric Water Quality Standards*. Prepared by: Water Quality Planning Bureau, Water Quality Standards Section, Helena, Montana. October 2012.

NewFields. 2014. *Revised Work Plan for Solute Transport Model Development Former East Helena Smelter*. June 25, 2014.

NewFields. 2015. *FINAL Fate and Transport Model Design and Calibration, East Helena Site Technical Memorandum*.

NewFields. 2015. *FINAL Predictive Fate and Transport Modelling, Interim Measures and Tier II Corrective Actions, East Helena Site*.

U.S. Environmental Protection Agency (USEPA). 1994. *RCRA Corrective Action Plan*. Final. Office of Waste Programs Enforcement and Office of Solid Waste. OSWER Directive 9902.3-2A. May 1994.

U.S. Environmental Protection Agency (USEPA). 2000. *Fact Sheet #3, Final Remedy Selection for Results-based RCRA Corrective Action*. Office of Solid Waste, RCRA Corrective Action Workshop on Results-Based Project Management: Fact Sheet Series. March 2000.

Tables

TABLE 2-1
Source Areas, Alternatives, Technology Designs, and Construction Approach

Area	Alternative	Technology Description/Assumptions	Dimensions/Unit Quantities	Construction Approach and Key Assumptions
West Selenium Area (COPC is selenium)	1 – Source Removal	Assumes physical excavation and relocation of saturated zone source materials to an onsite location that is beneath the future ET cover but above the saturated zone. The alternative is expected to reduce ongoing mobilization and leaching of selenium from the primary source area to groundwater. Removal of up to 70 percent of source material is considered achievable based on currently available information.	Area 100 x 200 x 48 ft bgs. Current estimates place source area at 0.25 to 0.75 acres (Hydrometrics 2015). Quantity estimates: • Interim measure cover: 2,222 yd^3 • Unsaturated zone: 29,629 yd^3 • Saturated zone (source removal): 4,444 yd^3 • Backfill of clean borrow material: 4,444 yd^3	• Saturated zone material placed under ICS-2 (and ET cover). • Clean borrow material obtained via onsite source placed in saturated zone. Clean onsite backfill material will have a higher hydraulic conductivity than excavated source materials. • Unsaturated zone soils placed back into excavation in unsaturated zone. • Dewatering limited because of soldier pile-sheet pile walls; sump-pump used to dewater saturated zone, groundwater pumped to temporary tank and hauled to existing treatment plant. • All earthwork done onsite; no offsite hauling or disposal.
	2 – PRB for Selenium	Technology assumes passive groundwater flow through the reactive media to treat selenium. PRB media consist of 90 percent organic mulch and 10 percent limestone sand placed across saturated interval. Influent selenium concentrations assume 3.0 mg/L; treatment targets assume 0.05 mg/L (Circular DEQ-7 groundwater standard). Media will have finite life and will require monitoring to determine when media needs replacement.	100-ft-long PRB with 25-ft funnels (slurry walls) at either end. PRB installed across saturated interval, wall width of 12 ft (perpendicular to flow) designed to achieve residence time of 2 days. Funnel walls installed from ash/clay to ground surface and designed to have limited influence on surrounding groundwater flow patterns. Design will incorporate hydraulic considerations to facilitate homogeneous flow through media.	• Passive treatment of selenium considered 'pilot study'; long-term viability/effectiveness uncertain. Limited formal research/documentation on full-scale studies over long-term. • Construction approach assumes long-arm excavator to install PRB and funnel ends. Capital costs include installation of 6 wells for final design and to monitor post-installation effectiveness of PRB. • Long-term O&M assumes full replacement of PRB media in years 10 and 20; actual replacement schedule determined from monitoring/effectiveness. • Spent media disposed of offsite; volume estimated at 444 yd^3.
	3 – Slurry Wall Enclosure	Technology assumes an effective, low-permeability enclosure "wall" located around the primary source area saturated zone; design assumptions are to reduce the mobility/flux from within the enclosure area. Design assumes slurry wall permeability of $1x10^{-6}$ cm/sec or lower.	Perimeter of 1,100 linear feet based on enclosure dimensions of 100 x 450 ft in plan view. Depth of slurry wall assumes 48 ft bgs down to ash/clay layer. Typical construction approach assumes slurry wall installed from ash/clay layer to ground surface.	• Construction approach assumes long-arm excavator to install slurry wall and use of excavated soil in soil-bentonite blend. • Permeability options: soil-bentonite wall $1x10^{-7}$ cm/sec or cement-bentonite wall $1x10^{-6}$ cm/sec; difference in cost is about $3/VSF. Costing approach is conservative and assumes soil-bentonite wall.
	4 – Pump and Treat (P&T)	Technology assumes a long-term groundwater extraction system extending across a width of about 100 ft (approximate width of plume) and then conveyance of groundwater to passive treatment system, which includes: • Biochemical reactor beds consisting of organic mulch, limestone, and sand • Aeration channel • Oxidation/settling ponds • Discharge to existing wetlands and Prickly Pear Creek	Groundwater Extraction System: • Three wells – combined total flow of 30 gallons per minute • Buried conveyance pipe: about 4,800 ft Treatment System: • Dual biochemical reactor beds: total volume 12,400 yd^3 • Dual oxidation ponds: total volume 584 yd^3 • See process flow diagram (Figure A-4.2) for details	• P&T option will require regulatory approvals and discharge permit to set monitoring requirements and effluent/discharge limits • Treatment system will require routine maintenance (weekly), monitoring, and intermittent replacement of spent media. Costing approach assumes biochemical reactor beds are replaced at year 15; actual replacement cycle depends on monitoring. • Treatment system will require winterization design for year-round operation (such as buried conveyance line, buried biochemical reactor beds, heat-traced lines, and heated blower or mechanical agitator). These items will add capital costs and also replacement costs to replace media.
North Plant (COPC is arsenic)	5 – PRB for Arsenic	Technology assumes passive groundwater flow through the reactive media to treat arsenic. PRB media consist of 100 percent pure ZVI (granular iron) placed across saturated interval. Influent arsenic concentrations assume 20 to 25 mg/L; treatment targets assume 0.01 mg/L (Circular DEQ-7 groundwater standard). Media will have finite life and will require monitoring to determine when media needs replacement.	400-ft-long PRB with 125-ft funnels at either end; alignment is adjusted to stay on Custodial Trust-owned property. PRB is 8 ft thick to achieve residence time of 2+ days. Funnel walls installed from ash/clay to ground surface and designed to have limited influence on groundwater flow patterns. Design will incorporate hydraulic considerations to facilitate homogeneous flow through media.	• Construction approach assumes long-arm excavator to install PRB and funnel ends. Capital costs include installation of 6 wells for final design and to monitor post-installation effectiveness of PRB. • Long-term O&M assumes full replacement of PRB media in year 10 and 20; actual replacement schedule determined from monitoring/effectiveness. • Spent media disposed of offsite; volume assumed at 2,370 yd^3. • Unit cost of pure ZVI is $1,020/ton; volume estimates assume the PRB will require approximately 5,000 tons, which is about 75 percent of the overall capital cost.
	6 – Slurry Wall Enclosure	Technology assumes an effective, low-permeability enclosure "wall" located around source area saturated zone; design assumptions are to reduce mobility/flux from within the enclosure area. Design assumes slurry wall permeability of $1x10^{-6}$ cm/sec or lower.	Perimeter of 1,560 linear feet based on dimensions shown in layout figure. Depth of wall to 51 ft bgs to ash/clay layer. Alignment of wall adjusted to stay within Custodial Trust-owned property.	• Construction approach assumes long-arm excavator to install slurry wall and use of excavated soil in soil-bentonite blend. • Permeability options: soil-bentonite wall $1x10^{-7}$ cm/sec or cement-bentonite wall $1x10^{-6}$ cm/sec; difference in cost is about $3/VSF. Costing approach is conservative and assumes soil-bentonite wall.

TABLE 2-1
Source Areas, Alternatives, Technology Designs, and Construction Approach

Area	Alternative	Technology Description/Assumptions	Dimensions/Unit Quantities	Construction Approach and Key Assumptions
	7 - In-Situ Injections (in conjunction with Alternative 6 slurry wall enclosure).	Technology assumes installation of injection wells within slurry walls to deliver (via injection) nanoslurry mixture within slurry wall enclosure. ZVI nanoparticles have relatively high-surface area to volume ratio and are demonstrated to be effective at binding arsenic in solution.	Design assumes five injection wells placed within the slurry wall enclosure. Injections assume ZVI micro/ nanoparticles placed (injected) via slurry form. Treatment assumes 2.4M gallons within the slurry walls.	• Conceptual-design estimates of weight/volume of ZVI nanoparticles assume 2 tons; however, actual volume needed for treatment dependent on batch testing and effectiveness monitoring after the first of four proposed injections. • Unit cost of ZVI nanoparticles in dry form (to be mixed into slurry) assumed at $40 per pound. • Costs assume that the 2 tons (total) applied over four separate injection events.

Notes:

1. Refer to cited figures for layouts, dimensions, and designs.

2. Alternative 7 (in-situ injections) is assumed supplemental to Alternative 6 (injections within the slurry wall). If Alternative 6 is selected, then the need for Alternative 7 may be evaluated and decided on after the slurry wall is constructed and the effectiveness evaluated, among other criteria.

bgs = below ground surface
cm/sec = centimeter(s) per second
COPC = constituent of potential concern
ET = evapotranspiration
ft = foot/feet
ICS = Interim Cover System
MDEQ = Montana Department of Environmental Quality
mg/L = milligram(s) per liter
P&T = pump and treat
PRB = permeable reactive barrier
VSF = vertical square foot
yd^3 = cubic yard
ZVI = zero-valent iron

TABLE 2-2

Predicted Effectiveness for West Selenium Tier II Alternatives

West Selenium Site Area (Control/Treat Selenium)	Interim Measures			
Calculated Location from Model	**2011 Conditions**	**PPC Bypass**	**PPC Realignment with ET Cover**	**Resulting Size (percent of current)**
Downgradient Mass (kg)	3,304	2,791	2,008	61%
Downgradient Volume (acre-ft)	1,865	1,502	1,079	58%

West Selenium Site Area (Control/Treat Selenium) Alternatives with Interim Measure Implementation

Alternatives	Interim Measures Mass (% of 2011)	Interim Measures Volume (% of 2011)	Remedy Components	Downgradient Mass (kg)	Downgradient Volume (acre-ft)	Mass (% of 2011)	Plume Volume (% of 2011)
1	61%	58%	Source Removal **70 percent**	1,233	366	37%	20%
2	61%	58%	Permeable Reactive Barrier (mulch and limestone) **76 percent**	1,162	273	35%	15%
3	61%	58%	Slurry Wall (hydraulic enclosure of source area) **K = 10^{-5} cm/s**	1,099	172	33%	9%
4	61%	58%	Focused Pump and Treat (semipassive treatment system)	845	137	26%	7%

Notes:

ET = evapotranspiration

kg = kilogram

PPC = Prickly Pear Creek

TABLE 2-3

Predicted Effectiveness for North Plant Tier II Alternatives

North Plant Site Arsenic (Control/Treat Arsenic)		Interim Measures		
Calculated Location from Model	**2011 Conditions**	**PPC Bypass**	**PPC Realignment with ET Cover**	**Resulting Size (percent of 2011)**
Downgradient Mass (kg)	1,445	700	377	26%
Downgradient Volume (acre-ft)	375	407	381	102%

North Plant Site Arsenic (Control/Treat Arsenic) after Interim Measure Implementation

Alternatives	Interim Measures Mass (% of 2011)	Interim Measures Volume (% of 2011)	Remedy Components	Downgradient Mass (kg)	Downgradient Volume (acre-ft)	Mass (% of 2011)	Plume Volume (% of 2011)
5	26%	102%	PRB (ZVI - granular iron) **55 percent**	250	392	17%	105%
6	26%	102%	Slurry Wall (hydraulic enclosure of source area) **K = 10^{-5} cm/s**	176	389	12%	104%
7	26%	102%	Slurry Wall with ZVI nanoparticle Injections (simulated by PRB with 100 percent effectiveness)	157	389	11%	104%

Notes:

cm/s = centimeters per second
ET = evapotranspiration
kg = kilogram
PPC = Prickly Pear Creek
PRB = permeable reactive barrier
ZVI = zero-valent iron

TABLE 2-4

RCRA Balancing Criteria, Definitions, and Interpretation/Application to Tier II Source Control Evaluation

Balancing Criteria	Definition (per RCRA [USEPA, 2000])	Interpretation and Application of Balancing Criteria to the Tier II Evaluation	Scoring Logic [+ positive, 0 neutral, - negative]
1. Long-term Effectiveness and Permanence	Decision-makers should evaluate remedies based on the long-term reliability and effectiveness they afford, along with the degree of certainty that they will remain protective of human health and the environment. Additional considerations include the magnitude of risks that will remain at a site from untreated hazardous wastes, hazardous wastes and hazardous constituents, and treatment residuals; and the reliability of any containment systems and institutional controls. A remedial option should include a description of the approaches and facilities that will be used to assess long-term performance and effectiveness.	Criteria evaluated as the relative improvement in groundwater concentrations for the COC of interest (selenium for West Selenium and arsenic in North Plant) over the long-term (assumed 30 years) as a result of implementing the alternative in addition to the interim measures; and also the permanence the alternative provides. Model simulations (by Newfields) will be used to quantify effectiveness considering the following metrics: (1) mass removal (in weight and percent), (2) plume geometry/volume reductions below MCL, and (3) the temporal timeframe to achieve stable ('steady-state') conditions following implementation. Alternatives providing the highest degree of long-term effectiveness are those that achieve the most mass and volume reductions, have the highest degree of permanence, leave little or no waste (source), do not require long-term maintenance, and minimize the need for institutional controls.	"+" = Highest degree or substantive improvements in groundwater metrics (reductions in mass and plume reduction); alternative is permanent over the long-term. "0" = Moderate or marginal improvement in groundwater metrics; and/or some uncertainties or risks relative to permanence. "-" = No substantive improvement in groundwater metrics and/or the alternative is lacking permanence or considered a high-risk, unproven technology.
2. Toxicity, Mobility, and Volume Reduction	Decision-makers should evaluate remedies based on the degree to which they employ treatment, including treatment of principal threats, that reduces the toxicity, mobility, or volume of hazardous wastes and hazardous constituents, considering, as appropriate: the treatment processes to be used and the amount of hazardous waste and hazardous constituents that will be treated; the degree to which treatment is irreversible; and the types of treatment residuals that will be produced.	Criteria focus on the degree to which an alternative does or does not employ a treatment technology. For alternatives that require treatment technology (such as PRB, pump and treat, and injections), the evaluation will describe (1) quantities and quality (i.e., concentrations) of groundwater requiring treatment, (2) degree in which treatment is irreversible, and (3) types and volumes of treatment residuals. For alternatives that do not require a geochemical alteration/treatment technology (such as source removal and slurry wall), the volume of source material will be estimated.	"+" = Alternative reduces toxicity and mobility of hazardous material; irreversible with limited or no residuals management. "0" = Alternative reduces toxicity, mobility, or volume; irreversible but with some residuals for management. "-" = Alternative has limited effect on toxicity, mobility, or volume reduction; reversible or has significant residual management.
3. Short-term Effectiveness	Decision-makers should evaluate remedies based on the short-term effectiveness and short-term risks that remedies pose, along with the amount of time it will take for remedy design, construction, and implementation.	Criteria address the effects during construction and implementation (i.e., short-term) and will focus on (1) short-term impacts/risks to human health (related to construction), (2) short-term impacts (i.e., releases) to the environment related to implementation of remedy, and (3) and how long it will take to design, construct, and implement the alternative.	"+" = No substantive risks/impacts to human health or environment. Short duration to establish effectiveness. "0" = Moderate risks/impacts to human health or environment. Longer duration to establish effectiveness. "-" = High-degree of risks/impact to human health or environmental impacts. Requires significant duration to establish effectiveness.
4. Implementability	Decision-makers should evaluate remedies based on the ease or difficulty of remedy implementation, considering as appropriate: the technical feasibility of constructing, operating, and monitoring the remedy; the administrative feasibility of coordinating with and obtaining necessary approvals and permits from other agencies; and the availability of services and materials, including capacity and location of needed treatment, storage, and disposal services.	Criteria focus on (1) administrative components, (2) regulatory coordination and approvals, and (3) overall ease or difficulty of constructing, operating, and monitoring the remedy; including availability of services relative of the types of alternatives and/or complexity of specialty services needed. Alternatives that are considered easiest or most favorable to implement are those which (1) do not require substantive agency approval or permits, (2) do not require long-term O&M, and (3) do not rely on specialty technologies, services, or materials.	"+" = Administrative items, regulatory approvals, construction, operation, and monitoring are considered relatively easy, feasible, or readily implementable. No long-term O&M. Short duration to implement alternative. "0" = Neutral score if not easy or "complex." Longer duration to establish effectiveness. "-" = Alternative requires agency substantive or nonstandard approvals or permits, substantive long-term O&M, specialty technology, and/or significant duration to implement alternative.
5. Cost	Decision-makers should evaluate remedies based on capital and O&M costs, and the net present value of the capital and O&M costs.	Estimated costs have been developed for each alternative using Study or Feasibility Class 4 guidance (Association for the Advancement of Cost Engineering, 2005) with expected accuracy of -30 to +50 percent. Costs reflect both capital and long-term O&M (when applicable) assuming a 30-year period net present worth at 5 percent rate of return (unless specified otherwise). The total cost reflects capital and long-term O&M (if applicable). Costs are based on conceptual designs and are not considered final designs; if an alternative is selected, a final design will be developed before implementation.	"+" = Relatively low. Cost is less than $2M. "0" = Moderate. Cost ranges from $2 to $5M. "-" = Relatively high. Cost is greater than $5M.
6. Community Acceptance	Decision-makers should evaluate remedies based on the degree to which they are acceptable to the interested community.	The Phase 2 evaluation is based on the first five technical criteria (listed above). Community acceptance will be evaluated as part of the public involvement process.	
7. State Acceptance	Decision-makers should evaluate remedies based on the degree to which they are acceptable to the state in which the subject facility is located. This is particularly important where the U.S. Environmental Protection Agency, not the state, selects the remedy.	The Phase 2 evaluation is based on the first five technical criteria (listed above). State acceptance will be evaluated as part of the public involvement process.	

Notes:

COC = constituent of concern
COPC = constituent of potential concern
M = million
MCL = maximum contaminant level
O&M = operations and maintenance
RCRA = Resource Conservation and Recovery Act

Reference: U.S. Environmental Protection Agency (USEPA). 2009. *Fact Sheet #3: Final Remedy Selection for Results-based RCRA Corrective Action*. RCRA Corrective Action Workshop on Results-Based Project Management: Fact Sheet Series. March.

TABLE 3-1
Criteria Evaluation for West Selenium Area: Source Removal – Alternative 1

Criteria	Factors/Assumptions	Evaluation	Scoring
1. Long-term Effectiveness and Permanence	• Mass removal: Reduced downgradient plume (as defined by 0.05 mg/L contour) from 2,008 kilograms (Tier I IM base case) to 1,233, with 37 percent remaining in downgradient plume remainder attributable primarily to East Selenium lobe). • Plume geometry/volume reductions: Reduced from 1,079 acre-feet (Tier I IM base case) to 366 acre-feet, with 20 percent of downgradient plume volume remaining above the maximum contaminant limit. • Schedule: The timeframe to establish effectiveness is estimated at roughly 10 years following implementation.	This alternative provides a high-degree [score +] of long-term effectiveness and permanence given that (1) remaining source mass is limited or moderate (or substantively reduced from IM baseline conditions), (2) the action does not require long-term maintenance, (3) there is a limited or minimized need for institutional controls, and (4) there is reasonable long-term reliability of engineering controls and protectiveness from residual source via ET cover system (i.e., ET cover provides barrier from human health contact, and low permeability to reduce infiltration and leaching to groundwater).	Overall Score: +
2. Reduction of Toxicity, Mobility, or Volume through Treatment	• Source removal is considered a physical removal and relocation. • Removal volume (saturated zone) estimated at 4,444 cubic yards placed under ET cover • For conservatism, the saturated soils within the source removal area are assumed to represent 70 percent of the current source mass (alternatively stated, the source removal alternative would leave 30 percent remaining source mass).	This alternative provides a high degree [score +] of reduction to toxicity and/or mobility to groundwater via physical removal of assumed 70% of saturated zone source and placement within unsaturated zone beneath the ET cover.	Overall Score: +
3. Short-term Effectiveness	• Human Health (offsite/community): There are no known risks to the community for this type of alternative. • Human Health (onsite workers): Construction activities for this type of removal action are expected to be completed in a relatively short duration (e.g., up to 3 months); however, the construction-related activities and conditions could pose 'moderate' short-term risks to workers related to the following: – Airborne dust (with selenium and arsenic-laden soils) – Management of contaminated soils – Management of contaminated groundwater – Enhanced onsite traffic/haul routes related to removal/disposal activities – Steep slopes/shoring; fall hazards with open excavation. • Environmental Impacts: In the short-term, the site disturbance related to soil removal actions would be expected to increase/spike concentrations in groundwater. However, potential increases in groundwater would be expected to be a short-duration phenomenon, with established effectiveness in groundwater estimated at approximately 10 years. • Schedule/time for design, construction, implementation: Less than or up to 1 year, considering: – Final design, work plan, and agency approval estimated at 4 months. – Subcontractor procurement estimated at 2 months. – Construction/removal activities assumed at up to 4 months (not scheduled or performed during winter months). – .	• Human Health (offsite/community): no known added risks/favorable alternative. [score +] • Human Health (onsite workers): construction-related activities and conditions could pose 'moderate' short-term risks to workers. [score 0] • Environmental Impacts: moderate risks due to the short-term increases/releases in groundwater concentration due to site disturbances; the short-term spikes are expected to change to substantive decreases over time so it's considered a moderate score. [score 0] • Schedule/time for design, construction, and implementation: the overall schedule and amount of time it will take for remedy design, construction, and implementation is considered moderate, given the estimated time of 10 months to fully implement. [score 0] Overall, the potential risks during construction, short-term increases to groundwater concentration, and moderate scheduling/timeframe support a 'neutral' score.	Overall Score: 0
4. Implementability	• Administrative, permits, agency approvals: Administrative elements needed: – Construction-related permitting. – Procurement of subcontractors with expertise and equipment suitable for earthwork and source removal activities and related services. • Constructing, operating, and monitoring the remedy: Assumes the following items: – All soils and groundwater (dewatering) generated/managed for this alternative will be managed onsite. – Contaminated soils in the saturated zone will be hauled a limited distance and placed under the future ET cover (IC-2). – Clean borrow materials from onsite source will be placed back into saturated zone relatively close to excavation area (West Bench). – Unsaturated zone soils will be placed back into the excavation. – Construction activities need to address the following: ➢ Excavation depths (up to 50 feet below ground surface) will require shoring on two sides of excavation; either end of excavation will be ramps with one-way traffic for haul trucks. ➢ The dimensions of removal area will create a tight workspace with one-way traffic through the excavation. ➢ Contractor will need to manage wet soils and groundwater during saturated zone excavation (i.e., dewatering). – The existing groundwater monitoring network is assumed to be suitable for monitoring remedy performance/ effectiveness. • Availability of services and materials [including capacity and location for treatment, storage, disposal]. Factors to consider:	• Administrative, permits, agency approvals: Overall considered technically feasible and readily implementable as the administrative items and permitting are limited. [score +] • Constructing, operating, and monitoring the remedy: Overall considered technically feasible and implementable. However, the sequencing of existing IM work with potential substantial source removal activities would require careful construction planning/design considerations. The magnitude of source removal depth is substantive which will result in shoring techniques and relatively tight workspace within the excavation. Groundwater from within the saturated zone will need to be managed and hauled to onsite treatment plant. Collectively, these technical components related to the removal efforts lend to a moderate. [score 0] • Availability of services and materials: Earthwork contractors are currently working onsite and are readily available. [score +] Although the administrative and availability of services is favorable, the alternative relies largely on deep excavation techniques with shoring elements and dewatering. As such, the overall score is considered 'neutral' and is scored a 0.	Overall Score: 0

TABLE 3-1
Criteria Evaluation for West Selenium Area: Source Removal – Alternative 1

Criteria	Factors/Assumptions	Evaluation	Scoring
	– Access to site is favorable near Helena, Montana. – Construction season for earthwork activities is likely 6 to 8 months (i.e., depending on weather). – A number of earthwork contractors have previously worked or are currently working onsite related to the IM cover, Prickly Pear Creek wetland complex, or other activities. – All excavation/earthwork/borrow materials located onsite; no offsite work or disposal.		
5. Cost	• Total Cost:[a] $2.8M (cost assumptions, accuracy, and limitations described in Appendix C) – Capital Cost: $2.8M. – Long-Term O&M: none/not significant.	Costs are considered relatively 'moderate' based on the Tier II cost scale.	Overall Cost Score: 0

[a] CONFIDENTIAL Business Information – Cost estimates based on rough order of magnitude Class 4 guidance (Association for the Advancement of Cost Engineering, 2005) with expected accuracy of -30 to +50 percent.

Notes:

ET = evapotranspiration
IM = interim measure
M = million
O&M = operations and maintenance

TABLE 3-2
Criteria Evaluation for West Selenium Area: PRB for Selenium – Alternative 2

Criteria	Factors/Assumptions	Evaluation	Scoring
1. Long-term Effectiveness and Permanence	• Mass removal: Reduced downgradient plume from 2,008 kilograms (Tier I interim measure base case) to 1,162 kilograms with 35 percent remaining in downgradient plume. • Plume geometry/volume reductions: Reduced from 1,079 acre-feet (Tier I interim measure base case) to 366 acre-feet with 15 percent of downgradient plume volume remaining above the maximum contaminant limit. • Schedule: The timeframe to establish effectiveness is estimated at roughly 10 years following implementation.	This alternative would provide long-term effectiveness but not permanence as it requires performance evaluation and long-term operations and maintenance. There is limited full-scale/long-term research on passive PRB for selenium performance, resulting in a 'neutral' score.	Overall Score: 0
2. Reduction of Toxicity, Mobility, or Volume through Treatment	• PRB is considered passive treatment as groundwater (flux) flows past/through the reactive materials precipitating dissolved phase contaminant for later removal. The technology relies capture of groundwater downgradient of source and eventual excavation and removal. • The groundwater flux across the PRB (assuming 100-foot width and 6-foot depth) is estimated at 5 to 7 gallons per minute; average selenium concentrations entering the PRB are assumed at 3.0 mg/L, and the treatment target for water exiting the PRB is 0.5mg/L (DEQ-7 criteria). • Passive dissolved phase removal in groundwater for selenium is considered permanent following media excavation and removal. • Volume of PRB media (mulch and limestone) is 444 cubic yards; each media replacement effort will require excavation and disposal as contaminated soil (waste) as residuals management.	This alternative reduces toxicity and mobility however also generates residuals requiring long-term management. Additionally technology has not been pilot tested at site, and limited long-term performance data is available from other sites. Overall score 'neutral' considering limited, site-specific or long-term industry data on dissolved phase capture and handling/management of residuals every 10 to 15 years.	Overall Score: 0
3. Short-term Effectiveness	• Human Health: Construction activities for installing a PRB are expected to be completed in a relatively short duration (such as up to 2 months); however, the construction-related activities and conditions could pose 'moderate' short-term risks related to the following: – Airborne dust (with selenium and arsenic-laden soils) – Management of contaminated soils – Management of contaminated groundwater – Temporary open trenches may be fall hazards during construction – Large earthwork equipment and support trucks for slurry wall materials and PRB media • Environmental Impacts: In the short-term, the site disturbance related to trenching (both slurry wall and PRB) would be expected to increase/spike concentrations in groundwater. However, potential increases in groundwater would be expected to be a short-duration phenomenon, with established effectiveness in groundwater at approximately 10 years. • Schedule/time for design, construction, implementation: The overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'favorable' given the following: – Design, workplan, subcontractor procurement estimated at 4 months. – Trenching/slurry wall/PRB installation activities assumed at up to 2 months. –	• Human Health (offsite/community): no known added risks/favorable alternative. [score +] • Human Health (onsite workers): construction-related activities and conditions could pose moderate, short-term risks to workers. [score 0] • Environmental Impacts: limited risks/impacts given the relatively small trenching area and short duration to construct. [score +] • Schedule/time for design, construction, and implementation: the overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'favorable' given the time estimated at 8 months to fully implement. [score +] Overall, considering there are limited risks to environment and human health (onsite) and relatively short duration to implement lends to a 'positive' score.	Overall Score: +
4. Implementability	• Administrative, permits, agency approvals. Administrative elements are considered 'easy' assuming the following will be needed: – Construction permitting. – Procurement of subcontractors with expertise and equipment suitable for trenching/excavation in alluvium with cobbles and boulders down to 50 feet bgs, and related slurry wall and PRB materials. • Constructing, operating, and monitoring the remedy. The PRB system to passively treat selenium in groundwater is considered moderate given the following assumptions: – Sparse literature is available on full-scale construction of passive treatment of selenium in groundwater. Implementation of PRB would require a pilot-study and is more complex than other PRBs used (such as zero-valent iron). – Installation of PRB system will require trenching with long-stick excavator to remove alluvial with cobbles and boulders down to about 50 feet bgs to contact the ash/clay layer. – Additional installation of monitoring for PRB to complexity and lack of pilot testing, long-term data from other systems. • Availability of services and materials [including capacity and location for treatment, storage, disposal]. The availability of services/materials is considered moderate' given the following assumptions: – Access to site is favorable near Helena, Montana.	• Administrative, permits, agency approvals: overall considered technically feasible and readily implementable as the administrative items and permits are standard. [score +] • Constructing, operating, and monitoring the remedy: overall considered implementable from a construction standpoint. Although, trenching through cobbles and boulders down to 50 feet bgs may pose construction challenges. Long-term monitoring will be needed to evaluate effectiveness and when media need replacement. [score 0] • Availability of services and materials: the trenchwork will require specialty 'long-arm' excavator, which are costly and not readily available. This scenario may pose moderate delays to project implementation schedule. [score 0] Considering this uncertainty with design and long-term implementation lends to a 'neutral' score.	Overall Score: 0

TABLE 3-2
Criteria Evaluation for West Selenium Area: PRB for Selenium – Alternative 2

Criteria	Factors/Assumptions	Evaluation	Scoring
	– Construction season for earthwork activities is likely 6 to 8 months (depending on weather). – Trenching work will require large Komatsu 1250 excavator to manage and remove boulders. – Media consist of organic mulch and limestone sand – both are readily available. – PRB construction may require specialty subcontractor with experience in PRBs – this may impact availability/scheduling of subcontractors.		
5. Cost	• Total Cost:[a] $2.8M (cost assumptions, accuracy, and limitations described in Appendix C) – Capital Cost: $1.5M. – Long-Term O&M: $1.3M (assumes media replacement years 10 and 20).	Costs are considered 'moderate' based on the Tier II cost scale.	Overall Cost Score: 0

[a] CONFIDENTIAL Business Information – Cost estimates based on rough order of magnitude Class 4 guidance (Association for the Advancement of Cost Engineering, 2005) with expected accuracy of -30 to +50 percent.

Notes:

bgs = below ground surface
ET = evapotranspiration
ICS = Interim Cover System
MDEQ = Montana Department of Environmental Quality
mg/L = milligram(s) per liter
P&T = pump and treat
PRB = permeable reactive barrier

TABLE 3-3
Criteria Evaluation for West Selenium Area: Slurry Wall Enclosure – Alternative 3

Criteria	Factors/Assumptions	Evaluation	Scoring
1. Long-term Effectiveness and Permanence	• Mass removal: Reduced downgradient plume from 2,008 kilograms (Tier I interim measure base case) to 1,099 kilograms with 33 percent remaining in downgradient plume. • Plume geometry/volume reductions: Reduced from 1,079 acre-feet (Tier I interim measure base case) to 172 acre-feet with 9 percent of downgradient plume volume remaining above maximum contaminant level. • Schedule: The timeframe to establish effectiveness is estimated at roughly 10 years following implementation.	This alternative provides a high-degree of long-term effectiveness given that source is contained. Although a slurry wall is an engineered feature in the subsurface, if installed properly across the saturated zone into ash/clay layer with an effective low permeability (at or < 1x10-6 cm/sec), the slurry wall is considered an equivalent geologic feature and thus permanent. Although groundwater concentrations within the wall are expected to remain high, the modeling simulations over a 50-year period support that the alternative provides a stable and permanent influence in areas downgradient of the slurry wall. Based on the groundwater chemistry for the West Selenium area, the groundwater quality will not adversely degrade or influence the permeability of the wall over time.	Overall Score: +
2. Reduction of Toxicity, Mobility, or Volume through Treatment	• The slurry wall is expected to reduce the contaminant flux from the source area to groundwater by at least two to three orders of magnitude; this process is not considered a treatment process but rather a physical subsurface containment that reduces contaminant flux. • The reduced contaminant flux effects of slurry wall are considered irreversible unless excavated or altered by some invasive means (such as digging, trenching, and drilling). • The volume of contaminated groundwater within the slurry walls is estimated at 323,000 gallons (based on 100 x 450 x 6 feet at 0.16 porosity) with average selenium concentration at about 3.0 milligrams per liter.	This alternative provides reduced toxicity and mobility through containment and does not produce treatment residuals. The process is considered permanent unless the subsurface is intentionally altered by some physical means (such as trenching, digging, and drilling). The groundwater within the slurry wall is expected to remain high concentration over the long-term. However, contaminant mass flux to groundwater is considered to be greatly reduced. Given that elevated concentrations remain within the slurry wall enclosure lends to a 'neutral' score.	Overall Score: 0
3. Short-term Effectiveness	• Human Health: Construction activities for installing a slurry wall are expected to be completed in a relatively short duration (such as up to 2 months); however, the construction-related activities and conditions could pose 'moderate' short-term risks related to the following: – Airborne dust (with selenium and arsenic-laden soils) – Management of contaminated soils (dry and wet) – Temporary open trenches may be fall hazards during construction – Large earthwork equipment and support trucks for slurry wall materials and related construction • Environmental Impacts: In the short-term, the site disturbance related to trenching (slurry wall) would be expected to increase/spike concentrations in groundwater. However, potential increases in groundwater would be expected to be localized and short-duration phenomenon (i.e., less than a couple years), and the overall benefits of the slurry wall would likely occur relatively quickly over the long-term (i.e., noticeable improvement estimated in years 2 and beyond). • Schedule/time for design, construction, implementation: The overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'favorable' given the following: – Final design, work plan, and agency approval estimated at 4 months. – Subcontractor procurement estimated at 2 months. – Trenching, slurry wall, and installation activities assumed at up to 2 months. –	• Human Health (offsite/community): No known added risks/favorable alternative. [score +] • Human Health (onsite workers): Construction-related activities and conditions could pose 'moderate' short-term risks to workers. [score 0] • Environmental Impacts: Limited risks/impacts given the relatively small trenching area and short duration to construct. [score +] • Schedule/time for design, construction, and implementation: The overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'favorable' given the time estimated at 8 months to fully implement. [score +] Overall, the limited risks to environment and human health (onsite) and relatively short duration to implement lends to a 'positive' score.	Overall Score: +
4. Implementability	• Administrative, permits, agency approvals. Administrative elements are considered 'easy' assuming the following will be needed: – Construction permitting – Procurement of subcontractors with expertise and equipment suitable for trenching/excavation in alluvium with cobbles and boulders down to 50 feet bgs, and related slurry wall materials • Constructing, operating, and monitoring the remedy. The slurry wall enclosure is considered favorable or easy to construct given the following assumptions: – Installation of slurry wall will require trenching with long-stick excavator to remove alluvial with cobbles and boulders down to about 50 feet bgs to contact the ash/clay layer. – Presence of large cobbles and boulders may pose a problem with excavation/trenchwork to keep trench open and/or reach depths down to ash/clay layer. – There are no long-term O&M requirements; monitoring the effectiveness of the alternative may be performed with the existing groundwater monitoring network.	• Administrative, permits, agency approvals: Overall, considered technically feasible and readily implementable as the administrative items and permitting are limited. [score +] • Constructing, operating, and monitoring the remedy: Overall, considered technically feasible and implementable as slurry walls have previously been implemented for the Speiss/Dross and Acid Plant Sediment Drying areas. However, trenching through cobbles and boulders down to 50 feet bgs may pose construction challenges. [score +] • Availability of services and materials: The trenchwork will require specialty 'long-arm' excavator, which are costly and not readily available. This scenario may pose moderate delays to project implementation schedule. [score 0] Although the alternative ranks 'neutral' with regard to specialty equipment and experienced subcontractors, the overall score is considered 'positive' given the administrative/agency approvals and the relatively basic design of the construction elements.	Overall Score: +

TABLE 3-3

Criteria Evaluation for West Selenium Area: Slurry Wall Enclosure – Alternative 3

Criteria	Factors/Assumptions	Evaluation	Scoring
	• Availability of services and materials (including capacity and location for treatment, storage, disposal). The availability of services/materials is considered 'neutral' given: – Access to site is favorable near Helena, Montana. – Construction season for earthwork activities is likely 6 to 8 months (depending on weather). – Trenching work will require large Komatsu 1250 excavator to manage and remove boulders. – Slurry wall materials require moderate quantities of either soil-bentonite (permeabilities of $1x10^{-7}$ cm/sec) or cement-bentonite (permeabilities of $1x10^{-6}$ cm/sec). – Trenching and construction of slurry wall may require specialty subcontractor with experience in handling large boulders, keeping trenches open, and mixing soil-bentonite or cement-bentonite walls.		
5. Cost	• Total Cost:[a] \$1.6M (cost assumptions, accuracy, and limitations described in Appendix C) – Capital Cost: \$1.6M – Long-Term O&M: None	Costs are considered relatively 'low' based on the Tier II cost scale.	Overall Cost Score: +

[a] CONFIDENTIAL Business Information – Cost estimates based on rough order of magnitude Class 4 guidance (Association for the Advancement of Cost Engineering, 2005) with expected accuracy of -30 to +50 percent.

Notes:

bgs = below ground surface
cm/sec = centimeters per second
M = million
O&M = operations and maintenance

TABLE 3-4
Criteria Evaluation for West Selenium Area: Focused Pump and Treat – Alternative 4

Criteria	Factors/Assumptions	Evaluation	Scoring
1. Long-term Effectiveness and Permanence	• Mass removal: Reduced downgradient plume from 2,008 kilograms (Tier I interim measure base case) to 845 kilograms with 26 percent remaining in downgradient plume. • Plume geometry/volume reductions: Reduced from 1,079 acre-feet (Tier I interim measure base case) to 137 acre-feet with 7 percent of downgradient plume volume remaining above maximum contaminant level. • Schedule: The timeframe to establish effectiveness is estimated at roughly 10 years following implementation.	This alternative provides a high-degree of long-term effectiveness given the groundwater (mass) is reduced from 61 percent (interim measure base case) to 26 percent. However, the permanence relies on maintaining a functional and effective groundwater extraction and treatment system that remains in place long-term (greater than 30 years). Although P&T is effective, its score is given a 'neutral' because the permanence depends on an active extraction and treatment system, operations and maintenance, and replacement.	Overall Score: 0
2. Reduction of Toxicity, Mobility, or Volume through Treatment	• The technology is an active and ex-situ process which requires capture of groundwater, removal of dissolved phase contaminants through precipitation, and effluent discharge to surface water. The technology relies on source capture from dissolved phase in groundwater and produces treatment residuals (effluent discharge to surface water and spent reactive media). • The BCR beds have a finite life and will need replacement; spent media will need to be disposed of as treatment residuals. • The oxidation ponds are designed to settle solids and will require periodic cleanout and generate residuals for management and disposal. • The flows to achieve plume capture are estimated at 25 to 30 gallons per minute; these flow-rates are anticipated over the long-term. Concentrations are currently about 3.0 milligrams per liter and are expected to remain high over the long-term. • The volume of media (mulch and limestone in the BCR systems) over a 30-year period is estimated at 37,200 cubic yards (which assumes original installation and replacements in year 10 and 20) and will generate additional residuals for management and disposal.	This alternative relies on capture and removal of dissolved phase from source in groundwater, and reducing toxicity and mobility downgradient in groundwater, while generating surface water effluent and residuals that will require offsite disposal. Overall score 'neutral' considering that only extracted groundwater is treated and given the amount of treatment residuals.	Overall Score: 0
3. Short-term Effectiveness	• Human Health: Construction activities for installing the groundwater extraction system and the semipassive treatment system are expected to be completed in a moderate duration (such as up to 12 months); and the construction-related activities and conditions could pose 'moderate' short-term risks related to the following [i.e., earthwork related to trenching and regrading for treatment system]: – Airborne dust (with selenium and arsenic-laden soils) – Management of contaminated soils – Management of contaminated groundwater – Temporary open trenches may be fall hazards during construction – Large earthwork equipment and support trucks for slurry wall materials and permeable reactive barrier media • Environmental Impacts: In the short-term, there are no substantive environmental impacts; the extraction system would require drilling and limited impacts; the treatment system would require regrading but no known impacts to the environment. • Schedule/time for design, construction, implementation: The overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'favorable' given the following: – Final design, work plan, and agency approval estimated at 4 months. – Subcontractor procurement estimated at 2 months. – Drilling/extraction system activities assumed at up to 2 months. – Piping/trenchwork from extraction system to treatment system; and from treatment system to discharge point, estimated at up to 2 months. – Treatment system (e.g., build BCRs, ox ponds, riprap channels) estimated at 6 months.	• Human Health (offsite/community): No known added risks/favorable alternative. [score +] • Human Health (onsite workers): Construction-related activities and conditions could pose 'moderate' short-term risks to workers. [score 0] • Environmental Impacts: Limited risks/impacts given the relatively small trenching area and short duration to construct. [score +] • Schedule/time for design, construction, and implementation: The overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'moderate' given the time estimated at 12 months to fully implement. [score 0] Overall, considered 'positive' score given the limited impacts or risks to human health and the environment.	Overall Score: +
4. Implementability	• Administrative, permits, agency approvals. Administrative elements are considered 'difficult' assuming the following will be needed: – Construction permitting – Discharge Permitting – Procurement of subcontractors with expertise and equipment suitable for: ➢ Installing extraction system (driller) ➢ Installing treatment system, including earthwork, piping, electrical, mechanical • Constructing, operating, and monitoring the remedy. The P&T system is considered 'difficult' given the following assumptions:	• Administrative, permits, agency approvals: Overall considered complex given agency approval of alternative including discharge permit. [score 0] • Constructing, operating, and monitoring the remedy: Overall considered complex considering the groundwater extraction system, conveyance pipe, treatment system, and winterization factors for the BCRs and oxidation ponds, additional area for wetlands. [score -] • Availability of services and materials: The trenchwork will require specialty 'long-arm' excavator, which are costly and not readily available. This scenario may pose moderate delays to project implementation schedule. [score 0]	Overall Score: -

TABLE 3-4

Criteria Evaluation for West Selenium Area: Focused Pump and Treat – Alternative 4

Criteria	Factors/Assumptions	Evaluation	Scoring
	– Construction elements include (1) drilling and installation of extraction system, (2) trenching for conveyance pipe, (3) regrading for treatment system, (4) treatment system [ponds, plumbing, mechanical, structural, and winterization components]. – Operations include (1) maintenance of extraction system, (2) maintenance of BCR and oxidation ponds; including periodic replacement of media and cleanout of oxidation ponds, and (3) monitoring effluent quality, and 4) operations during winter months – Monitoring the effectiveness of effluent discharge quality will be required routinely [likely monthly] (per the discharge permit). • Availability of services and materials [including capacity and location for treatment, storage, disposal]. The availability of services/materials is considered 'moderate' given: – Access to site is favorable near Helena, Montana. – Construction season for earthwork activities is likely 6 to 8 months (depending on weather). – Extraction (well) system will require drilling subcontractor. – Treatment system will require multiple specialty subcontractors (e.g., electrical, earthwork/piping/plumbing, mechanical).	Overall, the need for effluent discharge to surface water (wetland or PPC), complexity of winterization and extended cold weather operations, and O&M and monitoring for 30+ years, lends to a 'negative' score.	
5. Cost	• Total Cost:[a] $4.0M (cost assumptions, accuracy, and limitations described in Appendix C) – Capital Cost: $2.3M – Long-Term O&M: $1.7M (assumes media replacement years 10 and 20)	Costs are considered 'moderate' based on the Tier II cost scale.	Overall Cost Score: 0

[a] CONFIDENTIAL Business Information – Cost estimates based on rough order of magnitude Class 4 guidance (Association for the Advancement of Cost Engineering, 2005) with expected accuracy of -30 to +50 percent.

Notes:

BCR = biochemical reactor
M = million
O&M = operations and maintenance
P&T = pump and treat

TABLE 3-5
Criteria Evaluation for North Plant Area: PRB for Arsenic – Alternative 5

Criteria	Factors/Assumptions	Evaluation	Scoring
1. Long-term Effectiveness and Permanence	• Mass removal: Reduced downgradient plume from 377 kilograms (Tier I interim measure base case) to 250 kilograms with 17 percent remaining in downgradient plume. • Plume geometry/volume reductions: Reduced from 381 acre-feet (Tier I interim measure base case) to 392 acre-feet with 105 percent of plume remaining above maximum contaminant level (increased plume volume resulting from PRB influenced on groundwater flow. • Schedule: The timeframe to establish effectiveness is estimated at roughly 10 years following implementation.	In comparison to the IM base case, this alternative provides a marginal degree of improvement in groundwater source mass and a negligible effect on plume geometry concentration above the MCL. This alternative would provide long-term effectiveness but given a 'neutral' score as it requires long-term operations and maintenance.	Overall Score: 0
2. Reduction of Toxicity, Mobility, or Volume through Treatment	• PRB is considered passive treatment as groundwater (flux) flows past/through the reactive materials precipitating dissolved phase contaminant for later removal. The technology relies capture of groundwater downgradient of source and eventual excavation and removal. • The groundwater flux across the PRB (assuming 500-foot width and 13-foot depth) is estimated at 40 to 50 gallons per minute; average arsenic concentrations entering the PRB are assumed at 25 to 30 mg/L, and the Montana Department of Environmental Quality treatment target for water exiting the PRB is 0.01 mg/L. Toxicity and mobility are reduced, while plume extent relative of MCL remains relatively the same. • Passive dissolved phase removal in groundwater for arsenic is considered permanent following media excavation and removal. • Volume of PRB media (ZVI—granular iron) is 2,370 cubic yards; each media replacement effort will require excavation and disposal as contaminated soil (waste) as residuals management.	This alternative generates residuals requiring long-term management. Toxicity and mobility are relatively unchanged with plume concentrations reduced, but relatively minor changes in plume geometry above the MCL for arsenic. Overall score 'negative' considering long-term O&M, handling/management of treatment residuals every 10 to 15 years, and limited reductions in plume mobility and toxicity.	Overall Score: -
3. Short-term Effectiveness	• Human Health: Construction activities for installing a PRB are expected to be completed in a relatively short duration (such as up to 2 months); however, the construction-related activities and conditions could pose 'moderate' short-term risks related to the following: – Airborne dust (with selenium and arsenic-laden soils) – Management of contaminated soils – Management of contaminated groundwater – Temporary open trenches may be fall hazards during construction – Large earthwork equipment and support trucks for slurry wall materials and PRB media • Environmental Impacts: In the short-term, the site disturbance related to trenching (both slurry wall and PRB) would be expected to increase/spike concentrations in groundwater. However, potential increases in groundwater would be expected to be a short-duration phenomenon, with established effectiveness in groundwater at approximately 10 years. • Schedule/time for design, construction, implementation: The overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'favorable' given the following: – Final design, work plan, and agency approval estimated at 4 months. – Subcontractor procurement estimated at 2 months. – Trenching, slurry wall, and PRB installation activities assumed at up to 4 months.	• Human Health (offsite/community): No known added risks/favorable alternative. [score +] • Human Health (onsite workers): Construction-related activities and conditions could pose 'moderate' short-term risks to workers. [score 0] • Environmental Impacts: Limited risks/impacts given the relatively small trenching area and short duration to construct. [score +] • Schedule/time for design, construction, and implementation: The overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'moderate' given the time estimated at 10 months to fully implement. [score 0] Overall, considering there are limited risks to environment and human health (onsite) and relatively short duration to implement lends to a 'positive' score.	Overall Score: +
4. Implementability	• Administrative, permits, agency approvals. Administrative elements are considered 'easy' assuming the following will be needed: – Construction permitting. Procurement of subcontractors with expertise and equipment suitable for trenching/ excavation in alluvium with cobbles and boulders down to 50 feet bgs, and related slurry wall and PRB materials. • Constructing, operating, and monitoring the remedy. Construction of PRB system is considered 'moderate' given the following assumptions: – Installation of PRB system will require trenching with long-stick excavator to remove alluvial with cobbles and boulders down to about 50 feet bgs to contact the ash/clay layer. • Availability of services and materials (including capacity and location for treatment, storage, disposal). The availability of services/materials is considered 'moderate' given: – Access to site is favorable near Helena, Montana. – Construction season for earthwork activities is likely 6 to 8 months (depending on weather). – Trenching work will require large Komatsu 1250 excavator to manage and remove boulders. – Media consist of ZVI granular iron which is not readily available – nearest vendor is Detroit, Michigan.	• Administrative, permits, agency approvals: Overall considered technically feasible and readily implementable as the administrative items and permits are standard. [score +] • Constructing, operating, and monitoring the remedy: Overall considered implementable from a construction standpoint, while trenching through cobbles and boulders down to 50 feet bgs may pose construction challenges. Long-term monitoring will be needed to evaluate effectiveness and when media needs replacement. [score 0] • Availability of services and materials: The trenchwork will require specialty 'long-arm' excavator, which are costly and not readily available. This scenario may pose moderate delays to project implementation schedule. In addition, the ZVI media (granular iron) is costly and the nearest vendor is Detroit, Michigan; delivery of large quantities may require significant lead-time for delivery. [score 0] Considering the specialty excavator equipment and long lead-time for ZVI material lends to a 'neutral' score.	Overall Score: 0

TABLE 3-5

Criteria Evaluation for North Plant Area: PRB for Arsenic – Alternative 5

Criteria	Factors/Assumptions	Evaluation	Scoring
	– PRB construction may require specialty subcontractor with experience in PRBs; this may impact availability and scheduling of subcontractors.		
5. Cost	• Total Cost:[a] $20.3M (cost assumptions, accuracy, and limitations described in Appendix C) – Capital Cost: $9.9M – Long-Term O&M: $10.3M (assumes media replacement years 10 and 20)	Costs are considered 'high' based on the Tier II cost scale. Cost for media (ZVI granular iron) accounts for about 75 percent of total capital cost for installation.	Overall Cost Score: -

[a] CONFIDENTIAL Business Information – Cost estimates based on rough order of magnitude Class 4 guidance (Association for the Advancement of Cost Engineering, 2005) with expected accuracy of -30 to +50 percent.

Notes:

bgs = below ground surface
M = million
MCL = maximum contaminant level
mg/L = milligrams per liter
O&M = operations and maintenance
PRB = permeable reactive barrier
ZVI = zero-valent iron

TABLE 3-6
Criteria Evaluation for North Plant Area: Slurry Wall Enclosure – Alternative 6

Criteria	Factors/Assumptions	Evaluation	Scoring
1. Long-term Effectiveness and Permanence	• Mass removal: Reduced downgradient plume from 377 kilograms (Tier I interim measure base case) to 176 kilograms with 12 percent remaining in downgradient plume. • Plume geometry/volume reductions: Increased from 381 acre-feet (Tier I interim measure base case) to 389 acre-feet to 104 percent of downgradient plume volume remaining above maximum contaminant level as a result of changes in the groundwater flow due to slurry wall. • Schedule: The timeframe to establish effectiveness is estimated at roughly 10 years following implementation. • Contaminant flux: The reduced contaminant flux effects due to the slurry wall are considered stable or permanent reductions unless the slurry walls are excavated or altered by some invasive means (such as digging, trenching, and drilling).	In comparison to the IM base case, this alternative provides a marginal degree of improvement in groundwater source mass and a negligible effect on plume geometry concentration above the maximum contaminant level. Although a slurry wall is an engineered feature in the subsurface, if installed properly across the saturated zone down to ash/clay layer with an effective low permeability (at or < $1x10^{-6}$ cm/sec), the slurry wall is considered an equivalent geologic feature and thus permanent. Although groundwater concentrations within the wall are expected to remain high, the modeling simulations over a 50-year period support that the alternative provides a stable and permanent influence in areas downgradient of the slurry wall. Based on the groundwater chemistry for North Plant, the groundwater quality will not adversely degrade or influence the permeability of the wall over time.	Overall Score: 0
2. Reduction of Toxicity, Mobility, or Volume through Treatment	• The slurry wall provides source containments and reduces mass flux to groundwater outside the slurry wall perimeter. • The volume of contaminated groundwater within the slurry walls is estimated at 9.7M gallons (based on 500 x 200 x 13 feet at 0.18 porosity) with an average arsenic concentration at about 25 to 30 milligrams per liter.	This alternative provides reduced toxicity and mobility through containment and does not produce treatment residuals. The process is considered permanent unless the subsurface is intentionally altered by some physical means (such as trenching, digging, and drilling). Groundwater concentrations within the slurry wall are expected to remain high concentration over the long-term. In addition, the net reduction in toxicity and/or mobility of Tier II IM in comparison to Tier I IM case is limited, which supports a 0 (neutral) score.	Overall Score: 0
3. Short-term Effectiveness	• Human Health: Construction activities for installing a slurry wall are expected to be completed in a relatively short duration (such as up to 2 months); however, the construction-related activities and conditions could pose 'moderate' short-term risks related to the following: – Airborne dust (with selenium and arsenic-laden soils) – Management of contaminated soils (dry and wet) – Temporary open trenches may be fall hazards during construction – Large earthwork equipment and support trucks for slurry wall materials and related construction • Environmental Impacts: In the short-term, the site disturbance related to trenching (slurry wall) would be expected to increase/spike concentrations in groundwater. However, potential increases in groundwater would be expected to be localized and short-duration phenomenon (i.e., less than a couple years), and the overall benefits of the slurry wall would likely occur relatively quickly over the long-term (i.e., noticeable improvement in years 2 and beyond). • Schedule/time for design, construction, implementation: The overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'favorable' given the following: – Final design, work plan, and agency approval estimated at 4 months. – Subcontractor procurement estimated at 2 months. – Trenching, slurry wall, and installation activities assumed at up to 4 months.	• Human Health (offsite/community): no known added risks/favorable alternative. [score +] • Human Health (onsite workers): construction-related activities and conditions could pose 'moderate' short-term risks to workers. [score 0] • Environmental Impacts: limited risks/impacts given the relatively small trenching area and short duration to construct. [score +] • Schedule/time for design, construction, and implementation: the overall schedule and amount of time it will take for remedy design, construction, and implementation is considered 'moderate' given the time estimated at 10 months to fully implement. [score 0] Overall, the limited risks to environment and human health (onsite) and relatively short duration to implement lend to a 'positive' score.	Overall Score: +
4. Implementability	• Administrative, permits, agency approvals. Administrative elements are considered 'easy' assuming the following will be needed: – Work plan - describing the slurry wall as a remedial system in groundwater will require agency (U.S. Environmental Protection Agency) approval. – Procurement of subcontractors with expertise and equipment suitable for trenching/excavation in alluvium with cobbles and boulders down to 50 feet bgs, and related slurry wall materials. • Constructing, operating, and monitoring the remedy. The slurry wall enclosure is considered favorable or easy to construct given the following assumptions: – Installation of slurry wall will require trenching with long-stick excavator to remove alluvial with cobbles and boulders down to about 50 feet bgs to contact the ash/clay layer. – Presence of large cobbles and boulders may pose a problem with excavation/trenchwork to keep trench open and/or reach depths down to ash/clay layer. – There are no long-term O&M requirements; monitoring the effectiveness of the alternative may be performed with the existing groundwater monitoring network. • Availability of services and materials [including capacity and location for treatment, storage, disposal]. The availability of services/materials is considered 'neutral' given:	• Administrative, permits, agency approvals: Overall considered technically feasible and readily implementable as the administrative items are limited and no permits are required. [score +] • Constructing, operating, and monitoring the remedy: Overall considered technically feasible and implementable as slurry walls have been implemented for the Speiss/Dross and Acid Plant Sediment Drying areas. However, trenching through cobbles and boulders down to 50 feet bgs may pose construction challenges. [score +] • Availability of services and materials: The trenchwork will require specialty 'long-arm' excavator, which are costly and not readily available. This scenario may pose moderate delays to project implementation schedule. [score 0] Although the alternative ranks 'neutral' with regard to specialty equipment and experienced subcontractors, the overall score is considered 'positive' given the administrative/agency approvals and considering the construction elements are relatively basic in design.	Overall Score: +

TABLE 3-6
Criteria Evaluation for North Plant Area: Slurry Wall Enclosure – Alternative 6

Criteria	Factors/Assumptions	Evaluation	Scoring
	– Access to site is favorable near Helena, Montana. – Construction season for earthwork activities is likely 6 to 8 months (depending on weather). – Trenching work will require large Komatsu 1250 excavator to manage and remove boulders. – Slurry wall materials require moderate quantities of either soil-bentonite (permeabilities of 10^{-7} cm/sec) or cement-bentonite (permeabilities of $1X10^{-6}$ cm/sec). – Trenching and construction of slurry wall may require specialty subcontractor with experience in handling large boulders, keeping trenches open, and mixing soil-bentonite or cement-bentonite walls.		
5. Cost	• Total Cost:[a] $2.0M (cost assumptions, accuracy, and limitations described in Appendix C) – Capital Cost: $2.0M – Long-Term O&M: None	Costs are considered 'moderate' based on the Tier II cost scale.	Overall Cost Score: 0

[a] CONFIDENTIAL Business Information – Cost estimates based on rough order of magnitude Class 4 guidance (Association for the Advancement of Cost Engineering, 2005) with expected accuracy of -30 to +50 percent.

Notes:

bgs = below ground surface
cm/sec = centimeters per second
M = million
O&M = operations and maintenance

TABLE 4-1
Comparative Evaluation Summary

Area	Alternative	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, or Volume through Treatment	Short-Term Effectiveness	Implementability	Cost ($millions)[a] (total cost includes capital and long-term O&M [if applicable])	Combined Balancing Criteria Score
Long-term Effectiveness and Permanence	1 – Source Removal	+	+	0	0	0 **Total Cost: $2.8M** Capital: $2.8M Long-term O&M: none	+2
	2 – PRB for Selenium	0	0	+	0	0 **Total Cost: $2.8M** Capital: $1.5M Long-term O&M: $1.3M	+1
	3 – Slurry Wall Enclosure	+	0	+	+	+ **Total Cost: $1.6M** Capital: $1.6M Long-term O&M: none	+4
	4 –Pump and Treat	0	0	+	-	0 **Total Cost: $4.0M** Capital: $2.3M Long-term O&M: $1.7	0
North Plant (COPC is arsenic)	5 – PRB for Arsenic	0	-	+	0	- **Total Cost: $20.3M** Capital: $9.9M Long-term O&M: $10.3	-1
	6 – Slurry Wall Enclosure	0	0	+	+	0 **Total Cost: $2.1M** Capital: $2.1M Long-term O&M: none	+2
	7 – Slurry Wall Enclosure with Injections	0	+	+	+	0 **Total Cost: $2.5M** Alternative 6: $2.0M Alternative 7 Capital: $0.2M (wells) Alternative 7 Long-term O&M: $0.3M (injections)	+3

[a] CONFIDENTIAL Business Information – Cost estimates based on rough order of magnitude Class 4 guidance (Association for the Advancement of Cost Engineering, 2005) with expected accuracy of -30 to +50 percent.

Notes:

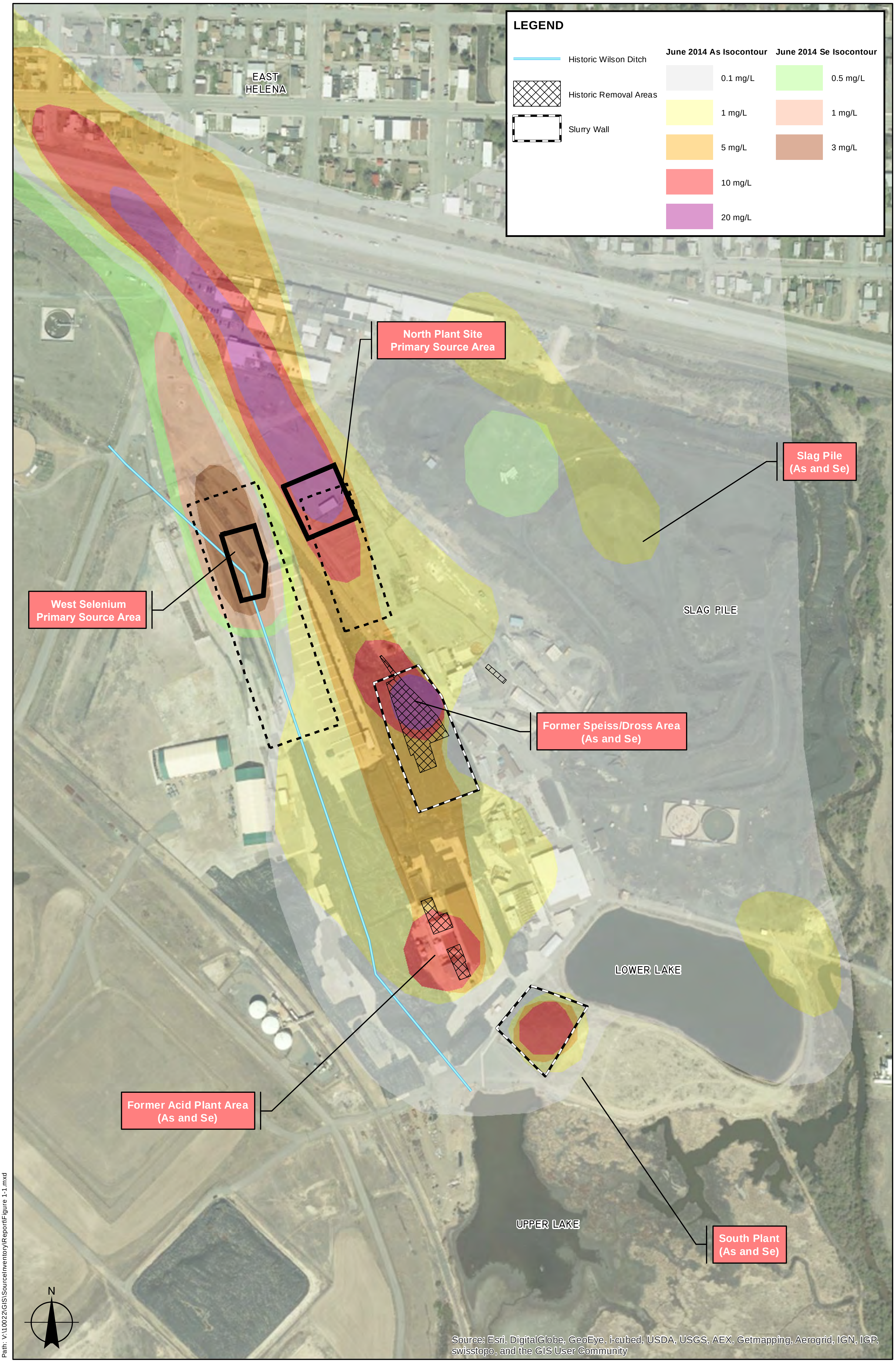
Cost assumptions: Long-term O&M assumed 30 years with Net Present Worth at 5 percent rate of return; refer to Appendix C for supporting rough order of magnitude Class 4 costing information.

Refer to Table 2-1 for alternative description, Table 2-4 for balancing criteria and definitions, and Tables 3-1 through 3-6 for details on the individual balancing criteria evaluation.

Alternative 7 is slurry wall with injections. If Alternative 6 is selected, then the need for Alternative 7 may be evaluated and decided on after the slurry wall is constructed and the effectiveness is evaluated.

COPC = constituent of potential concern
M = million
O&M = operations and maintenance
P&T = pump and treat
PRB = permeable reactive barrier

Figures



0 150 300 600
Scale in Feet

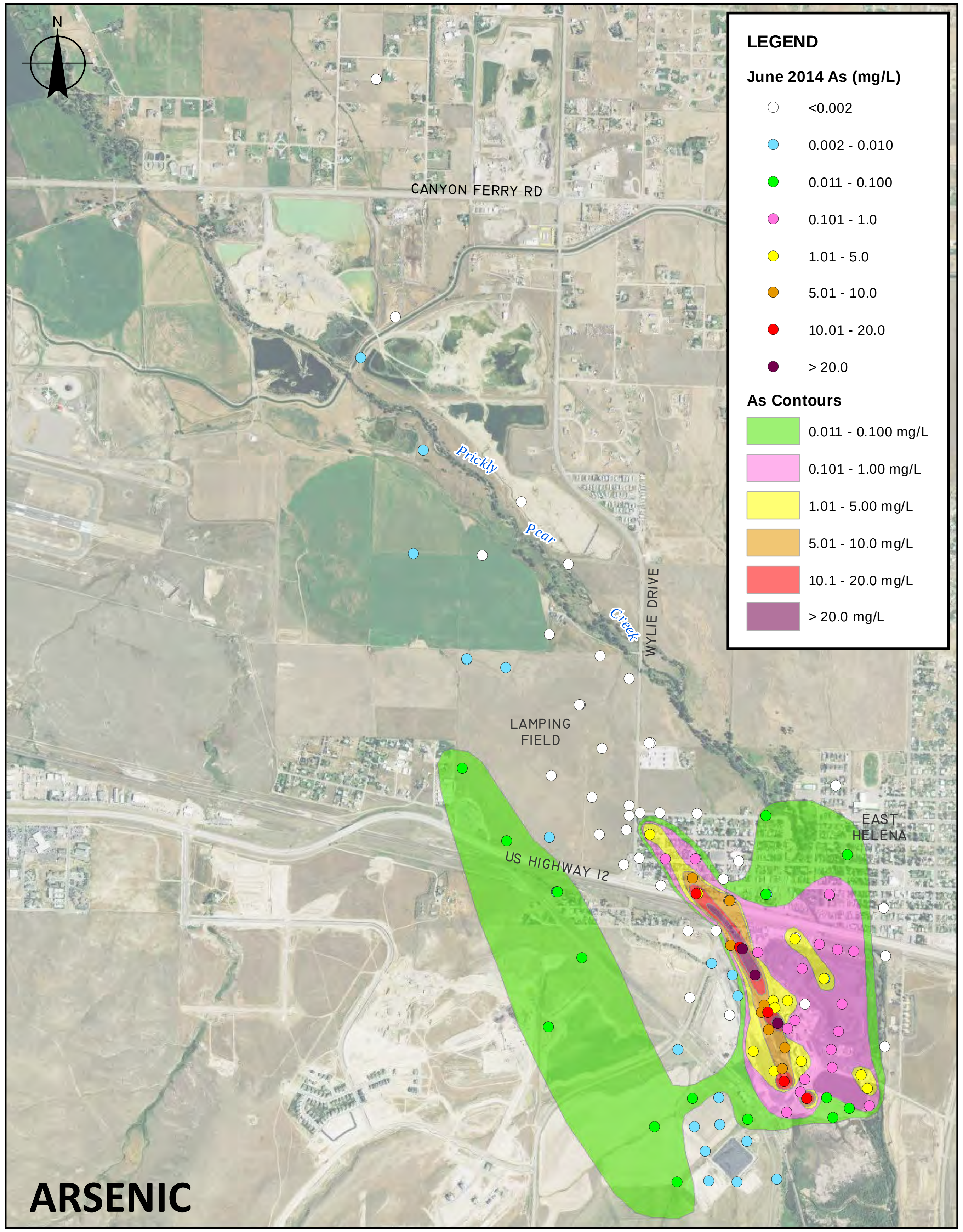
Hydrometrics, Inc.
Consulting Scientists and Engineers

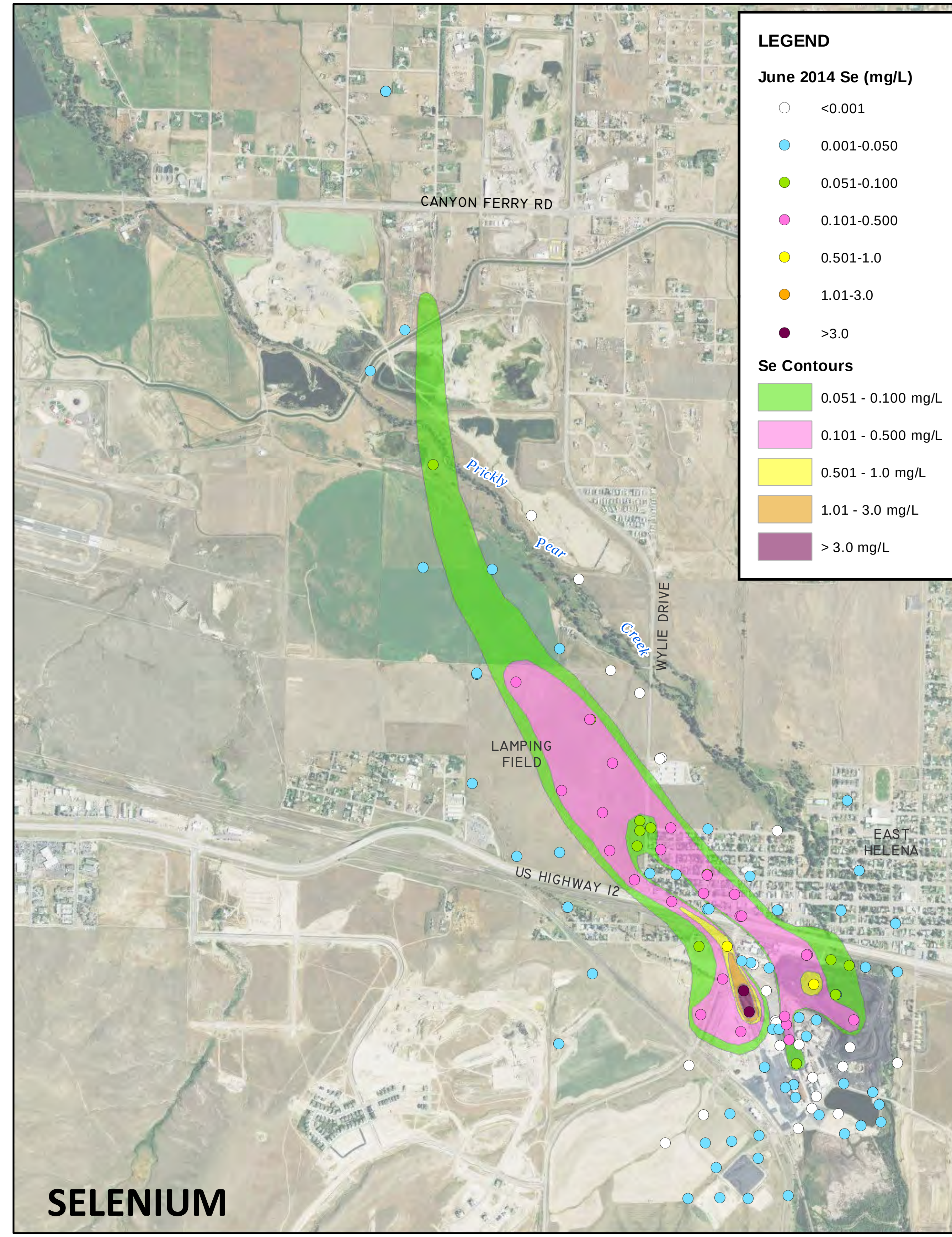
SOURCE: HYDROMETRICS, INC

2014 SUPPLEMENTAL CONTAMINANT SOURCE AREA INVESTIGATION AT THE FORMER EAST HELENA SMELTER

PRIMARY SOURCE AREAS

FIGURE 2-1





Path: V:\10022\GIS\SourceInventoryReport\Figure 1-2.mxd

Hydrometrics, Inc.
Consulting Scientists and Engineers

Date Saved: 1/7/2015 12:40:13 PM

0 1,000 2,000 4,000 Feet

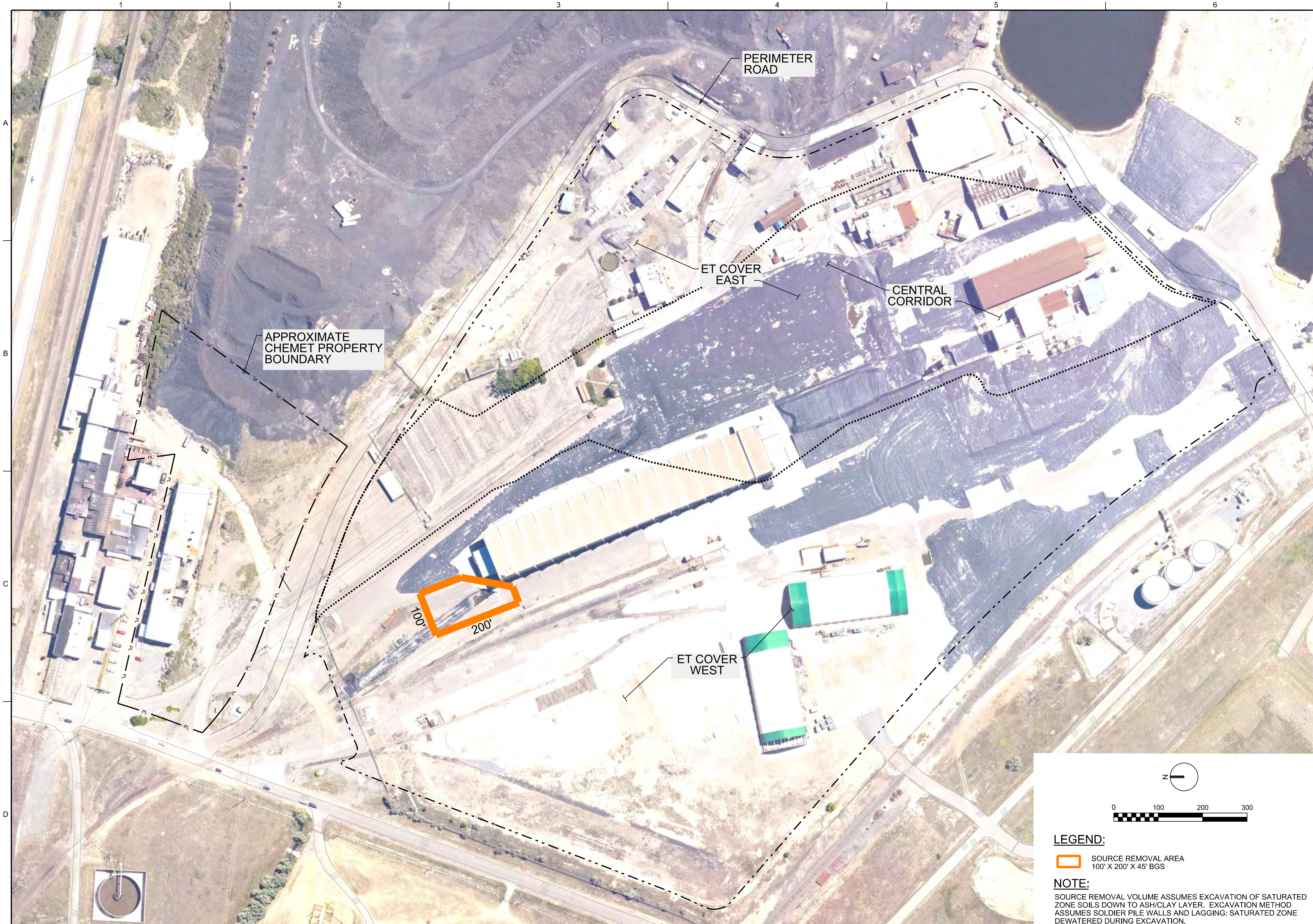
SOURCE: HYDROMETRICS, INC

2014 SUPPLEMENTAL CONTAMINANT SOURCE AREA INVESTIGATION AT THE FORMER EAST HELENA SMELTER

CURRENT EXTENT OF ARSENIC AND SELENIUM PLUMES FORMER EAST HELENA SMELTER

FIGURE

2-2



PRELIMINARY NOT FOR CONSTRUCTION

NO.	DATE	REVISION	BY	APVD
0				

DSGN DR CHK APVD

METG Montana Environmental Trust Group

Former ASARCO Smelter Site
East Helena, Montana
Montana Environmental Trust Group
East Helena, Montana

CH2MHILL

POWER BLOCK BUILDING
7 WEST 6TH AVE. # 519
HELENA, MT 59601-5036
PHONE: (406) 457-5494

TIER II GROUNDWATER SOURCE CONTROL EVALUATION

ALTERNATIVE 1
SOURCE REMOVAL - WEST SELENIUM AREA

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	DECEMBER 2014
PROJ	467300
DWG	FIGURE 2-3
SHEET	1 OF 7

FILENAME: P043_FIG001D_467300.dgn PLOT DATE: 2015\03\05 PLOT TIME: 4:29:32 PM

PRELIMINARY NOT FOR CONSTRUCTION

REVISION			
NO.	DATE	BY	APVD
0			

DSGN | DR | CHK | APVD

METG Montana Environmental Trust Group

Former ASARCO Smelter Site
East Helena, Montana
Montana Environmental Trust Group
East Helena, Montana

CH2MHILL
POWER BLOCK BUILDING
7 WEST 6TH AVE, # 519
HELENA, MT 59601-5036
PHONE: (406) 457-5494

TIER II GROUNDWATER SOURCE CONTROL EVALUATION

ALTERNATIVE 2
PRB - WEST SELENIUM AREA

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	DECEMBER 2014
PROJ	467300
DWG	FIGURE 2-4.1
SHEET	2 OF 7

FILENAME: P043_FIG002D_467300.dgn PLOT DATE: 2015\02\13 PLOT TIME: 8:11:08 AM

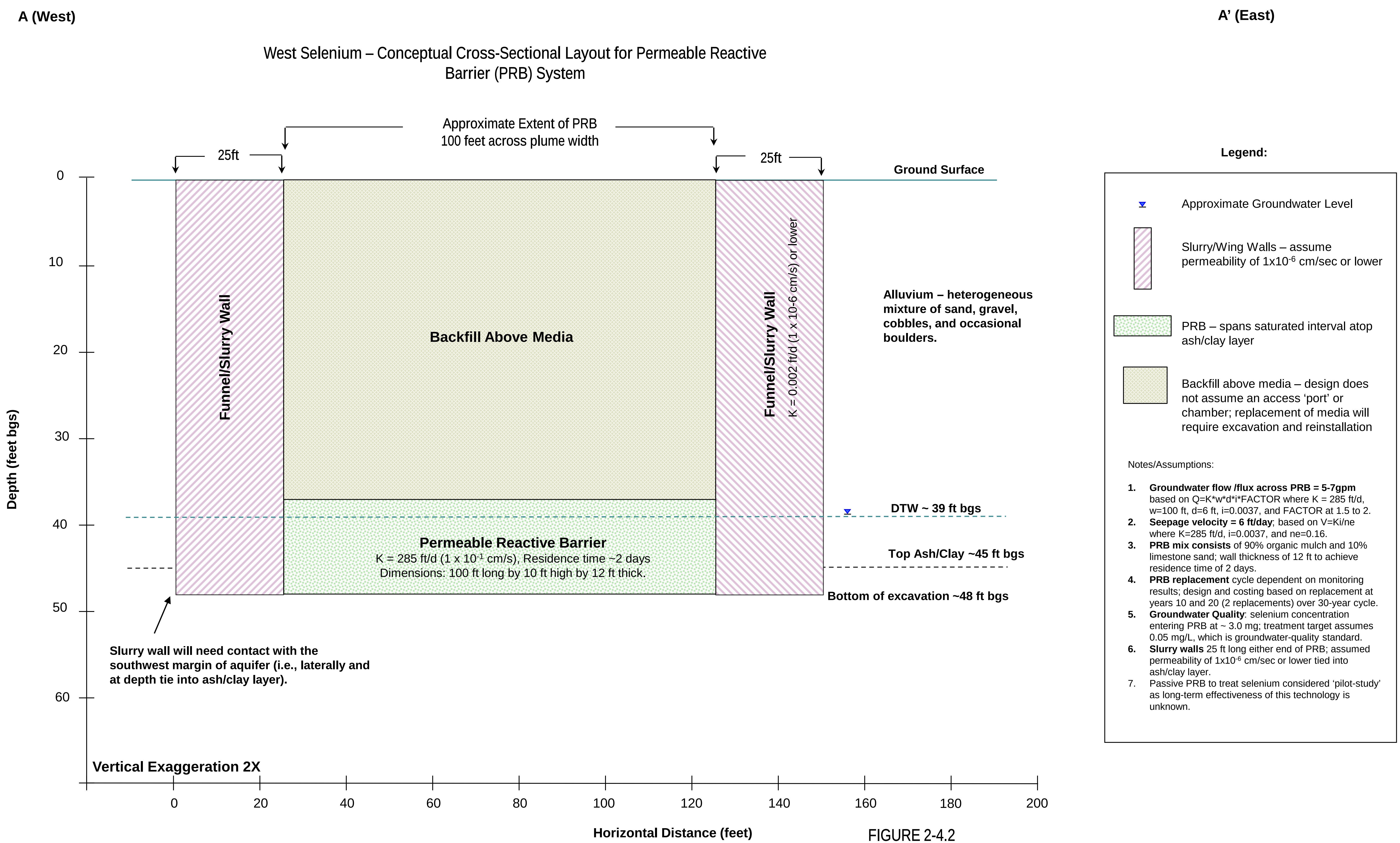
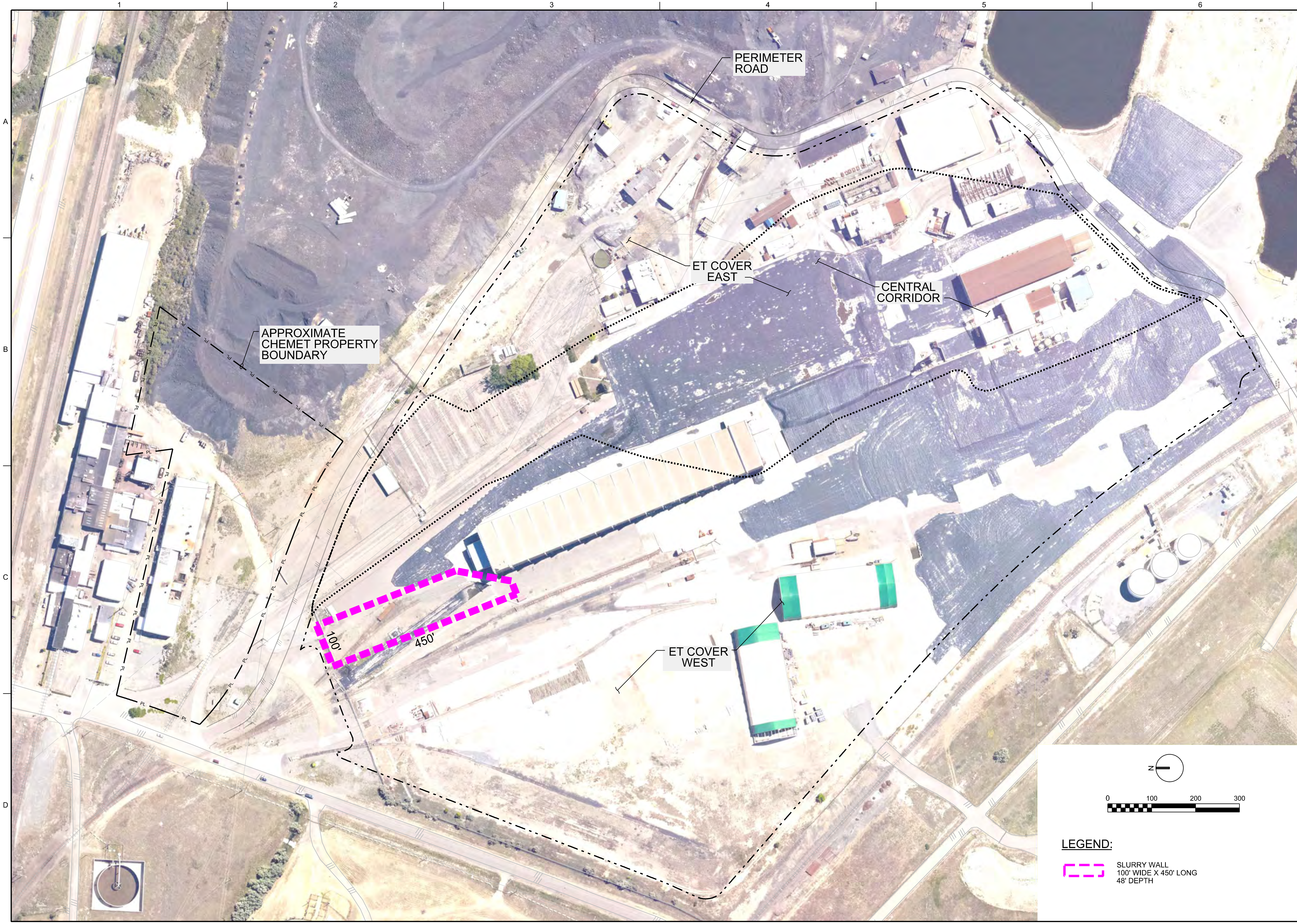


FIGURE 2-4.2
Alternative 2: PRB - West Selenium Area (conceptual layout in cross-section)
Tier II Source Control Evaluation



PRELIMINARY NOT FOR CONSTRUCTION

REVISION | NO. | DATE | DSGN | DR | CHK | APVD | BY | APVD

0

METG Montana Environmental Trust Group

Former ASARCO Smelter Site
East Helena, Montana
Montana Environmental Trust Group
East Helena, Montana

POWER BLOCK BUILDING
7 WEST 6TH AVE. # 519
HELENA, MT 59601-5036
PHONE: (406) 457-5494

CH2MHILL

TIER II GROUNDWATER SOURCE CONTROL EVALUATION

ALTERNATIVE 3
SLURRY WALL ENCLOSURE - WEST SELENIUM AREA

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	DECEMBER 2014
PROJ	467300
DWG	FIGURE 2-5
SHEET	3 OF 7

FILENAME: P043_FIG003D_467300.dgn PLOT DATE: 2015\02\13 PLOT TIME: 8:19:42 AM

0 200 400 600
SCALE IN FEET

LEGEND:

DWR — CONVEYANCE PIPE, PRESSURE, 4"-6" HDPE

TWR — OUTLET PIPE, GRAVITY, 4"-6" HDPE

WELLS AND PUMPS

PASSIVE TREATMENT SYSTEM, GRADED TO DRAIN

NOTE:

REFER TO FIGURE 2-6.2, PROCESS FLOW DIAGRAM

PRELIMINARY NOT FOR CONSTRUCTION

NO.	DATE	REVISION	BY	APVD
0				

DSGN | DR | CHK | APVD

CH2MHILL

POWER BLOCK BUILDING
7 WEST 6TH AVE, # 519
HELENA, MT 59601-5036
PHONE: (406) 457-5494

METG Montana Environmental Trust Group

Former ASARCO Smelter Site
East Helena, Montana
Montana Environmental Trust Group
East Helena, Montana

TIER II GROUNDWATER SOURCE CONTROL EVALUATION

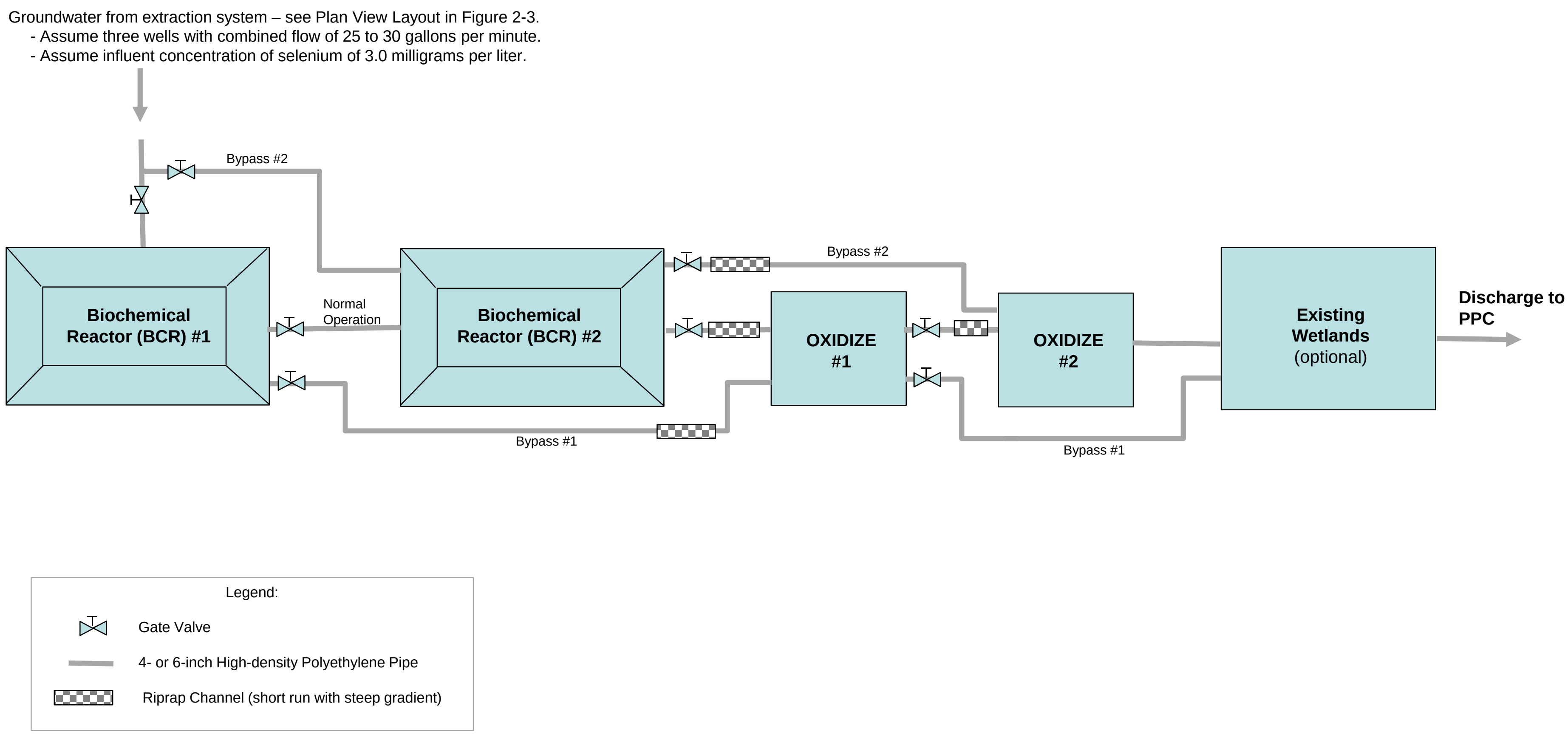
ALTERNATIVE 4
PUMP AND TREAT - WEST SELENIUM AREA

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	DECEMBER 2014
PROJ	467300
DWG	FIGURE 2-6.1
SHEET	4 OF 7

FILENAME: P043_FIG004D_467300.dgn PLOT DATE: 2015\02\13 PLOT TIME: 8:33:59 AM

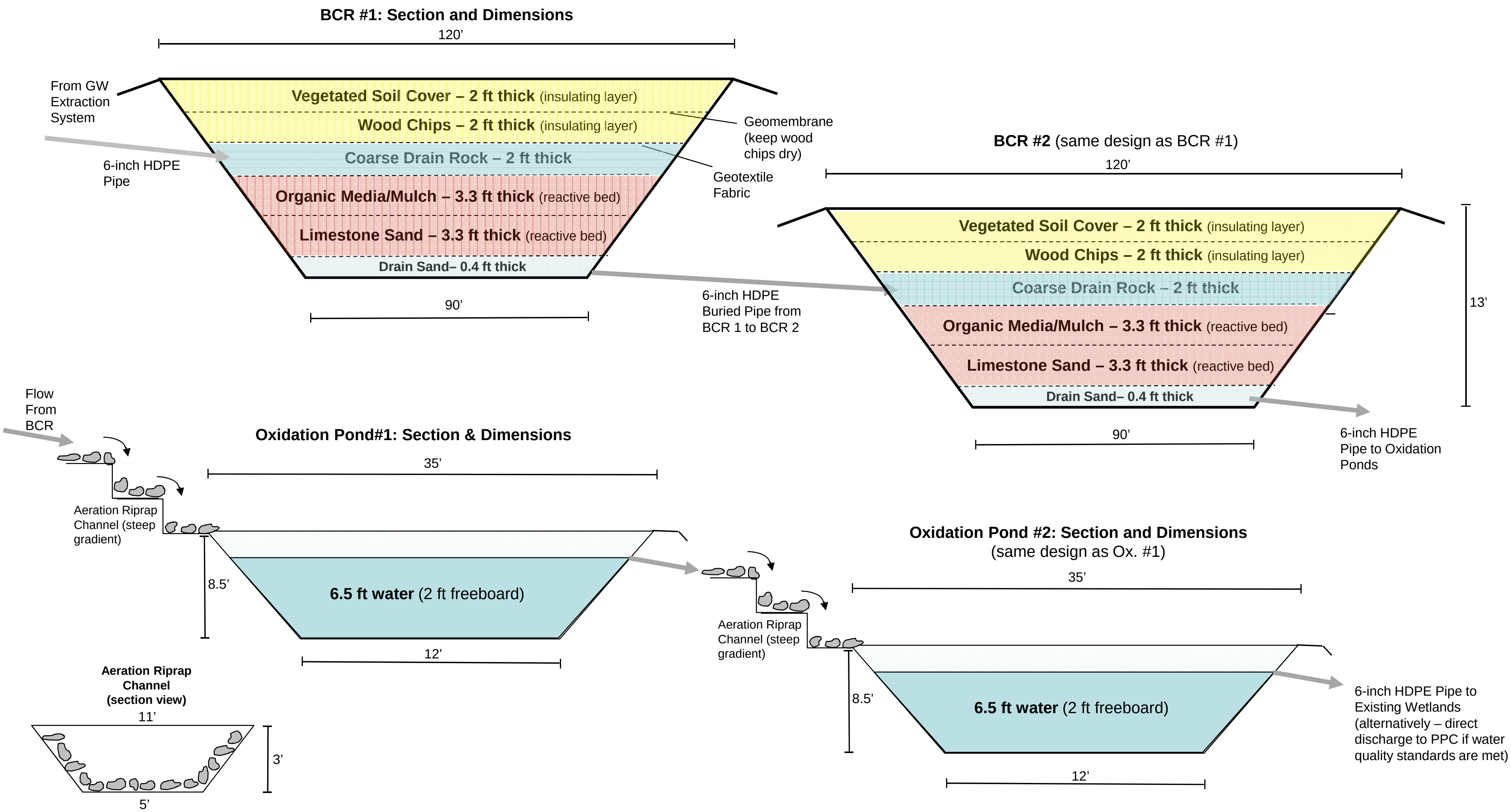
Conceptual Process Flow Diagram – Treatment of Selenium (pg. 1 of 2)



Notes:
1. Design modified from Alternative 6 of the *Crystal Mine Operable Unit 5 Final Interim Record of Decision* (USEPA, 2014).
2. Dual BCR and oxidizer ponds allow bypass for routine maintenance; normal operation is in series through both BCRs & Oxidizer ponds.
3. Effluent to PPC needs to meet surface water aquatic standard of 0.0005 mg/L (chronic).

Figure 2-6.2
Alternative 4 – Process Flow Diagram
Semipassive Treatment System for Selenium
***Tier II Source Control Evaluation* (pg. 1 of 2)**

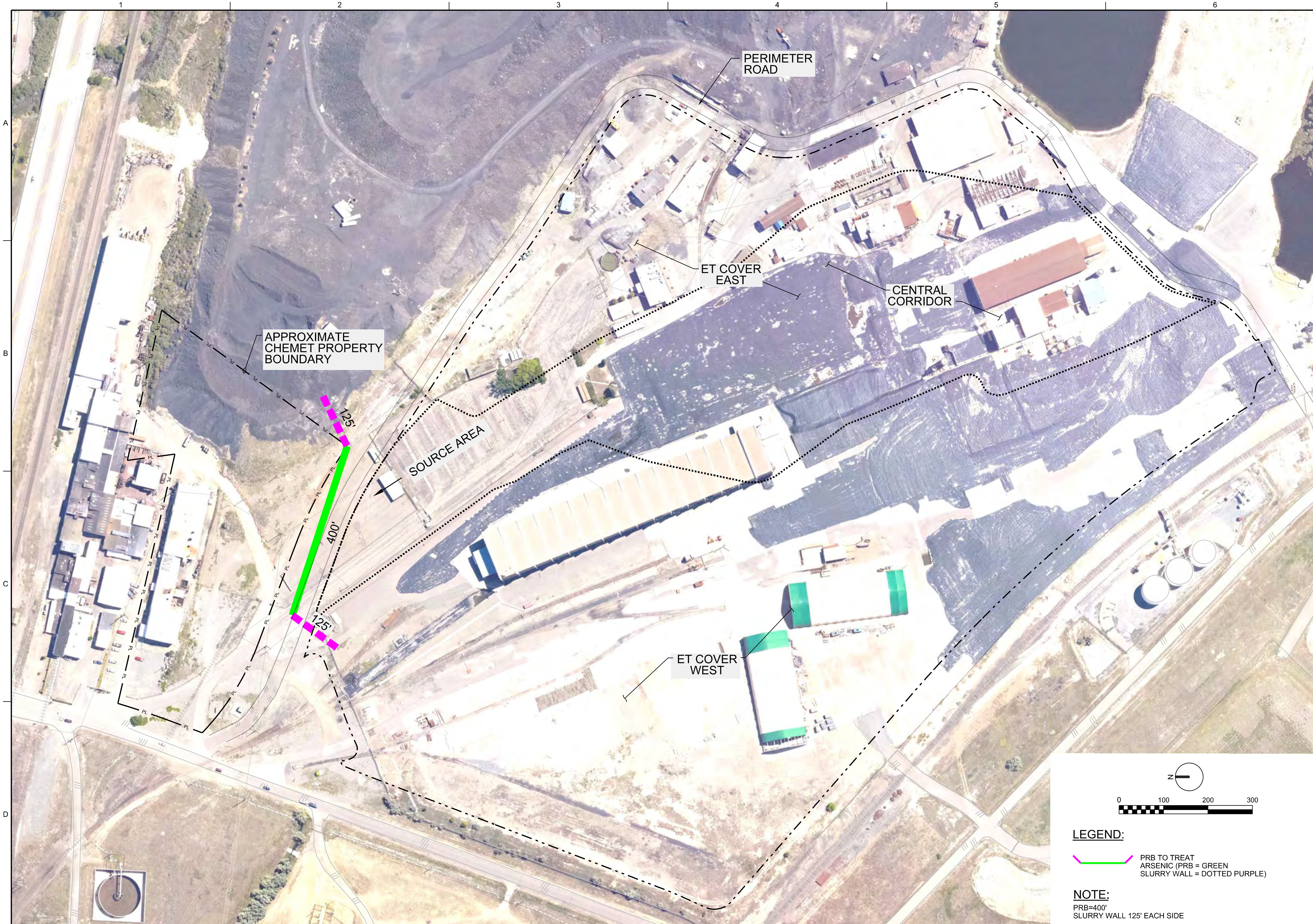
Conceptual Process Flow Diagram – Treatment of Selenium (pg. 2 of 2)



Notes:

1. BCRs designed with 4-foot-thick insulating later for continuous, year-round operation to prevent freeze (2-foot soil cover and 2-foot wood chips).
2. Aeration channels have short runs with steep gradient to prevent freeze; connector lines buried or heat trace to prevent freeze.
3. Oxidation ponds covered with 'pre-engineered' metal structure (50x50) with HVAC (heating) to prevent freezing conditions.
4. Drawings are not-to-scale and are conceptual for feasibility study costing and evaluation; if selected, a final design will be needed for construction.

Figure 2-6.2
Alternative 4 – Process Flow Diagram
Semipassive Treatment System for Selenium
***Tier II Source Control Evaluation* (pg. 2 of 2)**



PRELIMINARY NOT FOR CONSTRUCTION

NO.	DATE	REVISION	BY	APVD
0				

DSGN | DR | CHK | APVD

METG Montana Environmental Trust Group

Former ASARCO Smelter Site
East Helena, Montana
Montana Environmental Trust Group
East Helena, Montana

CH2MHILL

POWER BLOCK BUILDING
7 WEST 6TH AVE, # 519
HELENA, MT 59601-5036
PHONE: (406) 457-5494

TIER II GROUNDWATER SOURCE CONTROL EVALUATION

ALTERNATIVE 5
PRB - NORTH PLANT SITE AREA

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	DECEMBER 2014
PROJ	467300
DWG	FIGURE 2-7.1
SHEET	5 OF 7

PRELIMINARY - NOT FOR CONSTRUCTION

FILENAME: P043_FIG005D_467300.dgn PLOT DATE: 2015\02\13 PLOT TIME: 8:43:26 AM

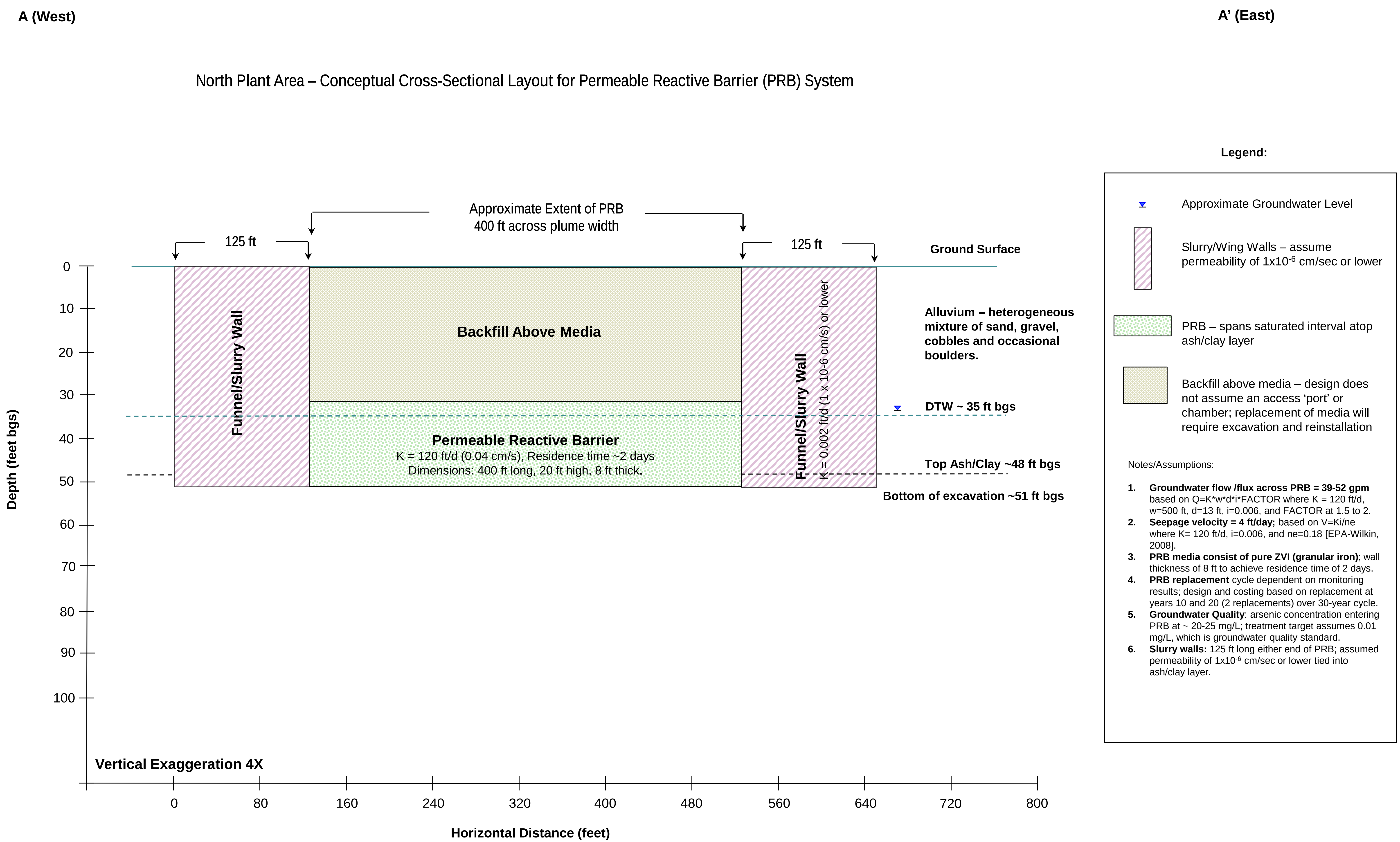
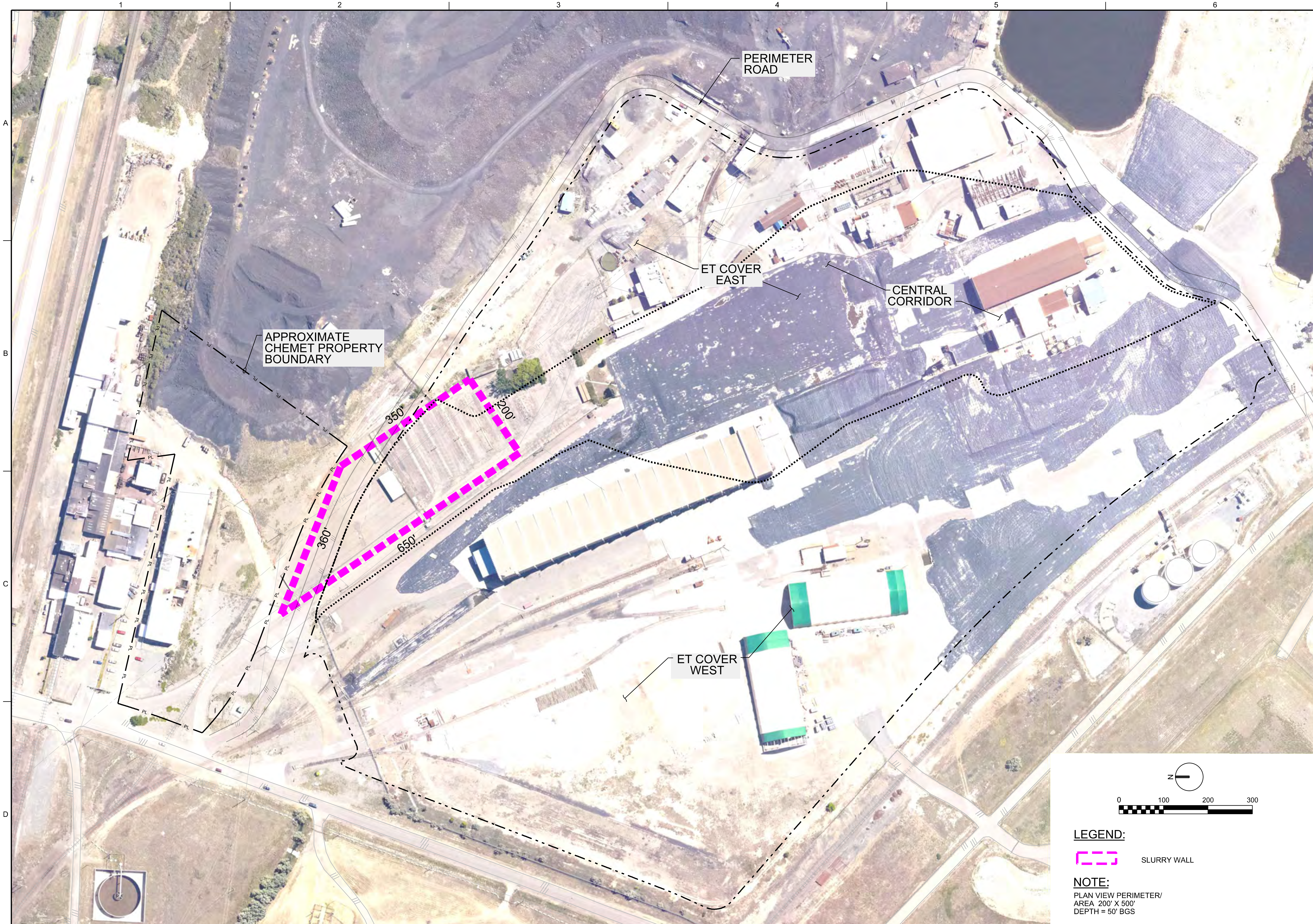


FIGURE 2-7.2
Alternative 5: PRB - North Plant Area (conceptual layout in cross-section)
Tier II Source Control Evaluation



PRELIMINARY NOT FOR CONSTRUCTION

NO.	DATE	REVISION	BY	APVD
0				

DSGN | DR | CHK | APVD

METG Montana Environmental Trust Group

Former ASARCO Smelter Site
East Helena, Montana
Montana Environmental Trust Group
East Helena, Montana

CH2MHILL

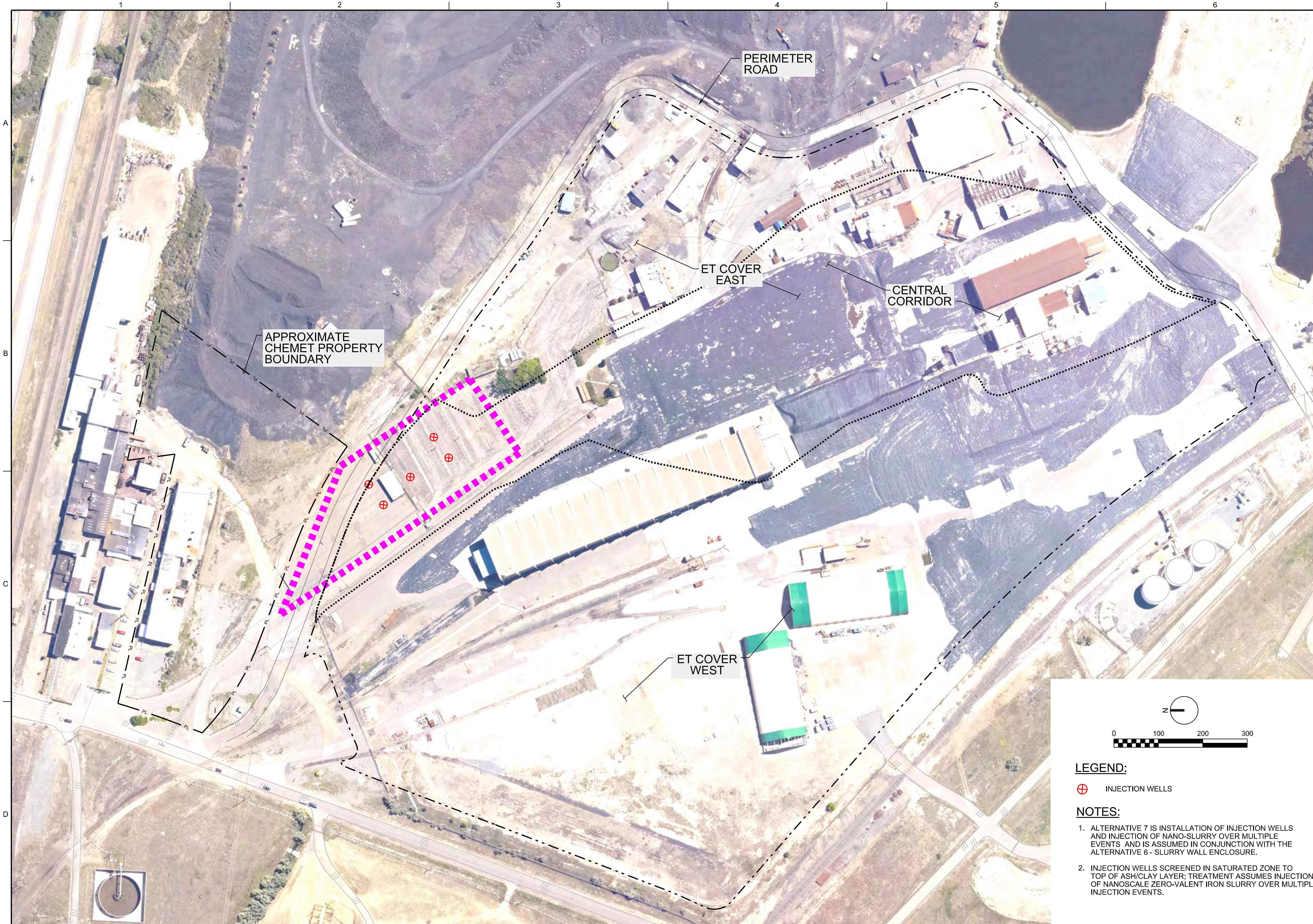
POWER BLOCK BUILDING
7 WEST 6TH AVE. # 519
HELENA, MT 59601-5036
PHONE: (406) 457-5494

TIER II GROUNDWATER SOURCE CONTROL EVALUATION

ALTERNATIVE 6
SLURRY WALL ENCLOSURE - NORTH PLANT AREA

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	DECEMBER 2014
PROJ	467300
DWG	FIGURE 2-8
SHEET	6 OF 7



0 100 200 300

LEGEND:

⊕ INJECTION WELLS

NOTES:

1. ALTERNATIVE 7 IS INSTALLATION OF INJECTION WELLS AND INJECTION OF NANO-SLURRY OVER MULTIPLE EVENTS AND IS ASSUMED IN CONJUNCTION WITH THE ALTERNATIVE 6 - SLURRY WALL ENCLOSURE.
2. INJECTION WELLS SCREENED IN SATURATED ZONE TO TOP OF ASH/CLAY LAYER; TREATMENT ASSUMES INJECTION OF NANOSCALE ZERO-VALENT IRON SLURRY OVER MULTIPLE INJECTION EVENTS.

PRELIMINARY NOT FOR CONSTRUCTION

NO.	DATE	REVISION	BY	APVD
0				

DSGN | DR | CHK | APVD

METG Montana Environmental Trust Group

Former ASARCO Smelter Site
East Helena, Montana
Montana Environmental Trust Group
East Helena, Montana

CH2MHILL

POWER BLOCK BUILDING
7 WEST 6TH AVE, # 519
HELENA, MT 59601-5036
PHONE: (406) 457-5494

TIER II GROUNDWATER SOURCE CONTROL EVALUATION

ALTERNATIVE 7
SLURRY WALL WITH INJECTIONS
NORTH PLANT AREA

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

DATE	DECEMBER 2014
PROJ	467300
DWG	FIGURE 2-9
SHEET	7 OF 7

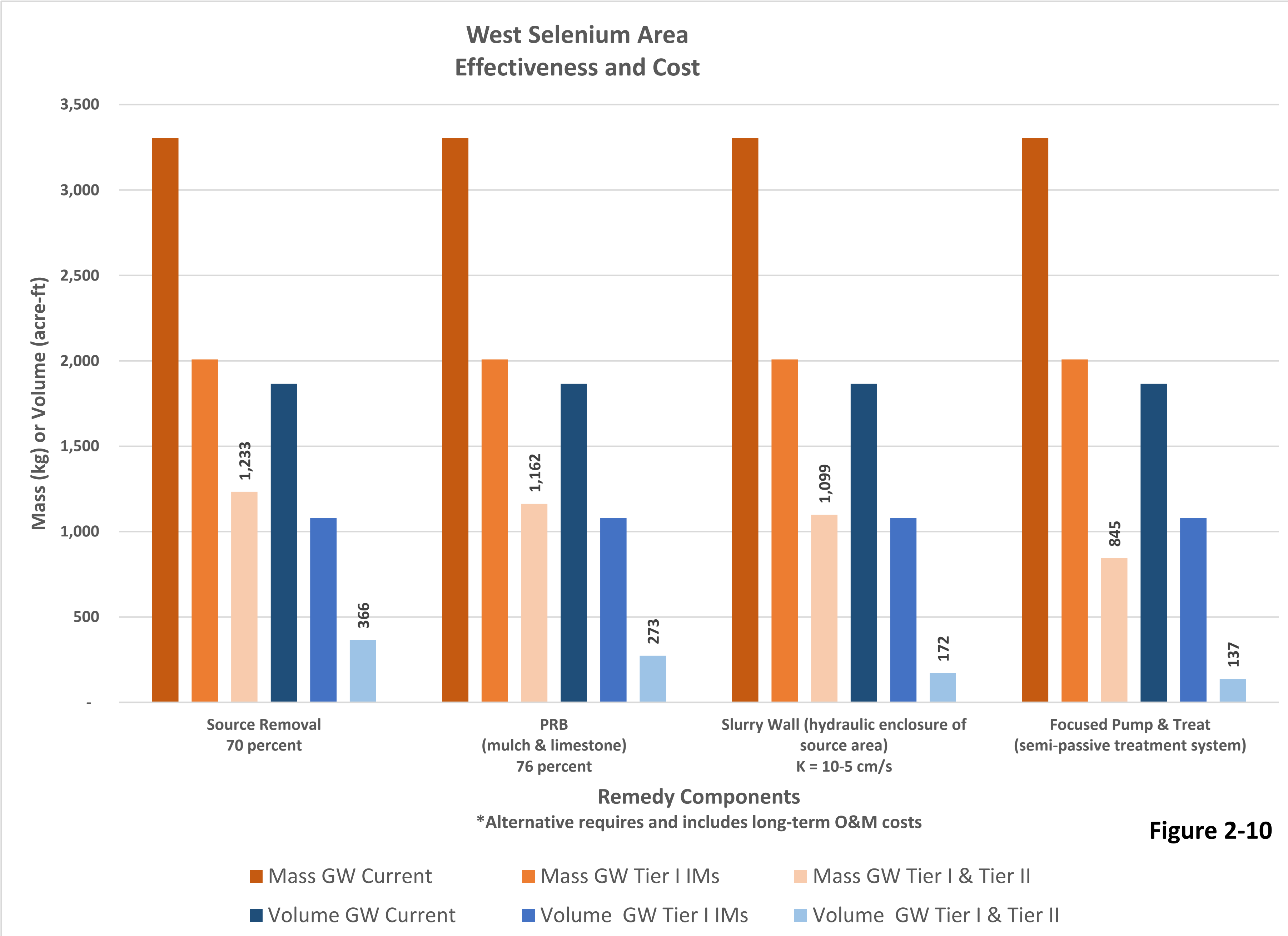

West Selenium Area
Effectiveness and Cost
Mass (kg) or Volume (acre-ft)
3,500
3,000
2,500
2,000
1,500
1,000
500
-
1,233
366
1,162
273
1,099
172
845
137
Source Removal
70 percent
PRB
(mulch & limestone)
76 percent
Slurry Wall (hydraulic enclosure of
source area)
K = 10-5 cm/s
Focused Pump & Treat
(semi-passive treatment system)
Remedy Components
*Alternative requires and includes long-term O&M costs
Mass GW Current
Mass GW Tier I IMs
Mass GW Tier I & Tier II
Volume GW Current
Volume GW Tier I IMs
Volume GW Tier I & Tier II

Figure 2-10

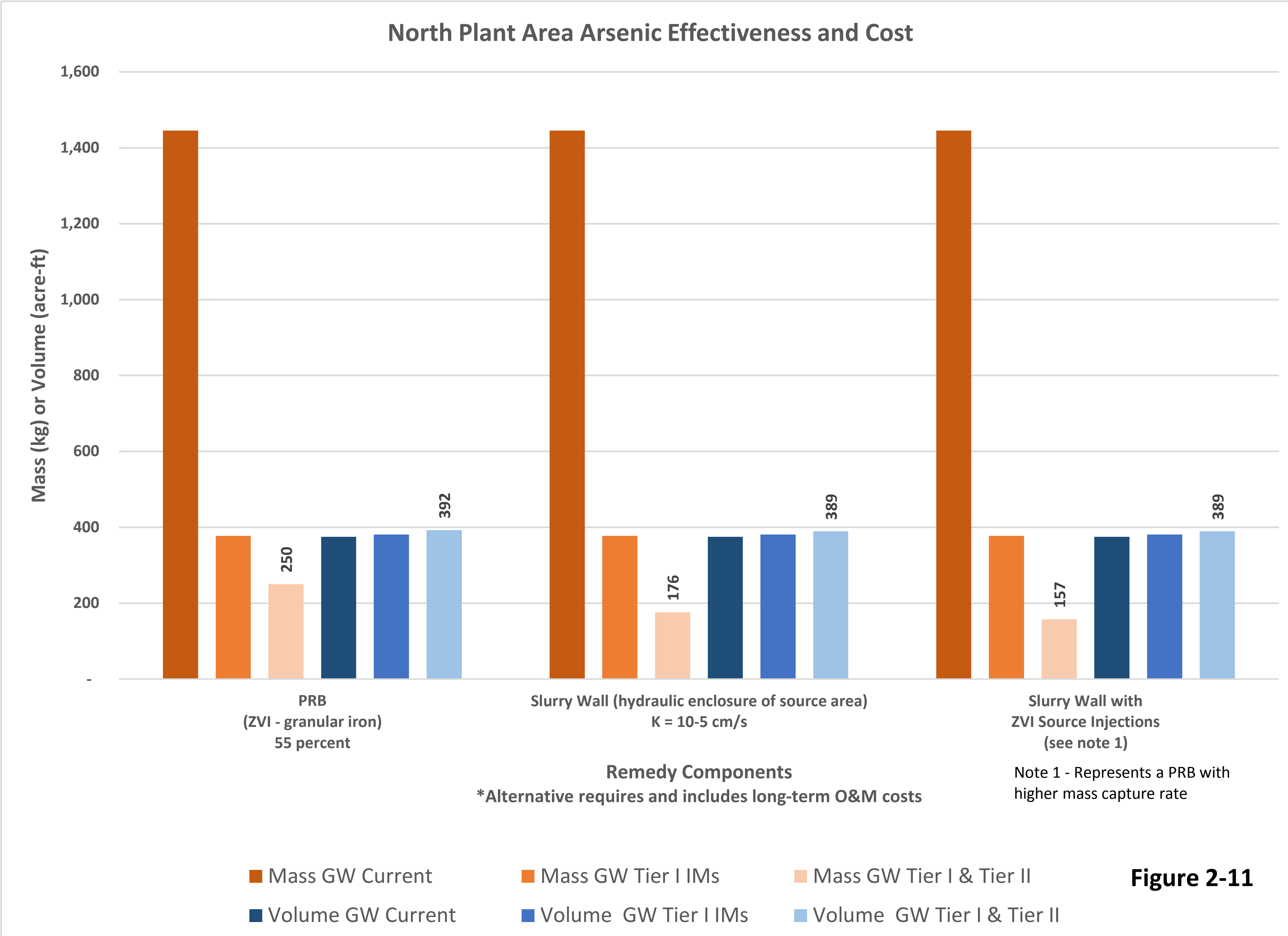
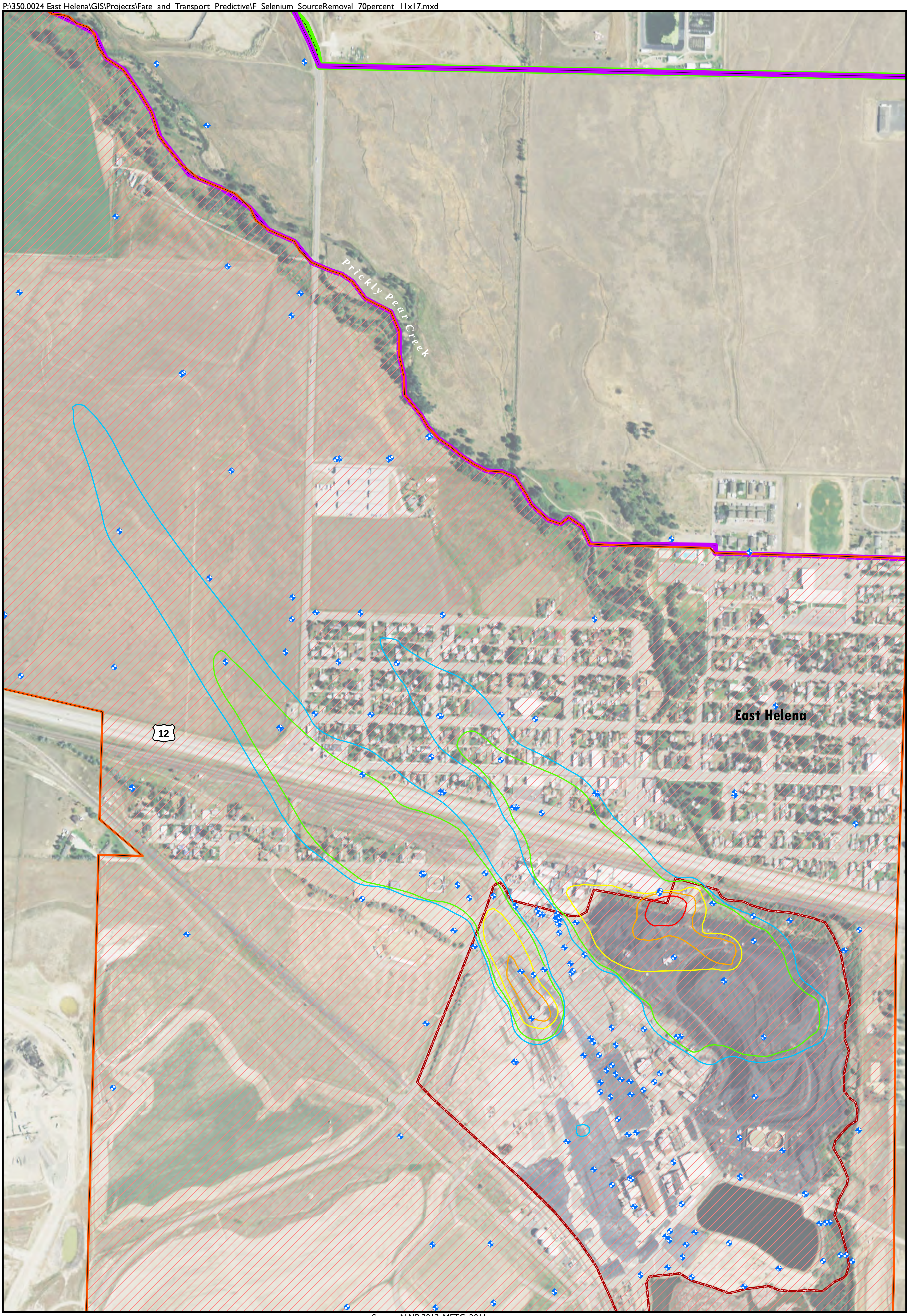
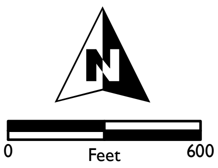

North Plant Area Arsenic Effectiveness and Cost
Mass (kg) or Volume (acre-ft)
1,600
1,400
1,200
1,000
800
600
400
200
-
392
250
389
176
389
157
PRB
(ZVI - granular iron)
55 percent
Slurry Wall (hydraulic enclosure of source area)
K = 10-5 cm/s
Slurry Wall with
ZVI Source Injections
(see note 1)
Remedy Components
*Alternative requires and includes long-term O&M costs
Note 1 - Represents a PRB with
higher mass capture rate
Mass GW Current
Mass GW Tier I IMs
Mass GW Tier I & Tier II
Volume GW Current
Volume GW Tier I IMs
Volume GW Tier I & Tier II

Figure 2-11

P:\350.0024 East Helena\GIS\Projects\Fate_and_Transport_Predictive\F_Selenium_SourceRemoval_70percent_11x17.mxd



Source: NAIP, 2013; METG, 2011



NewFields

Isoconcentration Contour (mg/L)

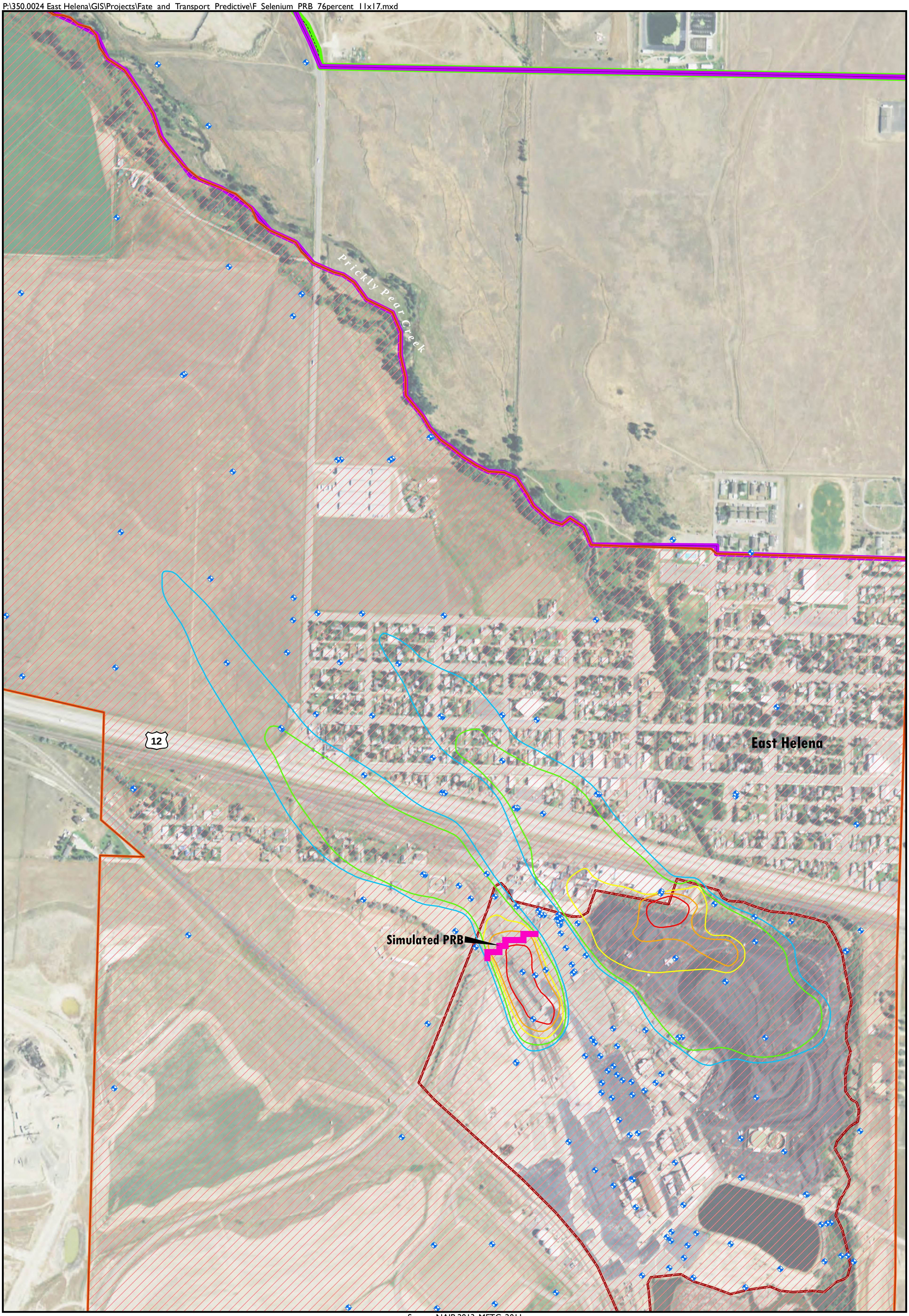
- 0.05
- 0.1
- 0.5
- 1
- > 3

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Note: Predictive results depict concentrations after model has reached steady-state.

FIGURE 2-12
Predicted Isoconcentration Contours
Selenium 70 Percent Source Removal Simulation
Tier II Source Control Evaluation

P:\350.0024 East Helena\GIS\Projects\Fate_and_Transport_Predictive\F_Selenium_PRB_76percent_11x17.mxd



Source: NAIP, 2013; METG, 2011

Isoconcentration Contour (mg/L)

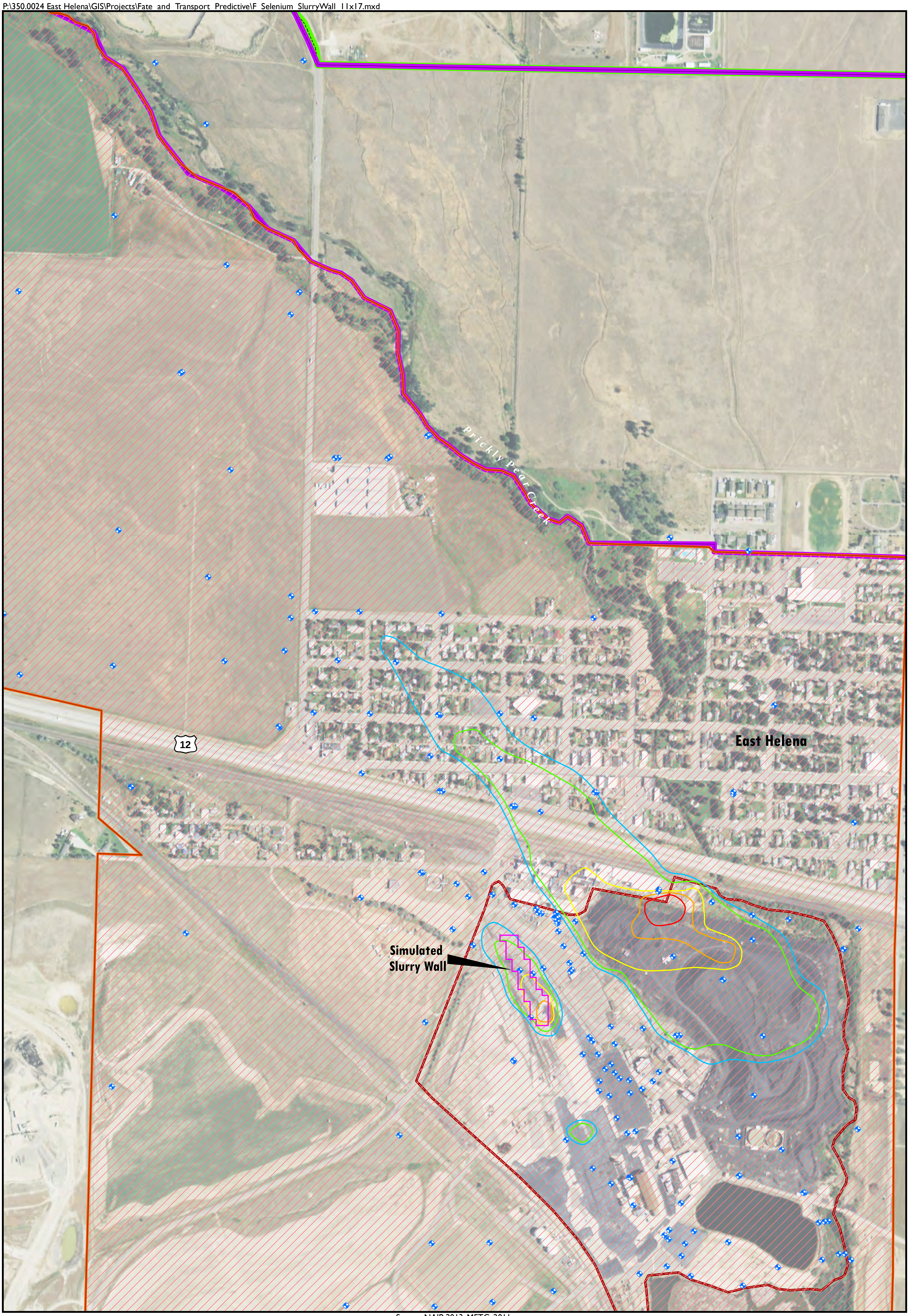
- 0.05
- 0.1
- 0.5
- 1
- > 3

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporary CGWA

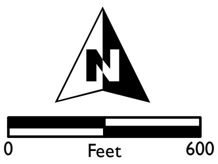
Note: Predictive results depict concentrations after model has reached steady-state.

FIGURE 2-13
Predicted Isoconcentration Contours
Selenium 76 Percent Effective PRB Simulation
Tier II Source Control Evaluation

P:\350.0024 East Helena\GIS\Projects\Fate_and_Transport_Predictive\F_Selenium_SlurryWall_11x17.mxd



Source: NAIP, 2013; METG, 2011



Isoconcentration Contour (mg/L)
- 0.05
- 0.1
- 0.5
- 1
- > 3

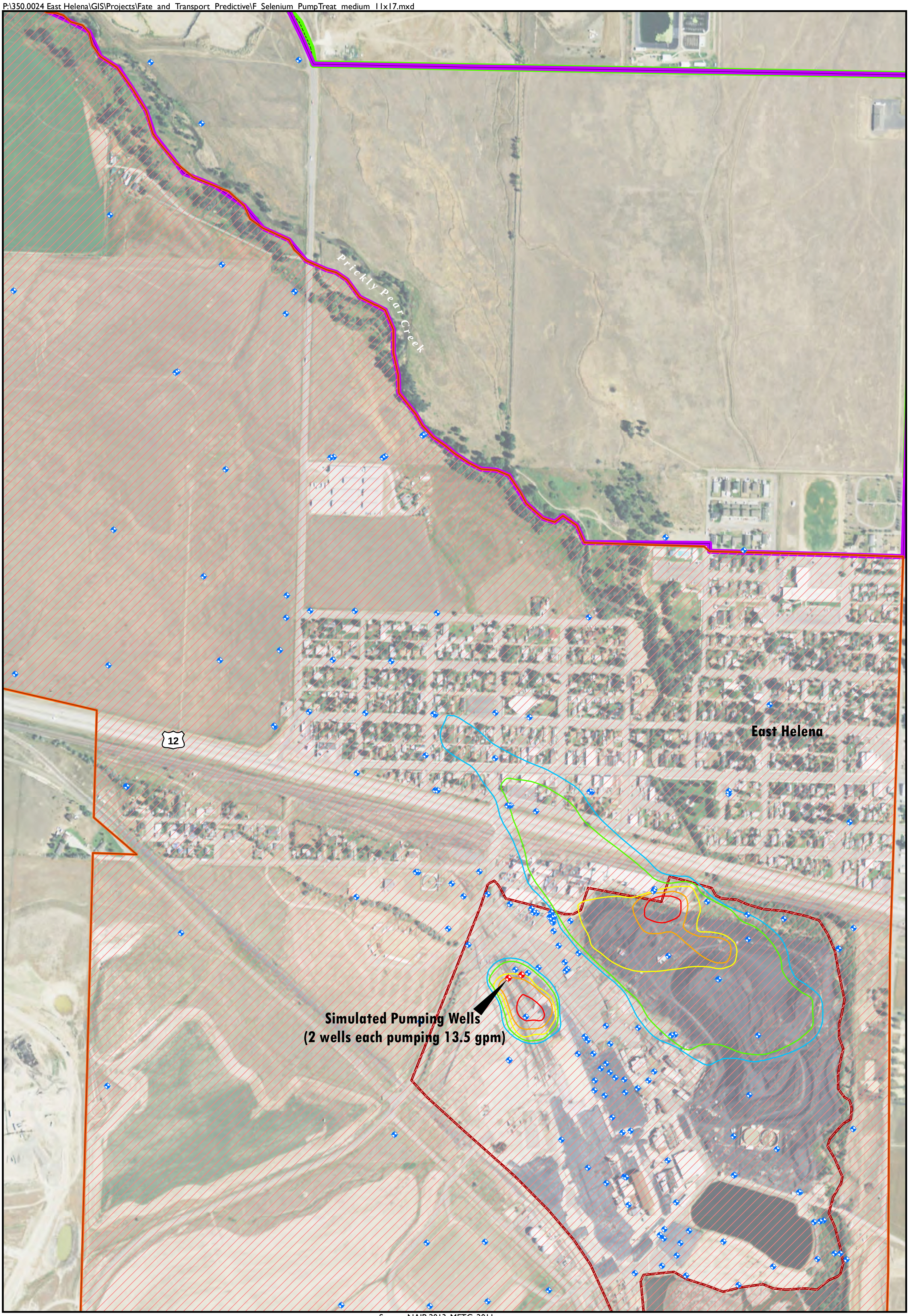
- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporary CGWA

NewFields

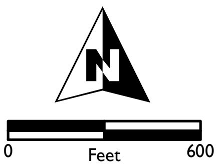
Note: Results depict concentrations after model has reached steady-state.
The slurry wall has a hydraulic conductivity of 0.01 feet/day and a thickness of 2 feet.

FIGURE 2-14
Predicted Isoconcentration Contours
Selenium Slurry Wall Low Permeability Simulation
Tier II Source Control Evaluation

P:\350.0024 East Helena\GIS\Projects\Fate_and_Transport_Predictive\F_Selenium_PumpTreat_medium_11x17.mxd



Source: NAIP, 2013; METG, 2011



Isoconcentration Contour (mg/L)

- 0.05
- 0.1
- 0.5
- 1
- > 3

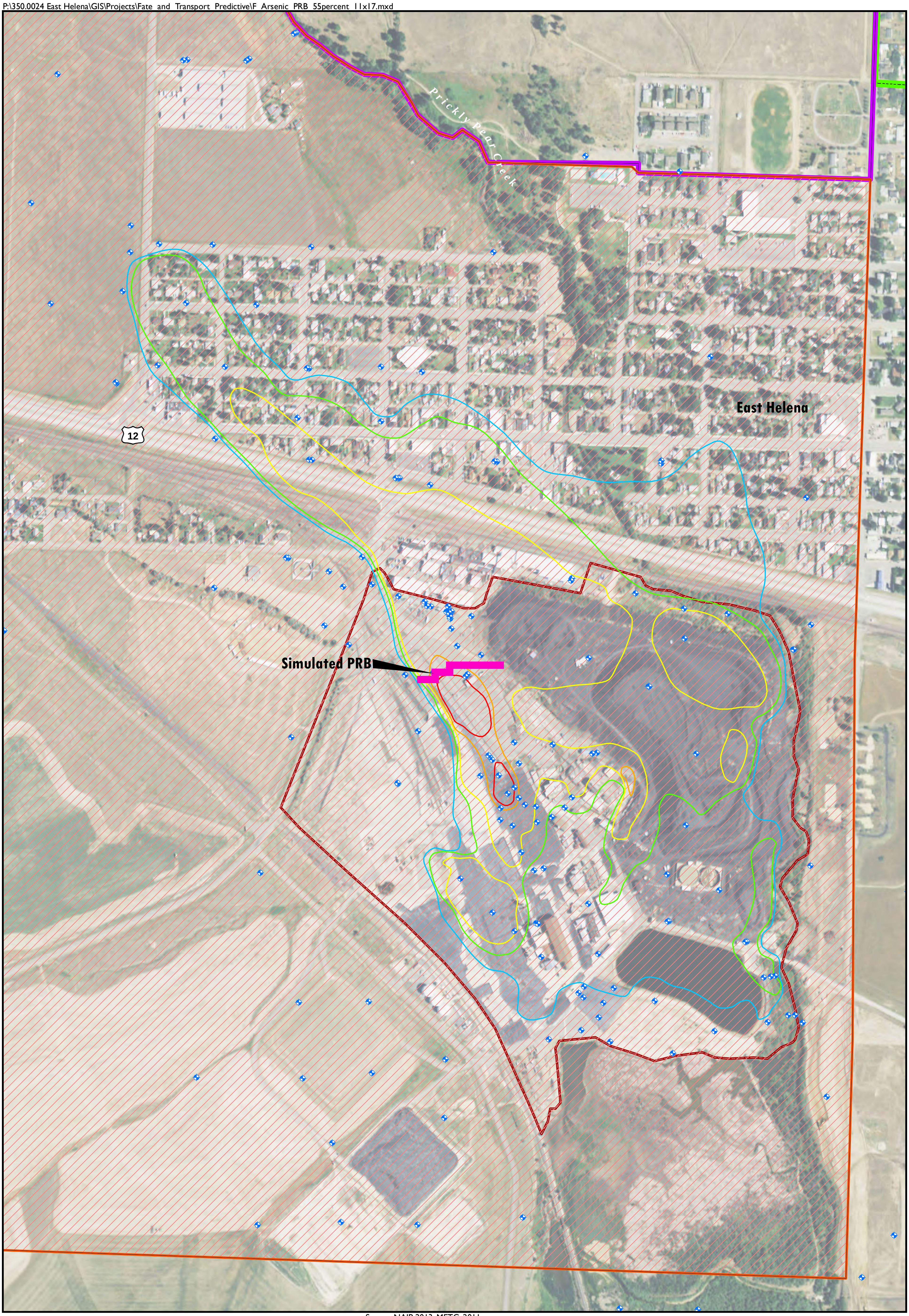
- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

NewFields

Note: Predictive results depict concentrations after model has reached steady-state.

FIGURE 2-15
Predicted Isoconcentration Contours
Selenium Pump and Treat Simulation
Tier II Source Control Evaluation

P:\350.0024 East Helena\GIS\Projects\Fate_and_Transport_Predictive\F_Arsenic_PRB_55percent_11x17.mxd



Source: NAIP, 2013; METG, 2011

Feet
0 500

Isoconcentration Contour (mg/L)
- 0.01
- 0.1
- 1
- 10
- > 20

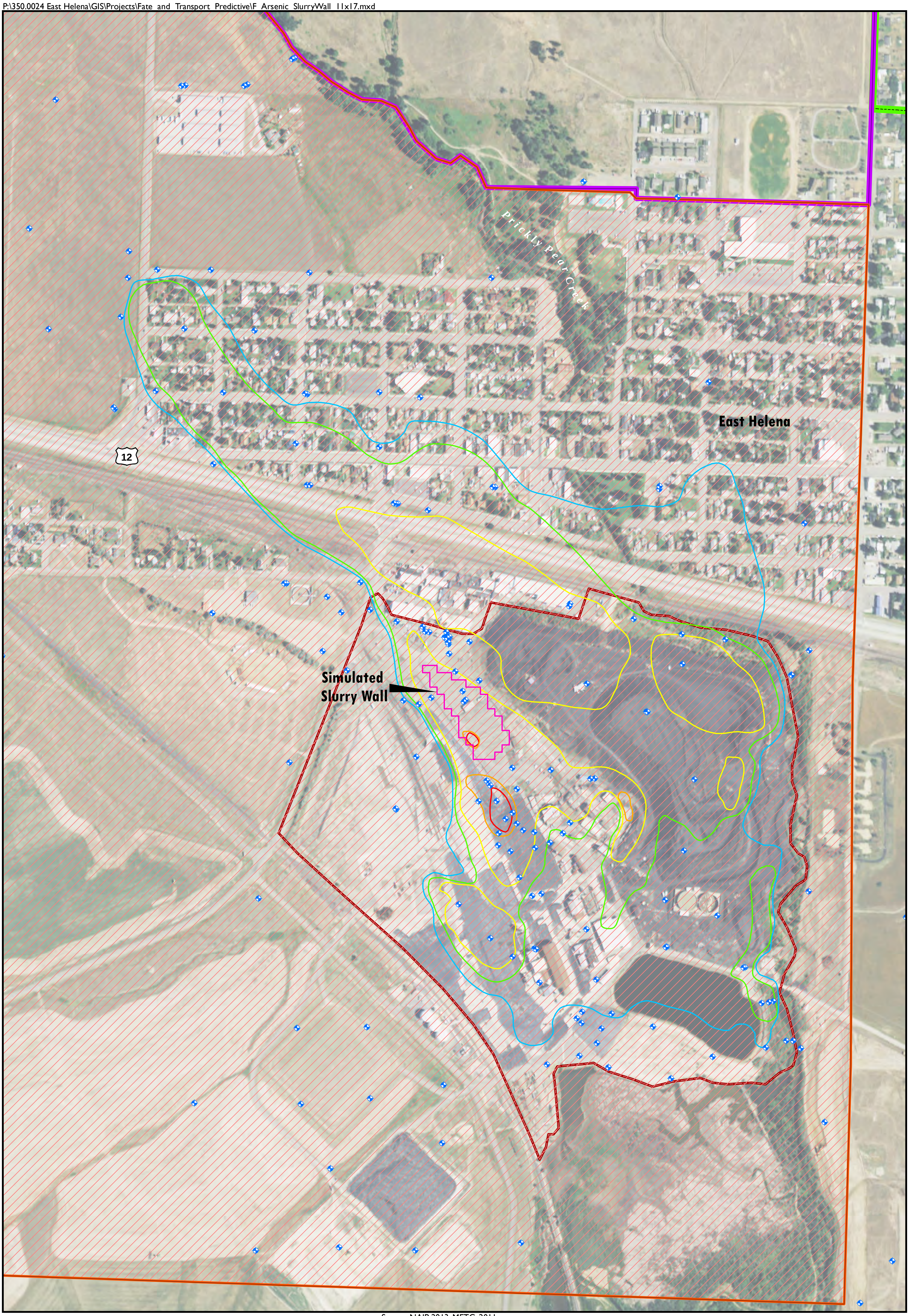
- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

NewFields

Note: Predictive results depict concentrations after model has reached steady-state.

FIGURE 2-16
Predicted Isoconcentration Contours
Arsenic 55 Percent Effective PRB Simulation
Tier II Source Control Evaluation

P:\350.0024 East Helena\GIS\Projects\Fate_and_Transport_Predictive\F_Arsenic_SlurryWall_11x17.mxd



Source: NAIP, 2013; METG, 2011

Feet 0 500

Isoconcentration Contour (mg/L)

- 0.01
- 0.1
- 1
- 10
- > 20

Monitoring Well

Facility Boundary

Permanent CGWA - Subarea1

Permanent CGWA - Subarea 2

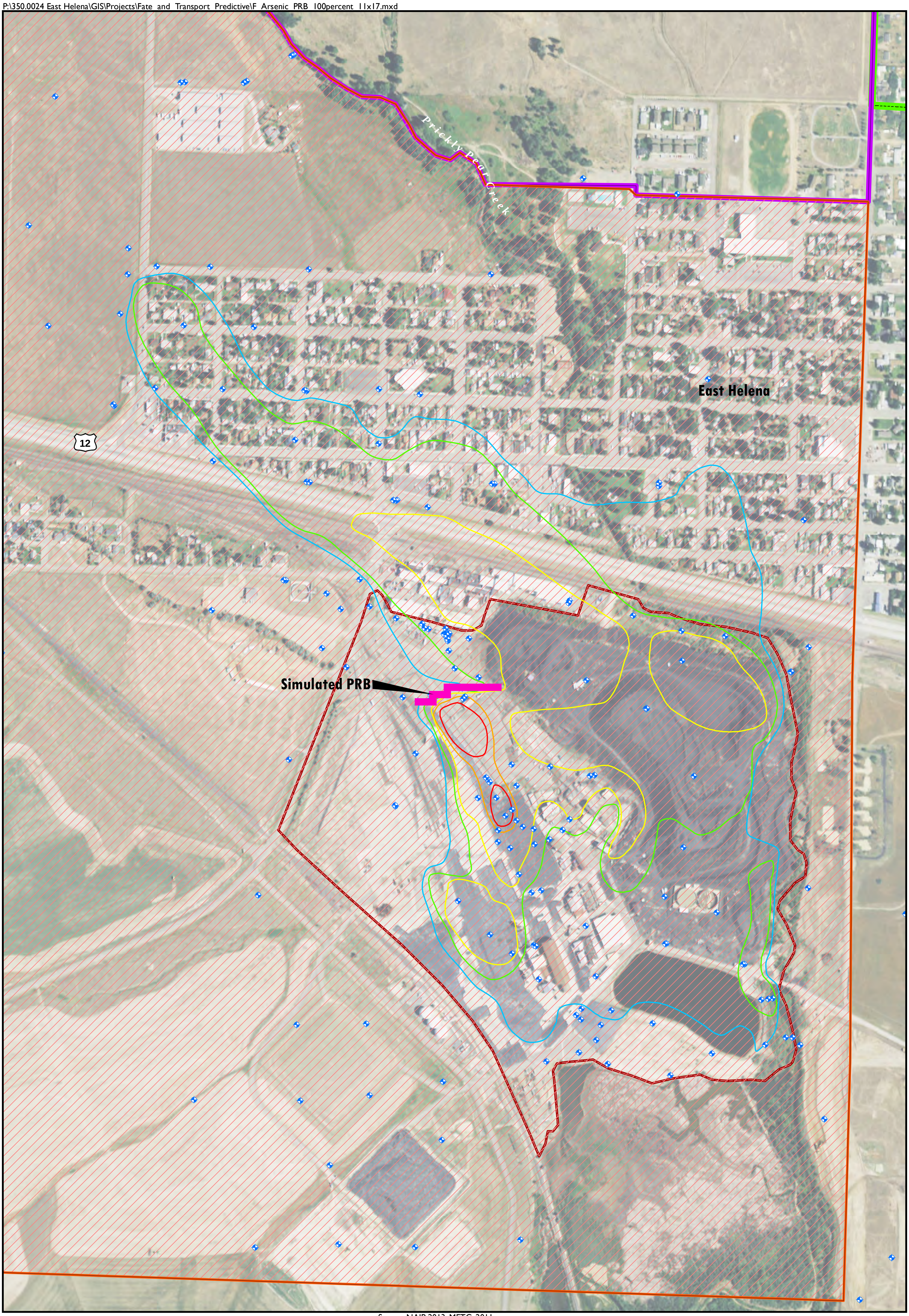
Temporary CGWA

Note: Results depict concentrations after model has reached steady-state.
The slurry wall has a hydraulic conductivity of 0.01 feet/day and a thickness of 2 feet.

NewFields

FIGURE 2-17
Predicted Isoconcentration Contours
Arsenic Slurry Wall Low Permeability Simulation
Tier II Source Control Evaluation

P:\350.0024 East Helena\GIS\Projects\Fate_and_Transport_Predictive\F_Arsenic_PRB_100percent_11x17.mxd



Source: NAIP, 2013; METG, 2011

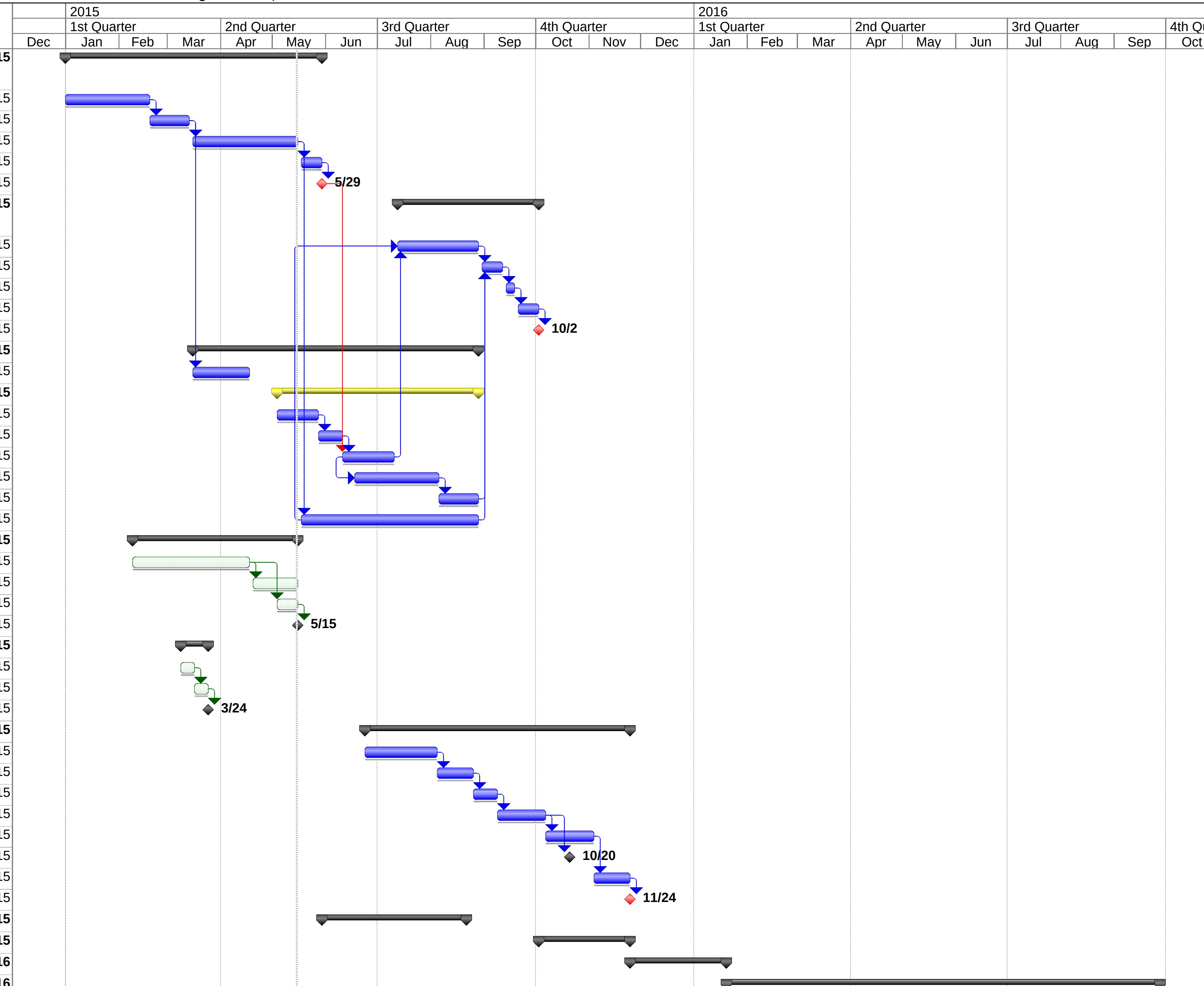
NewFields

Note: Predictive results depict concentrations after model has reached steady-state.

FIGURE 2-18
Predicted Isoconcentration Contours
Arsenic 100 Percent Effective PRB Simulation
Tier II Source Control Evaluation

Figure 5-1. Implementation Timeline

ID	Task Name	Duration	Start	Finish
1	**Tier II Groundwater Remedy Component Evaluation**	**107 days**	**Thu 1/1/15**	**Fri 5/29/15**
2	Complete Phase 2 TM Draft	35 days	Thu 1/1/15	Wed 2/18/15
3	Team Reviews and Fixup	17 days	Thu 2/19/15	Fri 3/13/15
4	Custodial Trust Final Review	45 days	Mon 3/16/15	Fri 5/15/15
5	Beneficiary Presentation	10 days	Mon 5/18/15	Fri 5/29/15
6	Pathforward Remedy Decision	0 days	Fri 5/29/15	Fri 5/29/15
7	**Tier II Supplemental Evaluation and Recommendations TM**	**60 days**	**Mon 7/13/15**	**Fri 10/2/15**
8	Draft TM Prep	35 days	Mon 7/13/15	Fri 8/28/15
9	Team Review and Fixup	10 days	Mon 8/31/15	Fri 9/11/15
10	Custodial Trust & EPA Final Review	5 days	Mon 9/14/15	Fri 9/18/15
11	Beneficiary Presentation	10 days	Mon 9/21/15	Fri 10/2/15
12	Pathforward Remedy Decision	0 days	Fri 10/2/15	Fri 10/2/15
13	**Groundwater Evaluation Activities**	**120 days**	**Mon 3/16/15**	**Fri 8/28/15**
14	Verification Modeling & Reporting	25 days	Mon 3/16/15	Fri 4/17/15
15	**Supplemental Field Investigations**	**85 days**	**Mon 5/4/15**	**Fri 8/28/15**
16	Work Scope Preparation/Approvals	18 days	Mon 5/4/15	Wed 5/27/15
17	Work Planning and Contracting	10 days	Thu 5/28/15	Wed 6/10/15
18	Field Work	22 days	Thu 6/11/15	Fri 7/10/15
19	Laboratory Testing	35 days	Thu 6/18/15	Wed 8/5/15
20	Reporting	17 days	Thu 8/6/15	Fri 8/28/15
21	Design Support Modeling & Reporting	75 days	Mon 5/18/15	Fri 8/28/15
22	**ET Cover IM Bidding Window**	**70 days**	**Mon 2/9/15**	**Fri 5/15/15**
23	Bidding	50 days	Mon 2/9/15	Fri 4/17/15
24	Bid Evaluation and Recommendation	20 days	Mon 4/20/15	Fri 5/15/15
25	CPO Preparation	10 days	Mon 5/4/15	Fri 5/15/15
26	Notice to Proceed	0 days	Fri 5/15/15	Fri 5/15/15
27	**ET Cover Addendum Package**	**12 days**	**Mon 3/9/15**	**Tue 3/24/15**
28	Package Design Preparation	6 days	Mon 3/9/15	Mon 3/16/15
29	Team Review and Fixup	6 days	Tue 3/17/15	Tue 3/24/15
30	Approval to Issue to Bidders	0 days	Tue 3/24/15	Tue 3/24/15
31	**IMWP Addendum**	**110 days**	**Wed 6/24/15**	**Tue 11/24/15**
32	Draft Preparation	30 days	Wed 6/24/15	Tue 8/4/15
33	CT Review and Fixup	15 days	Wed 8/5/15	Tue 8/25/15
34	EPA Review and Fixup	10 days	Wed 8/26/15	Tue 9/8/15
35	Beneficiary Review and Fixup	20 days	Wed 9/9/15	Tue 10/6/15
36	Public Review and Fixup	20 days	Wed 10/7/15	Tue 11/3/15
37	Public Meeting	0 days	Tue 10/20/15	Tue 10/20/15
38	EPA Response and Final IMWP Addendum	15 days	Wed 11/4/15	Tue 11/24/15
39	EPA Approval	0 days	Tue 11/24/15	Tue 11/24/15
40	**Preliminary GW Component Remedy Design**	**60 days**	**Fri 5/29/15**	**Fri 8/21/15**
45	**Final GW Component Remedy Design**	**37 days**	**Fri 10/2/15**	**Tue 11/24/15**
53	**GW Remedy Component Bidding Window**	**40 days**	**Wed 11/25/15**	**Tue 1/19/16**
58	**GW Remedy Component Construction**	**180 days**	**Wed 1/20/16**	**Tue 9/27/16**



Appendix A
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations (CH2M HILL, 2015)

Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

PREPARED FOR: Custodial Trust

COPY TO: Bob Anderson/Hydrometrics
Cam Stringer/NewFields

PREPARED BY: Yueh Chuang/CH2M HILL
Craig Sauer/CH2M HILL
Jay Dehner/CH2M HILL

DATE: Draft November 12, 2014; Final February 18, 2015

PROJECT NUMBER: 486085.46.06.01

Pursuant to Paragraph VI.10.c of the First Modification to the 1998 Resource Conservation and Recovery Act (RCRA) Consent Decree (First Modification; Dreher et al., 2012), the Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust (Custodial Trust) is performing a Corrective Measures Study (CMS) to "…identify and evaluate alternatives which will prevent or mitigate the continuing migration of or future release of hazardous waste or hazardous constituents at and/or from the ASARCO Properties, and to restore contaminated media to standards acceptable to EPA." This technical memorandum (TM) presents an initial evaluation (Phase 1) of Tier II source control measures and groundwater remedies being conducted in accordance with the draft CMS Work Plan (CH2M HILL, 2014). A second, more detailed Tier II evaluation (Phase 2) will be performed based on the results and recommendations presented in this Phase 1 effort.

This Tier II evaluation focuses on additional source control and groundwater corrective measures that would be implemented as needed to augment the overall performance of the three Interim Measures (IMs) currently underway. The Custodial Trust is implementing three interrelated, interdependent IMs at the East Helena Facility (Facility) that will form the foundation of final corrective measures. The IMs were approved by the U.S. Environmental Protection Agency (USEPA) as part of the IM Work Plan process, and they are: (1) South Plant Hydraulic Control (SPHC), (2) Source Removal, and (3) Evapotranspiration Cover System. Implementation of these IMs began in 2012 and completion currently is scheduled for 2016. If these Tier II evaluations determine that corrective measure if additional corrective measures are necessary to meet the remedy performance standards cited in the draft CMS Work Plan, they may be implemented as either another IM or a final corrective measure as part of the Corrective Measures Implementation work required by Paragraph VI.10.d of the First Modification.

Objectives

The overall objective of the Tier II evaluation is to determine if corrective measures, in addition to the three IMs currently underway, are necessary to meet the final remedy performance standards identified in the draft CMS Work Plan. The Tier II evaluations are being conducted in a two-phased approach. The objective of Phase 1 is to identify source control measures and groundwater remedies most applicable to site-specific conditions, and evaluate them via a screening process following USEPA RCRA corrective action guidance. The initial screening evaluation identifies a subset of corrective measures that warrant more detailed evaluation under Phase 2. This TM presents the results of the Phase 1 evaluation, with recommendations on specific source control measures/groundwater remedies that are recommended to be carried forward to Phase 2.

Tier II Phase 1 Screening Evaluation Approach

The Tier II Phase 1 evaluation approach summarized herein includes technical input on project objectives, soil and groundwater quality, and groundwater modeling from members of the groundwater team (consisting of staff from the Custodial Trust, Hydrometrics, NewFields, and CH2M HILL).

Source Control Measures and Groundwater Remedies

For the purpose of the Tier II evaluation, preference has been given to active source control measures/groundwater remedies to address the primary groundwater plume areas with respect to (1) West Selenium (selenium plume), and (2) North Plant (arsenic plume). The following corrective measures are included in the Phase 1 evaluation:

- Affected Area: Encompasses both the selenium (West Selenium) and arsenic (North Plant) plumes within the Facility boundaries, and extending outside of the Facility boundaries, which consider a large-scale groundwater extraction and treatment (pump and treat, or P&T) system for plume containment/remediation, and potential smaller-scale P&T system with focused objective(s).
- Within the Facility boundaries
  - Source removal
  - Subsurface treatment with hydraulic control (such as permeable reactive barrier [PRB] with funnel diversions [slurry walls])
  - Subsurface physical barriers (such as hydraulic isolation or enclosure of source via containment wall barriers)
  - Focused P&T
  - In-situ treatment (such as injection of ferrous sulfate and solidification/stabilization)

The "baseline action" for the Facility is assumed to include the following actions:

- Completion of the three planned IMs
- Long-term administration of institutional controls, including a Controlled Groundwater Area (Hydrometrics, 2014a)
- Long-term, monitored natural attenuation (Hydrometrics, 2014b)

Potential Tier II corrective measures and their associated costs are considered supplemental to these activities under the baseline action.

Screening Evaluation Process

The Phase 1 evaluation focused on the following primary source areas of concern:

- Affected Area: encompassing both onsite sources/groundwater plumes and offsite groundwater plumes
- West Selenium (Figure 1)
- North Plant (Figure 2)
- Former Speiss/Dross Area (Figure 3)

The Source Area Inventory (Hydrometrics, 2014c) identified West Selenium, North Plant, former Acid Plant Area, Slag Pile, and former Speiss/Dross Area as the primary source areas needing additional evaluation. These source areas were prioritized based on their process history and observed substantive impacts on existing soil and groundwater conditions on and around the former Smelter site. The 2014 field investigation data and preliminary results were used in the Phase 1 evaluation to refine the understanding of primary source areas/dimensions, depth to key subsurface features (such as top of ash/clay layer, depth to groundwater, and aquifer thickness), groundwater quality, and geochemistry (such as leach testing results).

Two of the five primary source areas (former Acid Plant Area and Slag Pile) were either deferred or eliminated from evaluation for the reasons described below. These two areas are discussed in terms of their contribution to the overall site conditions, potential impacts of the planned IMs on their ongoing contribution to site contamination, and accessibility once the planned IMs are in place. An evaluation of these areas may be conducted at a later date, based on the outcome of the Phase 1 or subsequent Phase 2 evaluations of the primary source areas of concern and groundwater quality conditions observed during annual monitoring events. A summary of the two deferred source areas is presented as follows:

- Former Acid Plant Area—Groundwater quality at the former Acid Plant Area is showing improvement as a result of the lowering of groundwater in the South Plant associated with the SPHC IM. The SPHC IM is predicted to have the biggest impact to reducing groundwater levels and therefore reducing contact with impacted soils for this area of the Facility. Consequently, no additional remedy evaluations are anticipated. Continued monitoring for the time being is recommended to validate the predictions. Upcoming performance groundwater fate and transport modeling of the IMs will help to support this determination.
- Slag Pile—Groundwater quality changes beneath the Slag Pile will be monitored to observe the effects of the SPHC IM. Any corrective measure found to be necessary to address the Slag Pile as an ongoing source of contamination to groundwater is expected to be implemented as a final corrective measure. Continued groundwater monitoring and upcoming performance modeling of the IMs will help to determine if additional evaluations in this area are appropriate, as well.

A screening evaluation process was performed for each primary source area and the potential source control measures/groundwater remedies against three of the balancing criteria identified in USEPA RCRA Corrective Action guidance (USEPA, 1994; USEPA, 2000):

1. **Effectiveness**: For the purpose of the Phase 1 screening evaluation, three of the balancing criteria were combined: (1) long-term effectiveness, (2) toxicity, mobility, and volume reduction, and (3) short-term effectiveness for the specific corrective measure proposed. The effectiveness of a corrective measure was evaluated against arsenic or selenium, the key contaminants of primary concern in groundwater.
2. **Implementability:** For the purpose of the Phase 1 screening evaluation, focused on: (1) construction and operation requirements, (2) technology reliability, (3) suitability to site conditions, and (4) onsite treatment options.
3. **Cost**: For the purpose of the Phase 1 screening evaluation, considered: (1) capital costs that are fixed, one-time expenses incurred as a result of implementation or construction in 2014 dollars, and (2) net present worth (NPW) of capital costs, and annual operations and maintenance and site control costs. The NPW was estimated assuming a fixed 30-year period at 5 percent discount.

Definitions of these criteria and how they are to be applied are provided in Attachment 1.

As appropriate, qualitative statements were developed and a relative score was applied for effectiveness and implementability, ranging from 1 to 3, whereby 1 was considered least effective/implementable, 2 was considered moderately effective/implementable, and 3 was considered most effective/implementable.

For the Phase 1 screening evaluation, an approach was developed to ensure that the estimated costs included a contingency to reflect the level of uncertainty associated with the current conceptual level of design and definition. The Phase 1 screening-level costs are considered rough order of magnitude (ROM) Class 5 (AACE, 2005) estimated at -50 percent to +100 percent accuracy and intended for concept-level screening with 0 to 2 percent design assumptions, and rely on professional judgment, analogies from other projects, and published literature for unit costs. Attachment 2 provides an explanation of screening-level cost assumptions common to several of the source areas and corrective measures.

The screening-level costs were also ranked using a numerical scoring scheme of 1 through 3, similar to the effectiveness and implementability factors, as shown in the following chart:

Cost ($Millions)	Relative Cost Classification	Screening Evaluation Score
Less than $2	Low	3 (most favorable)
$2 to less than $5	Medium	2
$5 or greater	High	1 (least desirable)

Tier II Phase 1 Evaluation Results

This section presents the Phase 1 Tier II evaluation results. The information, assumptions, and screening evaluations are provided in a series of three tables, titled as follows and located at the end of this TM:

- Table 1: Remedy Description, Quantities, and Cost Assumptions
- Table 2: Screening Evaluation (Effectiveness, Implementability, and Cost)
- Table 3: Comments and Recommendations
- Table 4: Summary of Screening Evaluation Results and Recommendations for Phase 2 Evaluation

Draft copies of the preliminary, working versions of Tables 1 through 4 were distributed to the groundwater team for review and comment on October 7, 2014. Preliminary results of the Source Area Investigation (Hydrometrics, 2014d), and comments and recommendations on the draft tables were reviewed to help guide the recommendations for Phase 2 evaluation as presented in the next section.

Recommendations for Tier II Phase 2 Evaluation

Table 4 provides a summary of the overall screening evaluation results presented in Tables 1 through 3, and an additional column to identify those corrective measures by area that are recommended for retention and further evaluation in Phase 2. Corrective measures were recommended for further evaluation based on a combined screening score, or threshold value, of 7 (including ranges that score to 7). A threshold value of 7 is considered an appropriate cutoff based on a review of the combined screening scores and the associated corrective measures considered to be favorable, as further described below.

A summary of the Phase 1 screening results and rationale is provided as follows:

- Affected Area:
  - No additional or specific alternatives recommended beyond the approved Tier I IMs, administration of the Controlled Groundwater Area Petition (institutional controls), potential Tier II groundwater components (if implemented), and Monitored Natural Attenuation. The various pump and treat alternatives were excluded due to very high cost (estimates ranging from $21 to 120 million) and the complexities associated with implementation of the P&T option at the affected area scale.
- West Selenium (selenium plume):
  - **Source Removal**. Retained for reasons of high effectiveness combined with moderate cost.
  - **PRB**. Retained for reasons of favorable effectiveness and implementability with low cost.
  - **Slurry Wall Enclosure**. Retained for reasons of favorable effectiveness and implementability with low cost.
  - **Focused Pump & Treat**. Retained for reasons of favorable effectiveness and implementability of semi-passive and low-flow volume treatment with potential low cost.
- North Plant (arsenic plume):
  - **Source Removal**. Excluded for reasons of moderate effectiveness and implementability, and relatively high cost.
  - **PRB**. Retained for reasons of favorable effectiveness and implementability and considering low cost.
  - **Slurry wall Enclosure**. Retained for reasons of favorable effectiveness and implementability score with low cost.
  - **In-Situ Injections**. Retained for reasons of moderate effectiveness & implementability combined with low cost.
- Former Speiss/Dross Area:
  - Nothing supplemental beyond the existing slurry wall.

The alternatives shown in bold font (above) are recommended to be retained as an outcome from the preliminary Tier II screening process to address the West Selenium and North Plant plumes. The corrective measures selected for Phase 2 evaluation will be subjected to a more detailed evaluation process (for example, to the complete list of balancing/evaluation criteria described in Attachment 1) and the effectiveness of potential corrective measures will be quantified with the fate and transport groundwater model (NewFields, 2014).

References

CH2M HILL. 2014. *Former ASARCO East Helena Facility Corrective Measures Study Work Plan 2013*. Draft—For Beneficiary Review Only. Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust. January 2014.

Dreher, Robert G., E. Rockler, M.W. Cotter, L. Johnson/United States District Court for the District of Montana. 2012. First Modification to the 1998 Consent Decree. Civil Action No. CV 98-H-CCL. Case 6:98-cv-00003-CCL. Document 38. Filed January 17, 2012.

Hydrometrics. 2014a. *Supporting Information for the East Helena Controlled Ground Water Area Petition*. Draft. Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust. September 2014.

Hydrometrics. 2014b. 2014 *Groundwater and Surface Water Corrective Action Monitoring Plan*. Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust. July 2014.

Hydrometrics. 2014c. Source Area Inventory deliverable table titled: "Former East Helena Smelter Groundwater Containment Source Inventory." Attachment to email transmittal from Bob Anderson/Hydrometrics to Lauri Gorton/Custodial Trust, dated August 28, 2014.

Hydrometrics. 2014d. Personal communications of Source Area Investigation results provided in various email transmittals in September and October 2014.

NewFields. 2014. *Revised Work Plan for Solute Transport Model Development Former East Helena Smelter*. June 25, 2014.

U.S. Environmental Protection Agency (USEPA). 1994. *RCRA Corrective Action Plan*. Final. Office of Waste Programs Enforcement and Office of Solid Waste. OSWER Directive 9902.3-2A. May 1994.

U.S. Environmental Protection Agency (USEPA). 2000. *Fact Sheet #3, Final Remedy Selection for Results-based RCRA Corrective Action*. Office of Solid Waste, RCRA Corrective Action Workshop on Results-Based Project Management: Fact Sheet Series. March 2000.

Tables

TABLE 1
Remedy Description, Quantities, and Cost Assumptions
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Source Area	COC Addressed	Source Control Measure/ Groundwater Remedy	Description	Quantity Estimates	Cost Assumptions/Unit Cost Basis
Sitewide	As, Se	Baseline action: includes planned IMs, CGWA, and MNA	Completion of the three planned IMs, long-term administration of institutional controls in the form of the CGWA, and long-term MNA. Note: It is assumed that the baseline action will be implemented regardless of the recommendations of the Tier II evaluation. As such, the baseline action is not included for screening evaluation as shown in Table 2. All other potential Tier II source control measures/groundwater remedies and their associated costs are considered supplemental.	Planned IMs: As described in the various IM Work Plans. CGWA: Assume an area of 3,920 acres (approximately 5.1 sq. miles); all water supply wells within the CGWA (Hydrometrics, 2014a). MNA: Assume 30 years of monitoring for key indicator parameters; performance monitoring well network generally similar to monitoring well network identified in the 2014 CAMP (Hydrometrics, 2014b).	Capital Cost: no substantive capital costs. Long-term O&M: assume 30 years of monitoring; cost based on current groundwater monitoring budget, which is on the order of $375,000 annually, as performed under FSAP Implementation. NPW calculation assumes 30 years at 5% discount.
		P&T – onsite and offsite groundwater	Installation of groundwater extraction wells and construction of WTP to achieve: Containment along northern site boundary Containment downgradient of the site and at edge of plumes Remediation along northwest-southeast axis of offsite plumes	Assume a need to treat 150 MGY (see Attachment 2).	P&T - Capital cost: assume new WTP, extraction wells, piping, etc. See P&T capital costs in Attachment 2. P&T - Treatment: 150 MGY at $0.05/gal (CH2M HILL, 2010); NPW calculation assumes 30 years at 5% discount.
		P&T – onsite groundwater	Installation of groundwater extraction wells and construction of WTP to achieve containment along northern site boundary.	Assume a need to treat 50 MGY (see Attachment 2).	P&T - Capital cost: assume new WTP, extraction wells, piping, etc. See P&T capital costs in Attachment 2. P&T - Treatment: 50 MGY at $0.05/gal (CH2M HILL, 2010); NPW calculation assumes 30 years at 5% discount.
		P&T combined with Slurry Wall	Installation of slurry wall (low-permeability barrier) along the northern site boundary, with hydraulic control (funnel-and-gate/diversion structure), plus limited P&T. Variation: Installation of slurry wall along the southern site boundary, and funnel-and-gate system to divert water around the site, where the most contaminated soil would be found.	Slurry wall construction: assume the dimension of the slurry wall is 240,000 VSF based on: • length of 4,000 ft along the northern site boundary • depth of 60 ft, the approximate depth to the ash/clay layer Surface preparation: assume a need to clear a 20-ft-wide by 7-ft-deep surface trench for the length of the slurry wall to facilitate installation. Calculation: 4,000 LF x 20 ft x 7 ft = 20,741 CY. P&T: assume a need to treat 20 MGY (40 percent of the estimated 50 MGY for "P&T – onsite groundwater" (see Attachment 2) for water pumped for hydraulic control.	Slurry Wall Installation – Capital Costs: Slurry wall construction: assume unit cost of $12 per VSF (see Attachment 2) at 240,000 VSF. Surface preparation: assume $47 per CY to clear a 20-ft-wide by 7-ft-deep surface trench; unit cost based on excavation of unsaturated soil estimated as part of the SRE (CH2M HILL, 2014). P&T - Capital cost: assume new WTP, extraction wells, piping, etc. P&T - Treatment: assume 20 MGY at $0.05/gal (CH2M HILL, 2010); NPW calculation assumes 30 years at 5% discount.
West Selenium Area	Se (and to a lesser extent As)	Source Removal	Removal via excavation of contaminated source area soil in the saturated zone and overlying soil. Recent source area investigation leaching test results (Hydrometrics, 2014c) suggest that relatively low total Se concentrations in soil yielded fairly high concentrations in the leachate. Removal is therefore recommended to extend down to the top of ash/clay layer.	Recent source area investigation data (Hydrometrics, 2014c) suggest the source area may extend from boring EHSB-6 north to DH-8 (approximately 200 ft) and approximately 100 ft wide. See Figure 1 for approximate location. Assume excavation of 45 ft down to the top of ash/clay layer, and the DTW is 25 ft. Unsaturated zone soil volume = 100 ft x 200 ft x 25 ft = 18,519 CY Saturated zone soil volume = 100 ft x 200 ft x 20 ft = 14,815 CY	Capital Cost: excavation/removal of unsaturated soils assume unit cost of $47 per CY; excavation/removal of saturated zone soils assume unit cost of $151 per CY (see Attachment 2). Long-term O/M: none.
		PRB, with funnel-and-gate system	Installation of PRB along northern site boundary; PRB oriented perpendicular to groundwater flow direction and spanning the width of Se plume. Note that if PRBs were recommended for both the West Selenium Area and the North Plant Site Area, installation activities of the PRBs may be combined.	Recent source area investigation data (Hydrometrics, 2014c) suggest the width of the Se plume is approximately 75 ft at the northern site boundary. To be conservative, assume the PRB measures 100 ft wide as shown in Figure 1. Depth of PRB extends down to top of ash/clay layer; assume the DTW is 25 ft bgs and depth to top of ash/clay is 45 ft bgs (PRB height spans saturated interval thickness approximately 25 ft high). Note: PRB reactive materials will need replacement; literature indicates a replacement frequency of every 5-15 years.	PRB - Capital Cost: unit cost at a site in Sunnyvale, CA (see Attachment 2) was $3,000 per LF (width) where the PRB was 700 ft wide and installed 24 to 33 ft deep (ITRC, 2011); apply 1.5x cost factor because PRB at the site requires even deeper installation, plus a funnel-and-gate system. PRB - Replacement Cost: Assume complete replacement of the PRB every 10 years; NPW calculation assumes two PRB replacements in 30 years (years 10 and 20) at 5% discount.

TABLE 1
Remedy Description, Quantities, and Cost Assumptions
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Source Area	COC Addressed	Source Control Measure/ Groundwater Remedy	Description	Quantity Estimates	Cost Assumptions/Unit Cost Basis
		Slurry Wall/Hydraulic Enclosure of Source Area	Slurry wall (low-permeable hydraulic barrier) installed around primary source area and extending downgradient several hundred feed to encompass secondary sources from within the saturated zone. Depth of slurry wall extending down to top of ash/clay layer.	Slurry wall assumed to encompass entire source area (as described above) plus several hundred feet downgradient of primary source area in the saturated zone (illustrated in Figure 1). Slurry wall construction: assume the dimension of the slurry wall is 63,000 VSF based on: 100-ft-wide perpendicular to flow 600-ft-long parallel to flow direction 45-ft depth installed down into the top of ash/clay layer Surface preparation: assume a need to clear a 20-ft-wide by 7-ft-deep surface trench for the length of the slurry wall to facilitate installation. Calculation: 1,400 LF x 20 ft wide x 7 ft deep = 7,259 CY. Note: Need to excavate through Interim Cover 1.	Capital Costs: Slurry wall construction: assume unit cost of $12 per VSF (see Attachment 2) at 63,000 VSF. Surface preparation: assume $47 per CY to clear a 20-ft-wide by 7-ft-deep surface trench; unit cost based on excavation of unsaturated soil estimated as part of the SRE (CH2M HILL, 2014). Long-term O&M: None.
		Focused P&T	Assume two or three extraction wells installed across center of West Se plume downgradient of source with combined flow rate of 25 gpm (Source: Capture Zone Analysis). Groundwater to be treated using a semi-passive system that can be integrated with the PPC wetlands and discharged to the realigned PPC. . The treatment technology would be similar to that described in the *Crystal Mine Operable Unit 5 Final Interim Record of Decision* [ROD] (USEPA, 2014), which consists of a process using sulfate reducing biochemical reactor, aeration systems, oxidation/settling ponds, a wetland polishing complex, and discharge system.	Assume need to treat **13.1 MGY** Note: Treatment quantity based on long-term extraction rate of 25 gpm = 13.1 MGY.	P&T - Capital Cost: Assume $1M in capital costs, based on *Crystal Mine Operable Unit 5 Final Interim* ROD] (USEPA, 2014). P&T - Treatment: assume $50K per year (USEPA, 2014); NPW calculation assumes 30 years at 5% discount.
North Plant Site Area	As, Se	Source removal	Removal via excavation of contaminated source area soil in the saturated zone and overlying soil. Source area assumed as 'Potential Source Area 4' in Hydrometrics Source Investigation Data [Hydrometrics, 2014c]). Consistent with West Selenium area approach, assume that North Plant Area source removal would be performed to depths down to ash/clay layer.	Plan-view dimensions assume source area of 200 feet by 200 feet as shown in Figure 2. Depth of source removal assumed at 50 feet down to ash/clay layer; assume 20 feet unsaturated and 30 feet saturated source materials. Unsaturated zone volume estimate = 200 ft x 200 ft x 20 ft = 29,630 CY Saturated zone volume estimate = 200 ft x 200 ft x 30 ft = 44,444 CY	Capital Cost: excavation/removal of unsaturated soils assume unit cost of $47 per CY; excavation/removal of saturated zone soils assume unit cost of $151 per CY (see Attachment 2). Long-term O/M: none.
		PRB with funnel-and-gate system	Assume installation of PRB orientated perpendicular to groundwater flow direction & spanning plume width - installed along northern site boundary.	Assume PRB measures 500 feet wide perpendicular to As plume as illustrated in Figure 2. Assume PRB is 20 feet high starting at 30 feet deep and installed into top of ash/clay layer.	Capital cost: assume same approach as West Selenium PRB with unit cost of $3000 per LF plus 1.5 times cost given relatively long PRB dimensions. PRB Replacement: assume a need to replace PRBs (media) every 10 years, thus two replacements in 30-year period at 5% discount.
		Slurry Wall (hydraulic enclosure of source area)	Slurry wall (low-permeable hydraulic barrier) installed around primary source/source removal area (described above) and also the 'secondary source' saturated zone several hundred feet downgradient of the primary source as shown in Figure 2. Depth of slurry wall extends from uppermost zone of saturation to top of ash/clay layer.	Slurry wall dimensions estimated at 200 ft wide by 600 ft long as illustrated in Figure 2. Depth of slurry wall extends to 50 feet bgs installed into top of ash/clay layer. Slurry wall construction: assume the dimension of the slurry wall is 80,000 VSF based on: 200 ft wide 600 ft long 50-ft depth installed down into the top of ash/clay layer Surface preparation: assume a need to clear a 20-ft-wide by 7-ft-deep surface trench for the length of the slurry wall to facilitate installation. Calculation: 1600 LF x 20 ft wide x 7 ft deep = 8,296 CY.	Capital Costs: Slurry wall construction: assume unit cost of $12 per VSF (see Attachment 2) at 80,000 VSF. Surface preparation: assume $47 per CY to clear a 20-ft-wide by 7-ft-deep surface trench; unit cost based on excavation of unsaturated soil estimated as part of the SRE (CH2M HILL, 2014). Long-term O/M: not significant.

TABLE 1
Remedy Description, Quantities, and Cost Assumptions
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Source Area	COC Addressed	Source Control Measure/ Groundwater Remedy	Description	Quantity Estimates	Cost Assumptions/Unit Cost Basis
		In-situ treatment (dosing of aquifer with Fe), to augment slurry wall	Focused wellpoint injection and/or use of trenches to deliver ferrous sulfate solution into the source area (soils and/or saturated zone) within the enclosed slurry wall. For the Phase 1 evaluation this in-situ remedy is only considered as supplemental to augment the slurry wall option.	Assume that injection wellfield would need to cover the approximate 200 ft x 200 ft source area (see Figure 2); assume a total of 5 injection wells installed/screened to top of ash/clay layer. Assume a minimum of 4 injection events (i.e., quarterly frequency) for one year followed by performance monitoring).	Capital Costs: assume $10K for installation of each injection well (total of $50K for five wells) – see Attachment 2 assumptions for unit costs. Injection Events: assume $75K per each injection event (includes media and labor to inject) – see Attachment 2 assumptions for unit costs.
		In-situ treatment (S/S, to augment slurry wall)	Similar to dosing of aquifer with Fe (above) but use of 'binder reagents' to control, limit, or reduce plume size. Binder reagents such as phosphorous, lime-based biosolid, or Portland Cement may be injected via wellpoints.	Assume in-situ treatment area of 200-ft-wide by 200-ft-long (same as source area); depth of treatment area 25-50 ft bgs (target saturated zone). Soil volume for treatment: 29,600 CY or 44,500 tons (1.5 tons per CY soil) Soil volume for excavation: 37,000 CY vadose zone	S/S: Assume $100/ton [USEPA, 2006, p. 8): $46-125/ton soil; plus, Excavation/Dewatering: assume $47 per CY for vadose zone soil plus dewatering.
Former Speiss/Dross Area	As, Se	No Further Action (includes existing slurry walls)	Continue operations with existing slurry walls	See dimensions of existing and expanded slurry wall as shown in Figure 3.	Same approach as 'Sitewide' (above).
		Source Removal	Removal via excavation of source soils in unsaturated zone and within the saturated zone to depths down to ash/clay layer.	Removal quantities assume a source area of 250 feet by 50 feet in plan-view (marked as area 8 in source characterization work plan – See Figure 3) to depths of 45 feet bgs to top of ash/clay layer. Unsaturated Soil Volume = 250 ft x 50 ft x 25 ft = 11,574 CY Saturated Zone Soil Volume = 250 ft x 50 ft x 20 ft = 9,259 CY	Capital Cost: excavation/removal of unsaturated soils assume unit cost of $47 per CY; excavation/removal of saturated zone soils assume unit cost of $151 per CY (see Attachment 2). Long-term O/M: none.
		Expand slurry wall system to encompass former Speiss Storage & Handling Area	Expand existing slurry wall sides to encompass the Speiss Storage and Handling Area (Area 8) as shown in Figure 3. Only three sides given existing slurry wall along eastern edge of source area.	Slurry wall dimensions estimated at 50 ft wide (north and south walls) by 250 ft long (west wall) as illustrated in Figure 3. Slurry wall construction: assume the dimension of the slurry wall is 14,000 VSF based on: 50 ft wide (2 sides – north and south) 250 ft long (west wall) 40-ft depth installed down into the top of ash/clay layer Surface preparation: assume a need to clear a 20-ft-wide by 7-ft-deep surface trench for the length of the slurry wall to facilitate installation. Calculation: 350 LF x 20 ft wide x 7 ft deep = 1,815 CY.	Capital Costs: Slurry wall construction: assume unit cost of $12 per VSF (see Attachment 2) at 14,000 VSF. Surface preparation: assume $47 per CY to clear a 20-ft-wide by 7-ft-deep surface trench; unit cost based on excavation of unsaturated soil estimated as part of the SRE (CH2M HILL, 2014). Long-term O/M: not significant.
		In-situ treatment (Dosing of aquifer with Fe), to augment slurry wall	Focused wellpoint injection or use of trenches to deliver ferrous sulfate solution into the source area (soils or saturated zone) within the enclosed slurry wall.	As shown in Figure 3, assume that the injection areas would be within the existing slurry wall around Area 7 - Speiss Granulation (total of five injection wells) and Area 8 - Speiss Storage and Handling (one injection well). Assume total of six injection wells installed/screened to top of ash/clay layer; assume minimum of 4 injection events (i.e., quarterly frequency) for one year followed by performance monitoring.	Capital Costs: assume $10K for installation of each injection well (total of $60K for six wells) – see Attachment 2 assumptions for unit costs. Injection Events: assume $75K per each injection event (includes media and labor to inject) – see Attachment 2 assumptions for unit costs.

Abbreviations:

As	=	arsenic
bgs	=	below ground surface
CA	=	California
CAMP	=	Corrective Action Monitoring Plan
CGWA	=	Controlled Groundwater Area
COC	=	constituent of concern
CY	=	cubic yard
DTW	=	depth to water
Fe	=	ferrous sulfate
FSAP	=	Field Sampling and Analysis Plan
ft	=	foot/feet
gpm	=	gallon(s) per minute
IM	=	interim measure

TABLE 1
Remedy Description, Quantities, and Cost Assumptions
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Source Area	COC Addressed	Source Control Measure/ Groundwater Remedy	Description	Quantity Estimates	Cost Assumptions/Unit Cost Basis

LF = linear foot
MGY = million gallons per year
MNA = monitored natural attenuation
NPW = net present worth
O&M = operations and maintenance
P&T = pump & treat, abbreviation of groundwater extraction and treatment
PPC = Prickly Pear Creek
PRB = permeable reactive barrier
Se = selenium
SRE = Soil Removal Evaluation, Appendix E of CH2M HILL (2014)
S/S = Solidification/Stabilization
USEPA = U.S. Environmental Protection Agency
VSF = vertical square ft
WTP = water treatment plant

References:

CH2M HILL. 2010. *Review of Available Technologies for the Removal of Selenium from Water*. Final Report. Prepared for North American Metals Council.

CH2M HILL. 2014. *Former ASARCO East Helena Facility Corrective Measures Study Work Plan 2013*. Draft—For Beneficiary Review Only.
Appendix E: *Summary of Soil Removal Alternatives Evaluation at the East Helena Former ASARCO Smelter Site* (November 12, 2013).
Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust. January 2014.

Hydrometrics. 2014a. *Supporting Information for the East Helena Controlled Ground Water Area Petition*. Draft.
Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust. September 2014.

Hydrometrics. 2014b. 2014 *Groundwater and Surface Water Corrective Action Monitoring Plan*.
Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust. July 2014.

Hydrometrics. 2014c. Personal communications of Source Area Investigation results provided in various email transmittals in September and October 2014.

Interstate Technology & Regulatory Council (ITRC). 2011. *Technical/Regulatory Guidance Document: Permeable Reactive Barrier: Technology Update*. PRB-5. June 2011.

U.S. Environmental Protection Agency (USEPA). 2006. *In-Situ Treatment Technologies for Contaminated Soil, Engineering Issue Forum Paper*. EPA 542/F-06/013. November 2006.

U.S. Environmental Protection Agency (USEPA). 2014. *Crystal Mine Operable Unit 5 Final Interim Record of Decision* [ROD].

TABLE 2
Screening Evaluation (Effectiveness, Implementability, and Cost)
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Source Area	COC Addressed	Source Control Measure/Groundwater Remedy	Description	Screening Evaluation Criteria and Scoring: Effectiveness (Soring 1, 2, or 3; less to more effective)	Screening Evaluation Criteria and Scoring: Implementability (Scoring 1, 2, or 3; most difficult to easiest)	Screening Evaluation Criteria and Scoring: Cost – Scoring 1, 2, or 3 where (1 = High >$5M, 2=Med $2-5M, 3= Low <$2M)
Sitewide	As, Se	Baseline action: includes planned IMs, CGWA, and MNA.	Completion of the three planned IMs, long-term administration of institutional controls in the form of the CGWA, and long-term MNA.	NA NA – See note under 'Description' heading on Table 1.	NA NA – See note under 'Description' heading on Table 1.	NA **$5.8 M** <u>Capital Cost:</u> No substantive capital costs. <u>Long-term O/M</u> (i.e., monitoring): Assumes current groundwater monitoring budget of $375K annually as performed under FSAP Implementation. NPW calculation assumes 30 years at 5% discount.
		P&T – onsite and offsite groundwater	Installation of groundwater extraction wells and construction of WTP to achieve: • Containment along northern site boundary • Containment downgradient of the site and at edge of plumes • Remediation along northwest-southeast axis of offsite plumes	3 Can design wellfield(s) to contain/remediate plumes, and WTP to treat groundwater.	2 Drilling and water treatment technologies available; access agreements for wells and piping will need to be worked out. Development of new WTP to discharge to PPC and/or other locations will be difficult to implement.	1 **$120 M** <u>Capital cost</u>: **$3-5M** (assumes new WTP, extraction wells, piping, etc.) <u>Treatment</u>: **$115M** NPW (150 MGY, $0.05/gal, 30 years, at 5% discount)
		P&T – onsite groundwater	Installation of groundwater extraction wells and construction of WTP to achieve containment along northern site boundary.	3 Can design wellfield to contain plumes, and WTP to treat groundwater.	2 Drilling and water treatment technologies available; less effort than P&T – onsite and offsite groundwater, but access agreements for wells and piping will need to be worked out. Development of new WTP to discharge to PPC will be difficult to implement.	1 **$40.5 M** <u>Capital cost:</u> **$2.5M** (replacement WTP, extraction wells, piping, etc.). Assumes roughly one-half of combined onsite and offsite capital cost estimate (see above). <u>Treatment</u>: **$38M** NPW (50 MGY, $0.05/gal, 30 years, at 5% discount)
		P&T combined with Slurry Wall	Installation of slurry wall (low-permeability barrier) along the northern site boundary, with hydraulic control (funnel-and-gate/diversion structure), plus limited P&T. <u>Variation</u>: Installation of slurry wall along the southern site boundary, and funnel-and-gate system to divert water around the site, where the most contaminated soil would be found.	2 Can design/install physical barrier, diversion structures and wellfield for hydraulic control, and WTP to treat groundwater; however, highly uncertain about effects of barrier/hydraulic control on downgradient flow field and how that affects plume stability and geometry.	1 - 2 Earthwork, drilling, water treatment technologies available; likely need additional exploratory drilling (key to ash/clay layer), will need to work out access agreements. Development of new WTP to discharge to PPC will be difficult to implement.	1 **$21.8 M** <u>Slurry Wall Construction – Capital Cost:</u> **$2.9M** (assumes $12 per VSF @ 240,000 VSF) <u>Slurry Wall Surface Preparation – Capital Cost:</u> **$1.0M** (assumes $47 per CY @ 20,741 CY) <u>P&T - Capital Cost:</u> **$2.5M** (assume same as on-site for treatment plant) <u>P&T - Treatment:</u> **$15.4M** NPW (20 MGY, $0.05/gal, 30 years, at 5% discount)
West Selenium Area	Se (and to lesser extent As)	Source Removal	Removal via excavation of contaminated source area soil in the saturated zone and overlying soil. Recent source area investigation leaching test results (Hydrometrics, 2014) suggest that relatively low total Se concentrations in soil yielded fairly high concentrations in the leachate. Removal is therefore recommended to extend down to the top of ash/clay layer.	2 - 3 Source removal effective technology for primary source; however, ranked 2 to 3 considering the leaching test results suggest secondary source within saturated zone downgradient of primary source soils.	1 - 2 Earthwork technologies available. Considerations: Will need to excavate through ICS 1. Key into ash/clay later, some additional exploratory borings.	2 **$3.1M** <u>Capital Cost</u>: **$3.1M** Assume $47/CY unit cost at 18,519CY unsaturated soil removal = **$871K**; assume $151/CY unit cost for saturated zone @ 14,815CY = **$2.2M**. <u>Long-term O/M</u>: none.

TABLE 2
Screening Evaluation (Effectiveness, Implementability, and Cost)
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Source Area	COC Addressed	Source Control Measure/Groundwater Remedy	Description	Effectiveness (Soring 1, 2, or 3; less to more effective)	Implementability (Scoring 1, 2, or 3; most difficult to easiest)	Cost – Scoring 1, 2, or 3 where (1 = High >$5M, 2=Med $2-5M, 3= Low <$2M)
				Screening Evaluation Criteria and Scoring		
		PRB with funnel-and-gate system	Installation of PRB along northern site boundary; PRB oriented perpendicular to groundwater flow direction and spanning the width of Se plume. Note that if PRBs were recommended for both the West Selenium Area and the North Plant Site Area, installation activities of the PRBs may be combined.	2 to 3* Effective, based on ITRC (2011) and other literature. To treat Se and As, will need to construct PRB with different substrates (e.g., ZVI and organics [mulch]) in each. *Although lower As concentrations, As treatment will need to account for changes in geochemistry; for example, ZVI increases pH, so need to lower pH for oxidization. Possible formation of noxious by-products (hydrogen sulfide).	2 Technologies available. Will need to work along northern edge of ET Cover - West, but should not be difficult to install PRB if deemed appropriate. Assume can be installed on Custodial Trust property, so no access agreements needed. Will need to replenish substrate(s) every 5-15 years (frequency depends on contaminant, mass loading rate, and substrate)	**3** **$1.5M** **<u>Capital Cost</u>: $0.5M** (assumes unit cost of $3,000 per LF @ 100 ft long PRB with 1.5x factor and rounded up from $450K to 0.5M) **<u>PRB Replacement</u>: $1.0M NPW.** Assume complete replacement of the PRB system every 10 years; NPW calculation assumes two PRB replacements in 30 years (years 10 and 20) at 5% discount.
		Slurry Wall (hydraulic enclosure of source Area)	Slurry wall (low permeable hydraulic barrier) installed around all four sides of primary West Selenium source area to depths extending down to top of ash/clay layer. Note – uncertainty exists as to the actual size of source area.	2 - 3 Existing slurry walls at site (S/D and APSD) shown generally to be effective, despite uncertain design/construction specifications.	2 Earthwork technologies available. Considerations: Will need to excavate through ICS 1. Key into ash/clay later, some additional exploratory borings.	3 **$1.5M** <u>Slurry wall – Capital Cost</u>: **$1.0M** (assume $12 per VSF at 63,000 VSF = $756K; round up to $1.0M) <u>Surface Preparation – Capital Cost</u>: **$0.5M** (assumes $47 per CY at 7,259 CY = $341K; round up to $0.5M) <u>Long-term O/M</u>: none.
		Focused P&T	Assume two or three extraction wells installed across center of West Se plume downgradient of source with combined flow rate of 25 gpm (Source: Capture Zone Analysis).	2 - 3 Reasonably effective, extraction well(s) can be strategically placed to contain Se plume.	2 - 3 Drilling and water treatment technologies available. Assume no access agreements needed. Development of new WTP to discharge to PPC may be difficult to implement.	3 **$1.9 M** <u>Capital cost</u>: **$1.0M** (replacement WTP, extraction well(s), piping, etc.). <u>Treatment</u>: **$0.9M** (assumes $50K per year [USEPA, 2014] NPW calculation at 30 years, 5% discount).
North Plant Site Area	As, Se	Source Removal	Removal via excavation of contaminated source area soil in the saturated zone and overlying soil. Consistent with West Selenium area approach, assume that North Plant Area source removal would be performed to depths down to ash/clay layer.	2 - 3 Effective, if excavated to top of ash/clay layer and assuming source area is properly delineated.	1 - 2 Technologies (excavation, drive sheet piles, dewatering) readily available. However, need clear near-surface debris to access soil. If extent of removal zone is offsite on Chemet property, then access agreement needed.	1 **$8.1 M** <u>Capital Cost</u>: **$8.1M** Assumptions: overburden estimated at $47/CY @ 29,630 CY= $1.4M; saturated soils estimated at $151/CY @ 44,444 CY= $6.7M. <u>Long-term O/M</u>: none.
		PRB with funnel-and-gate system	Assume installation of PRB oriented perpendicular to groundwater flow direction and spanning plume width and installed along northern site boundary.	2 to 3* Effective, based on ITRC (2011) and other literature. To treat Se and As, will need to construct PRB with different substrates (e.g., ZVI and organics [mulch]) in each. *As treatment will need to account for changes in geochemistry; for example, ZVI increases pH, so need to lower pH for oxidization. Possible formation of noxious by-products (hydrogen sulfide).	2 Earthwork technologies available. Considerations: Key into ash/clay layer, some additional exploratory borings would be necessary. If extent of PRB wall is offsite on Chemet property and/or require RR ROW, then access agreements needed.	2 **$4.6 M** <u>Capital Cost</u>: **$2.3M** (assumes 500 ft long PRB at $3,000 per LF plus 1.5x cost). <u>PRB Replacement</u>: **$2.3M** NPW. Assume complete replacement of the PRB system every 10 years; NPW calculation assumes two PRB replacements in 30 years (years 10 and 20) at 5% discount.

TABLE 2
Screening Evaluation (Effectiveness, Implementability, and Cost)
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

				Screening Evaluation Criteria and Scoring		
Source Area	**COC Addressed**	**Source Control Measure/Groundwater Remedy**	**Description**	**Effectiveness (Soring 1, 2, or 3; less to more effective)**	**Implementability (Scoring 1, 2, or 3; most difficult to easiest)**	**Cost – Scoring 1, 2, or 3 where (1 = High >$5M, 2=Med $2-5M, 3= Low <$2M)**
North Plant Site Area	As, Se	Slurry Wall (hydraulic enclosure of source area)	Slurry wall (low-permeable hydraulic barrier) installed around primary source/source removal area (described above) and also the 'secondary source' saturated zone several hundred feet downgradient of the primary source as shown in Figure 2.	2-3 Existing slurry walls at site (S/D and APSD) observed to be effective, despite uncertain design/construction documentation.	2 Earthwork technologies available. Considerations: Key into ash/clay layer, some additional exploratory borings would be necessary. If extent of slurry wall is offsite on Chemet property and/or require RR ROW, then access agreements needed.	3 **$1.5 M** <u>Slurry Wall – Capital Cost:</u> **$1.0M** (assumes $12 per VSF at 80,000 VSF = $960Kround up to $1.0M) <u>Surface Preparation – Capital Cost:</u> **$0.5M** (assumes $47 per CY at 8,296 CY = $389K; round up to $0.5M) <u>Long-term O/M</u>: none.
		In-situ treatment (Dosing of aquifer with Fe), to augment slurry wall	Focused wellpoint injection and/or use of trenches to deliver ferrous sulfate solution into the source area (soils and/or saturated zone) within the enclosed slurry wall. **For the Phase 1 evaluation this in-situ remedy is only considered as supplemental to augment the slurry wall option.**	2 Effectiveness of delivery (via injection points) dependent on complexity and heterogeneity of saturated zone – which will impact the effectiveness of delivery. Deliver ferrous sulfate, solution using well points/trenches, will require periodic dosages; may experience pH increase	2 See effectiveness – number and spacing of wells dependent on understanding of subsurface conditions.	3 Less than **$1 M** <u>Capital Cost</u>: **$50K** (assumes installation of 5 injection wells into saturated zone). <u>Treatment/Injection Events</u>: **$300K** (assumes media and labor for 4 injection events).
	As, Se	In-situ Treatment (Solidification/Stabilization), to augment slurry wall	Similar to above but use of 'binder reagents' such as phosphorous, lime based biosolid, Portland cement, etc.	2 Same rationale as above. Use of binder reagents; likely will require a combination, if treating both Arsenic and Selenium. Soil mixing/stabilization, included with phosphorus, lime-based biosolid, Portland cement (physico-chemical process)	1 - 2 Technologies available. Likely require auger mixing for deeper soil. Literature indicates can go down to 150 ft. However, need to clear near-surface concrete, metal, and other debris to access soil. Large clast sizes will impede mixing; need achieve adequate "mixing."	1 **$6.5 M** <u>S/S – Capital Cost</u>: **$4.5M** (Assume $100/ton [USEPA, 2006, p. 8): $46-125/ton soil) plus, <u>Excavation/Dewatering – Capital Cost</u>**: $2M** (SRE: $47/CY for vadose zone soil plus dewatering) <u>Long-term O/M</u>: none.
Former Speiss/Dross Area	As, Se	No Further Action (includes existing slurry wall)	Completion of the three planned IMs, long-term administration of institutional controls in the form of the CGWA, and long-term MNA.	NA NA – See note under 'Description' heading on Table 1.	NA NA – See note under 'Description' heading on Table 1.	NA See Sitewide Costs (above).
		Source Removal	Removal via excavation of source soils in unsaturated zone and within the saturated zone to depths down to ash/clay layer.	2 Conceptually this remedy is effective, however, ranked 2 considering source removal dimensions are relatively small in comparison to overall plume and other source contributions.	1 Technologies (excavation, drive sheet piles, dewatering) readily available. However, need clear near-surface debris to access soil; very close to the Ore Storage Building	3 **$1.9 M** <u>Capital Cost</u>: **$1.9M** Assumptions: unsaturated soils estimated at $47 per CY at 11,574 CY= $0.5M; saturated soils estimated at $151 per CY at 9,259 CY= $1.4M. <u>Long-term O/M</u>: none.
		Expand slurry wall system to encompass former Speiss Storage and Handling Area	Expand existing slurry wall sides to encompass the Speiss/Dross feature marked as 'Potential Source Area 8' – as shown in Figure 3. Only 3 sides given existing slurry wall along eastern edge of source area.	2 Existing slurry walls at site (S/D and APSD) shown to be effective, despite less than well-known design/construction specifications. Conceptually this remedy is effective, however, ranked 2 considering source removal dimensions are relatively small in comparison to overall plume and other source contributions.	1 Earthwork technologies available. However, very close to the Ore Storage Building Considerations: Key into ash/clay layer, tie into existing slurry wall; possibly some additional exploratory borings.	3 $0.3 M <u>Slurry Wall – Capital Cost:</u> **$0.2M** (assumes $12 per VSF at 14,000 VSF = $0.2M) <u>Surface Preparation – Capital Cost:</u> **$0.1M** (assumes $47 per CY at 1,815 CY = $85K; round up to $0.1M) <u>Long-term O/M</u>: none.

TABLE 2
Screening Evaluation (Effectiveness, Implementability, and Cost)
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

				Screening Evaluation Criteria and Scoring		
Source Area	**COC Addressed**	**Source Control Measure/Groundwater Remedy**	**Description**	**Effectiveness (Soring 1, 2, or 3; less to more effective)**	**Implementability (Scoring 1, 2, or 3; most difficult to easiest)**	**Cost – Scoring 1, 2, or 3 where (1 = High >$5M, 2=Med $2-5M, 3= Low <$2M)**
		In-situ treatment (Dosing of aquifer with Fe), to augment existing and/or new slurry wall	Focused wellpoint injection and/or use of trenches to deliver ferrous sulfate solution into the source area (soils and/or saturated zone) within the enclosed slurry wall. For the Phase 1 evaluation this in-situ remedy is only considered as supplemental to augment the slurry wall option.	2 Effectiveness of delivery (via injection points) dependent on complexity and heterogeneity of saturated zone – which will impact the effectiveness of delivery. Deliver ferrous sulfate, solution using well points/trenches, will require periodic dosages; may experience pH increase	1 - 2 See effectiveness – number and spacing of wells dependent on understanding of subsurface conditions.	3 Less than **$1 M** <u>Capital Cost</u>: **$60K** (assumes installation of 6 injection wells into saturated zone). <u>Treatment/Injection Events</u>: **$300K** (assumes media and labor for 4 injection events).

Abbreviations:

As = arsenic
CGWA = Controlled Groundwater Area
COC = constituent of concern
Fe = ferrous sulfate
gpm = gallon(s) per minute
IM = interim measure
MNA = monitored natural attenuation
O&M = operations and maintenance
P&T = pump & treat, abbreviation of groundwater extraction and treatment
PRB = permeable reactive barrier
Se = selenium
SRE = Soil Removal Evaluation, Appendix E of CMS Work Plan (CH2M HILL, 2014) (see CH2M HILL work products)
S/D = Speiss/Dross
S/S = Solidification/Stabilization
WTP = water treatment plant

<u>References</u>:

CH2M HILL. 2014. *Former ASARCO East Helena Facility Corrective Measures Study Work Plan 2013*. Draft—For Beneficiary Review Only.
Appendix E: *Summary of Soil Removal Alternatives Evaluation at the East Helena Former ASARCO Smelter Site* (November 12, 2013).
Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust. January 2014.

Hydrometrics. 2014. Personal communications of Source Area Investigation results provided in various email transmittals in September and October 2014.

Interstate Technology & Regulatory Council (ITRC). 2011. *Technical/Regulatory Guidance Document: Permeable Reactive Barrier: Technology Update*. PRB-5. June 2011.

U.S. Environmental Protection Agency (USEPA). 2006. *In-Situ Treatment Technologies for Contaminated Soil, Engineering Issue Forum Paper*. EPA 542/F-06/013. November 2006.

TABLE 3
Comments and Recommendations
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Source Area	COC Addressed	Source Control Measure/Groundwater Remedy	Description	Comments / Information Needs	Recommendations	Combined Screening Score (highest possible = 9, most favorable remedy)
Sitewide	As, Se	Baseline action: includes planned IMs, CGWA, and MNA	Completion of the three planned IMs, long-term administration of institutional controls in the form of the CGWA, and long-term MNA.	Assume CGWA will be in place by 2016. The effectiveness of planned IMs will be modeled using NewFields' groundwater model.	NA – see comments in 'Description' in Table 1.	NA
		P&T – onsite and offsite groundwater	Installation of groundwater extraction wells and construction of WTP to achieve: • Containment along northern site boundary • Containment downgradient of the site and at edge of plumes • Remediation along northwest-southeast axis of offsite plumes	P&T can be implemented independent of planned IMs. Need to extract and treat groundwater essentially in perpetuity, especially if need to meet MCLs/DEQ-7 standards.	Too costly overall. Team discussed balancing the high cost of whole-sale groundwater cleanup with uncertain results versus incurring costs for point-of-use: stabilize the plumes within boundaries of CGWA, and drill new wells for owners impacted when needed. At this stage, all the larger-scale P&T remedies are not recommended for further evaluation in Phase 2.	6
		P&T – onsite groundwater	Installation of groundwater extraction wells and construction of WTP to achieve containment along northern site boundary.	Same as P&T – onsite & offsite (above).	Same as above.	6
		P&T combined with Slurry Wall	Installation of slurry wall (low-permeability barrier) along the northern site boundary, with hydraulic control (funnel-and-gate/diversion structure), plus limited P&T. <u>Variation</u>: Installation of slurry wall along the southern site boundary, and funnel-and-gate system to divert water around the site, where the most contaminated soil would be found.	Slurry wall/hydraulic control can be implemented independent of planned IMs.	Not recommended for further evaluation in Phase 2. Uncertain effects on downgradient plume stability and geometry.	4 to 5
West Selenium Area	Se (and to a lesser extent As)	Source Removal	Removal via excavation of contaminated source area soil in the saturated zone and overlying soil. Recent source area investigation leaching test results (Hydrometrics, 2014) suggest that relatively low total Se concentrations in soil yielded fairly high concentrations in the leachate. Removal is therefore recommended to extend down to the top of ash/clay layer.	Additional borings will be required to better define the West Selenium source area dimensions. Source removal will require excavation through ICS 1. .	Recommended for Phase 2 evaluation; groundwater flow model will be used to determine effectiveness in comparison to other remedies.	5 to 7
		PRB with funnel-and-gate system	Installation of PRB along northern site boundary; PRB oriented perpendicular to groundwater flow direction and spanning the width of Se plume. Note that if PRBs were recommended for both the West Selenium Area and the North Plant Site Area, installation activities of the PRBs may be combined.	More critical design variables to consider for As treatment. Se treatment technologies are better understood. Need to evaluate effect of PRB on groundwater flow.	Recommend further evaluation in Phase 2; may be preferred option if source area investigation yields inconclusive results in delineating the exact source area.	7 to 8
		Slurry Wall (hydraulic enclosure of source area)	Slurry wall (low-permeable hydraulic barrier) installed around primary source area and extending downgradient several hundred feed to encompass secondary sources from within the saturated zone. Depth of slurry wall extending down to top of ash/clay layer.	Dimensions of the slurry wall enclosure are assumed to encompass the source soils and also several hundred feet downgradient of the source in saturated zone. This approach may be more cost-effective than source removal.	Recommend further evaluation in Phase 2; slurry walls have been shown to be effective (S/D and APSD) and appears to be cost-effective.	7 to 8
		Focused P&T	Assume 2 or 3 extraction wells installed across center of West Se plume downgradient of source with combined flow rate of 25 gpm (Source: Capture Zone Analysis).	If selected remedy, should consider combining with neighboring As plume in mind.	Recommended for further evaluation in Phase 2.	7 to 9
North Plant Site Area	As, Se	Source Removal	Removal via excavation of contaminated source area soil in the saturated zone and overlying soil. Source area assumed as 'Potential Source Area 4' in Hydrometrics Source Investigation Data [Hydrometrics, 2014d]). Consistent with West Selenium area approach, assume that North Plant Area source removal would be performed to depths down to ash/clay layer.	Deep excavations to saturated zone within site footprint difficult to implement over substantial portion of impacted area. Assume will not need L-T O&M, so just roll up under ET Cover.	Not recommended for further evaluation in Phase 2; slurry wall is considered a more cost-effective option.	4 to 6

TABLE 3
Comments and Recommendations
Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Source Area	COC Addressed	Source Control Measure/Groundwater Remedy	Description	Comments / Information Needs	Recommendations	Combined Screening Score (highest possible = 9, most favorable remedy)
		PRB – with funnel-and-gate system	Assume installation of PRB orientated perpendicular to groundwater flow direction and spanning plume width - installed along northern site boundary.	Uncertain downgradient impacts based on geochemical changes to groundwater from PRB.	Recommended for further evaluation in Phase 2to compare against slurry wall and other potential options.	6 to 7
		Slurry Wall/ (hydraulic Enclosure of Source Area)	Slurry wall (low-permeable hydraulic barrier) installed around primary source/source removal area (described above) and also the 'secondary source' saturated zone several hundred feet downgradient of the primary source as shown in Figure 2.Depth of slurry wall extends from uppermost zone of saturation to top of ash/clay layer.	Some additional exploratory borings would be necessary to ensure wall keyed into ash/clay layer. If extent of slurry wall is offsite on Chemet property and/or require RR ROW, then access agreements needed.	Recommend further evaluation in Phase 2; slurry walls have been observed to be effective (S/D and APSD) and appears to be cost-effective.	7 to 8
		In-situ treatment (dosing of aquifer with Fe), to augment slurry wall	Focused wellpoint injection and/or use of trenches to deliver ferrous sulfate solution into the source area (soils and/or saturated zone) within the enclosed slurry wall. **For the Phase 1 evaluation this in-situ remedy is only considered as supplemental to augment the slurry wall option.**	Overall, remedy scores favorably for cost and implementability.	Recommend further evaluation in Phase 2 if used in conjunction with slurry wall.	7
		In-situ treatment (S/S, to augment slurry wall)	Similar to dosing of aquifer with Fe (above) but use of 'binder reagents' to control, limit, and/or reduce plume size. Binder reagents such as phosphorous, lime-based biosolid, Portland Cement may be injected via wellpoints or.	Would require significant additional subsurface information to design and implement.	Not recommended for Phase 2 considering overall high costs and implementability factors.	4 to 5
Former Speiss/Dross Area	As, Se	No Further Action (includes existing slurry wall)	Completion of the three planned IMs, long-term administration of institutional controls in the form of the CGWA, and long-term MNA.	Evaluate whether additional action in a focused area would measurably improve current situation – which may be the primary limiting factor for all remedies in the former Speiss/Dross area.	Recommend no additional action because existing slurry wall appears to be effective. Continue to monitor downgradient groundwater quality.	NA
		Source removal	Removal via excavation of source soils in unsaturated zone and within the saturated zone to depths down to ash/clay layer.	Assume will not need long-term O&M so just roll up under ET Cover. As above, limited area may not measurably improve current situation.	Not recommended for further evaluation; additional cost not justified when existing slurry wall appears generally to be effective.	6
		Expand slurry wall system to encompass former Speiss Storage and Handling Area	Expand existing slurry wall sides to encompass the Speiss Storage and Handling Area (Area 8) as shown in Figure 3. Only three sides given existing slurry wall along eastern edge of source area.	Proximity to Ore Storage and Handling Building would make it difficult to install.	Not recommended for further evaluation.	6
		In-situ treatment (dosing of aquifer with Fe), to augment slurry wall	Focused wellpoint injection or use of trenches to deliver ferrous sulfate solution into the source area (soils or saturated zone) within the enclosed slurry wall. **For the Phase 1 evaluation this in-situ remedy is only considered as supplemental to augment the slurry wall option.**	None.	This type of source control remedy is recommend for further evaluation if combined with another technology such as slurry wall. However, considering the limited area for source removal or slurry wall this supplemental remedy not recommended for further evaluation at this time.	6 to 7

TABLE 3

Comments and Recommendations

Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Source Area	COC Addressed	Source Control Measure/Groundwater Remedy	Description	Comments / Information Needs	Recommendations	Combined Screening Score (highest possible = 9, most favorable remedy)

Abbreviations:

As = arsenic
CGWA = Controlled Groundwater Area
COC = constituent of concern
Fe = ferrous sulfate
gpm = gallon(s) per minute
IM = interim measure
MNA = monitored natural attenuation
O&M = operations and maintenance
P&T = pump & treat, abbreviation of groundwater extraction and treatment
PRB = permeable reactive barrier
Se = selenium
SRE = Soil Removal Evaluation, Appendix E of CMS Work Plan (CH2M HILL, 2014) (see CH2M HILL work products)
S/D = Speiss/Dross
S/S = Solidification/Stabilization
WTP = water treatment plant

References:

CH2M HILL. 2014. *Former ASARCO East Helena Facility Corrective Measures Study Work Plan 2013*. Draft—For Beneficiary Review Only. Appendix E: *Summary of Soil Removal Alternatives Evaluation at the East Helena Former ASARCO Smelter Site* (November 12, 2013). Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust. January 2014.

Hydrometrics. 2014. Personal communications of Source Area Investigation results provided in various email transmittals in September and October 2014.

TABLE 4

Summary of Screening Evaluation Results and Recommendations for Phase 2 Evaluation

Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 1 Screening Results and Recommendations

Area(s)	Source Control Measure - Groundwater Remedy	Screening Evaluation Results Summary (where 3 is most effective/easiest to implement and lowest cost; 1 is the least effective/hardest to implement and highest cost)					Combined Screening Evaluation Score via Sum of Three Criteria (9 is best-case scenario)[a]	Recommendation for Phase 2 Evaluation (Retain or Exclude)[b]
		Effectiveness	Implementability	Cost: Relative (high-low)	Cost: Score (1-3)	Cost ($million)		
Sitewide (onsite and offsite groundwater)	Baseline Action (Planned IM's, CGWA, and MNA)	NA	NA	NA	NA	$5.8	NA	NA
	P&T - onsite and offsite groundwater	3	2	high	1	$120	6	Exclude
	P&T - onsite groundwater	3	2	high	1	$40.5	6	Exclude
	P&T combined with Slurry Wall	2	1 to 2	high	1	$21.8	4 to 5	Exclude
West Selenium Area	**Source Removal**	**2 to 3**	**1 to 2**	**medium**	**2**	**$3.1**	**5 to 7**	✓ **Retain**
	PRB	**2 to 3**	**2**	**low**	**3**	**$1.5**	**7 to 8**	✓ **Retain**
	Slurry Wall (hydraulic enclosure of source area)	**2 to 3**	**2**	**low**	**3**	**$1.5**	**7 to 8**	✓ **Retain**
	Focused P&T	**2 to 3**	**2 to 3**	**low**	**3**	**$1.9**	**7 to 9**	✓ **Retain**
North Plant Site Area	Source Removal	2 to 3	1 to 2	high	1	$8.1	4 to 6	Exclude
	PRB	**2 to 3**	**2**	**medium**	**2**	**$4.6**	**6 to 7**	✓ **Retain**
	Slurry Wall (hydraulic enclosure of source area)	**2 to 3**	**2**	**low**	**3**	**$1.5**	**7 to 8**	✓ **Retain**
	In-Situ (Injection of Fe) [in conjunction with Slurry Wall][c]	**2**	**2**	**low**	**3**	**Less than $1**	**7**	✓ **Retain**
	In-Situ (Solidification/Stabilization)	2	1 to 2	high	1	$6.5	4 to 5	Exclude
Former Speiss/Dross Storage Area	No Further Action (includes existing slurry walls)	NA	NA	NA	NA	NA	NA	NA
	Source Removal	2[d]	1	low	3	$1.9	6	Exclude
	Expanded Slurry Wall (hydraulic enclosure of source)	2[d]	1	low	3	$0.3	6	Exclude
	In-Situ (Injection of Fe)	2[d]	1 to 2	low	3	Less than $1	6 to 7	Exclude

Notes:

[a] Sum of combined screening scores where 9 would represent best-case scenario; a value of 7 or higher considered as a general guide for selecting favorable remedies for Phase 2 evaluation.

[b] **Bold-green** font with checkmark and "Retain" indicates source control measure-remedy recommended for detailed Phase 2 evaluation.

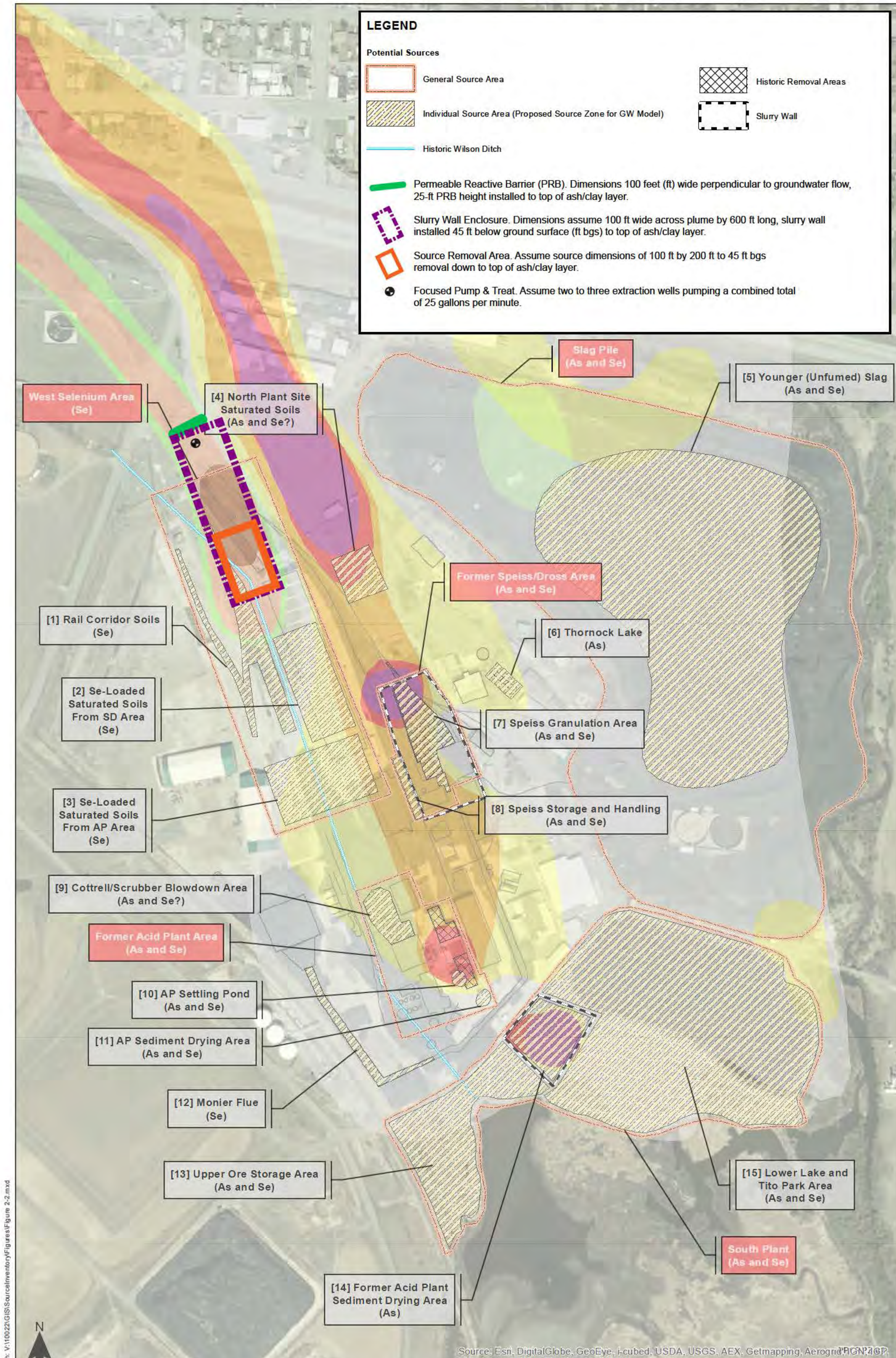
[c] In-Situ option only considered in conjunction with slurry wall - costs listed would be supplemental to the slurry wall.

[d] See screening evaluation rationale in Table 2 (i.e., relatively small dimensions and uncertain source area is rationale for moderate ranking).

Abbreviatons:

CGWA - controlled groundwater area
MNA = monitored natural attenuation
NA = not applicable
P&T = Pump and Treat
PRB = Permeable Reactive Barrier (assumes some type of slurry wall in conjunction with PRB)

Figures



0 150 300 600

Scale in Feet

Hydrometrics, Inc.
Consulting Scientists and Engineers

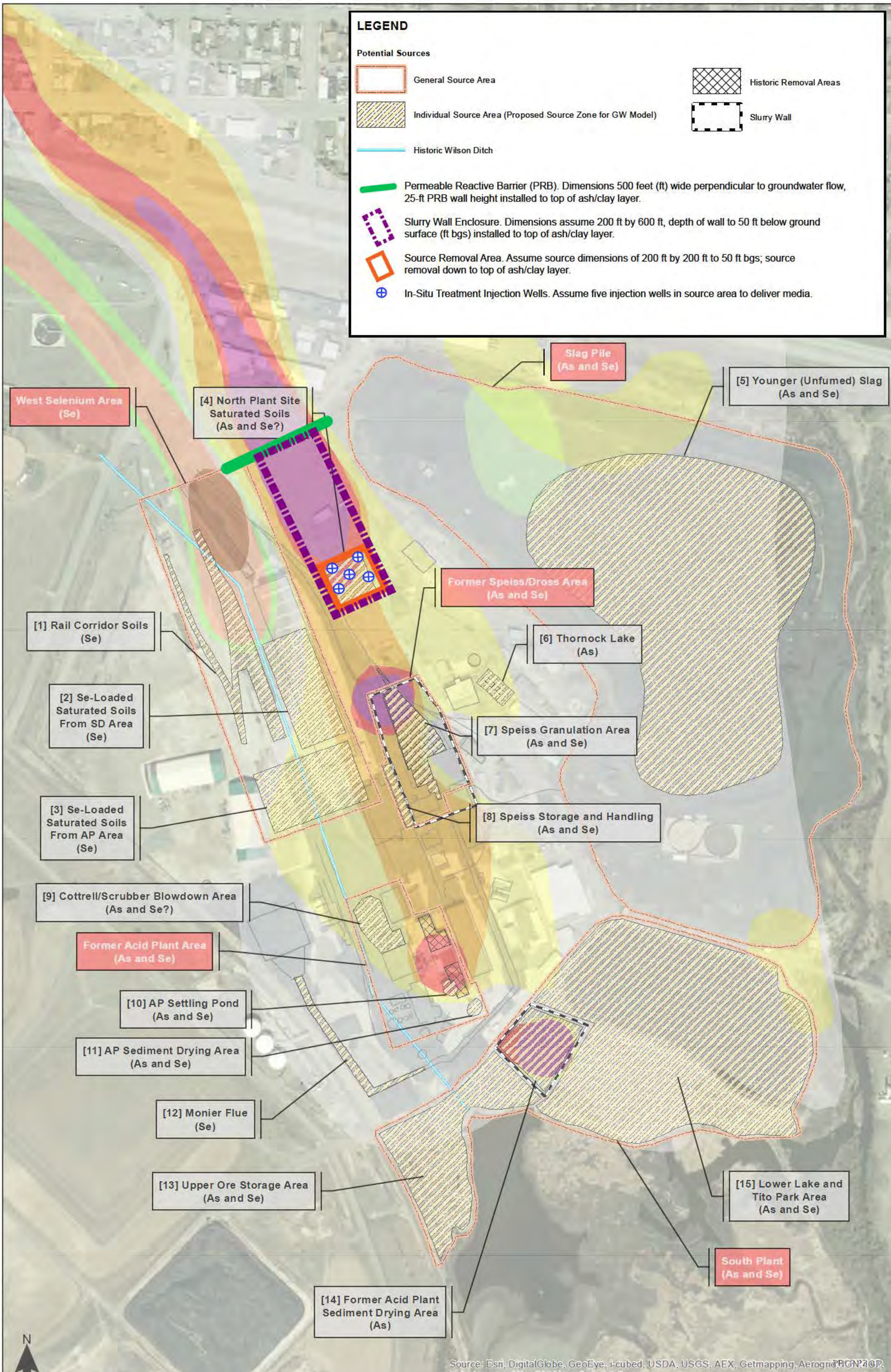
Date Saved: 8/27/2014 4:27:43 PM

SOURCE AREA CHARACTERIZATION WORK PLAN FOR THE FORMER EAST HELENA SMELTER

SOURCE: HYDROMETRICS, INC.

WEST SELENIUM AREA
SOURCE CONTROL MEASURES

FIGURE 1



Path: V:\10022\GIS\SourceInventory\Figures\Figure 2-2.mxd

0 150 300 600

Scale in Feet

Hydrometrics, Inc.
Consulting Scientists and Engineers

Date Saved: 8/27/2014 4:27:43 PM

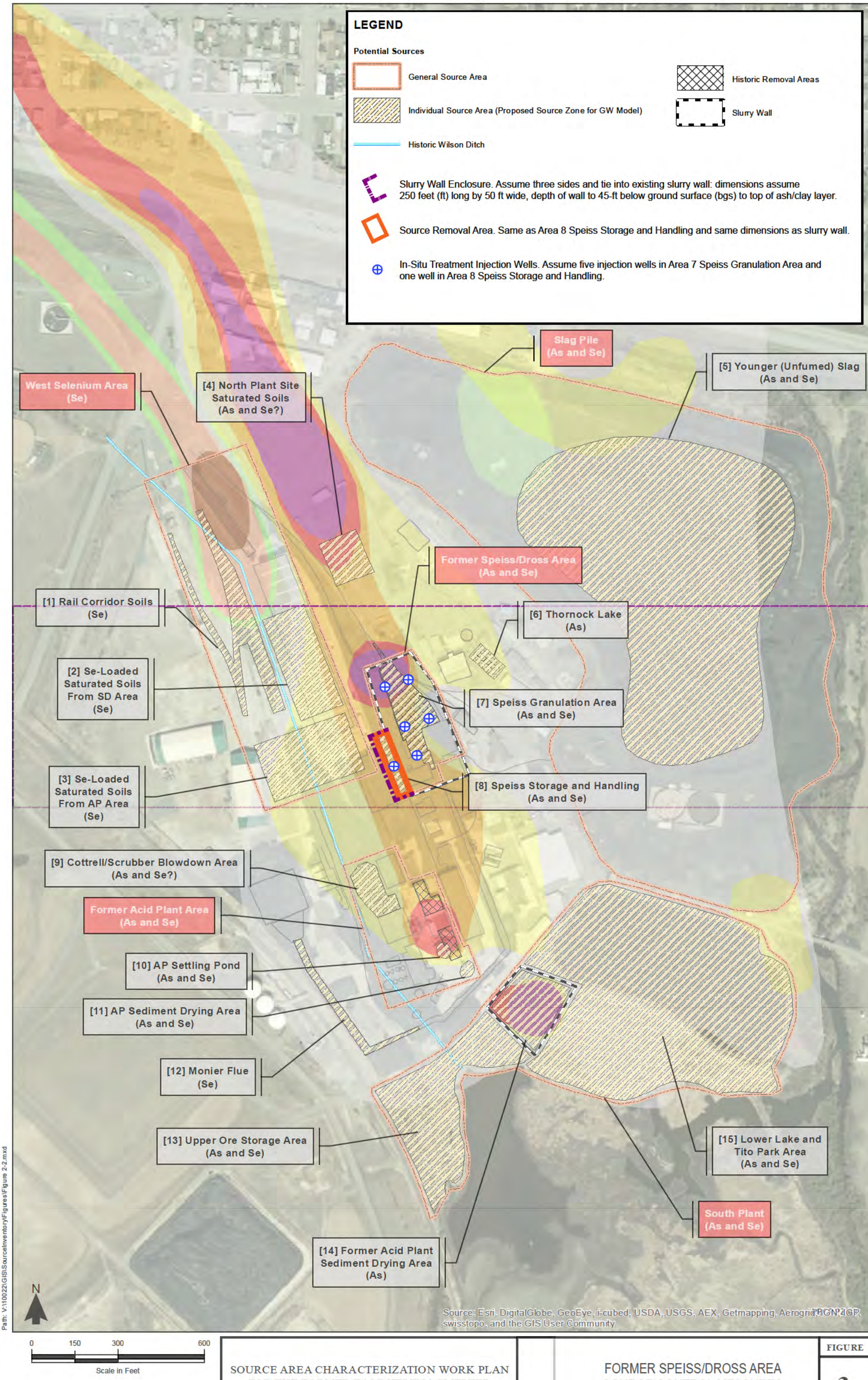
SOURCE AREA CHARACTERIZATION WORK PLAN FOR THE FORMER EAST HELENA SMELTER

SOURCE: HYDROMETRICS, INC.

NORTH PLANT SITE AREA
SOURCE CONTROL MEASURES

FIGURE

2



SOURCE AREA CHARACTERIZATION WORK PLAN
FOR THE FORMER EAST HELENA SMELTER

SOURCE: HYDROMETRICS, INC.

FORMER SPEISS/DROSS AREA
SOURCE CONTROL MEASURES

FIGURE

3

Attachment 1
U.S. Environmental Protection Agency
Balancing/Evaluation Criteria

ATTACHMENT 1

U.S. Environmental Protection Agency Balance/Evaluation Criteria

Resource Conservation and Recovery Act (RCRA) Corrective Action Workshop on Results-Based Project Management: Fact Sheet Series

FACT SHEET #3: FINAL REMEDY SELECTION FOR RESULTS-BASED RCRA CORRECTIVE ACTION (pp. 3-4)

When one or more alternatives appear to be capable of achieving the three final remedy performance standards […], EPA recommends that decision-makers use the seven attributes (called Balancing/Evaluation Criteria) listed below to help identify the “best” option.

1. **Long-Term Effectiveness**: Decision-makers should evaluate remedies based on the long-term reliability and effectiveness they afford, along with the degree of certainty that they will remain protective of human health and the environment. Additional considerations include: the magnitude of risks that will remain at a site from untreated hazardous wastes, and hazardous wastes and hazardous constituents, and treatment residuals; and the reliability of any containment systems and institutional controls. A remedial option should include a description of the approaches facilities will be used to assess long-term performance and effectiveness.
2. **Toxicity, Mobility, and Volume Reduction**: Decision-makers should evaluate remedies based on the degree to which they employ treatment, including treatment of principal threats, that reduces the toxicity, mobility or volume of hazardous wastes and hazardous constituents, considering, as appropriate: the treatment processes to be used and the amount of hazardous waste and hazardous constituents that will be treated; the degree to which treatment is irreversible; and the types of treatment residuals that will be produced.
3. **Short-term Effectiveness**: Decision-makers should evaluate remedies based on the short-term effectiveness and short-term risks that remedies pose, along with the amount of time it will take for remedy design, construction, and implementation.
4. **Implementability**: Decision-makers should evaluate remedies based on the ease or difficulty of remedy implementation, considering as appropriate: the technical feasibility of constructing, operating, and monitoring the remedy; the administrative feasibility of coordinating with and obtaining necessary approvals and permits from other agencies; and the availability of services and materials, including capacity and location of needed treatment, storage, and disposal services.
5. **Cost**: Decision-makers should evaluate remedies based on capital and operation and maintenance costs, and the net present value of the capital and operation and maintenance costs.
6. **Community Acceptance**: Decision-makers should evaluate remedies based on the degree to which they are acceptable to the interested community.
7. **State Acceptance**: Decision-makers should evaluate remedies should be evaluated based on the degree to which they are acceptable to the State in which the subject facility is located. This is particularly important where EPA, not the State, selects the remedy.

Attachment 2
Unit Costs and Cost Assumptions

ATTACHMENT 2

Unit Costs and Cost Assumptions

P&T[1]— Methods for Estimating Groundwater Flow and Treatment Volume Quantities

Onsite Groundwater: Achieve containment along northern site boundary.

- Method (A): Capture Zone Analysis as described in *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems* (U.S. Environmental Protection Agency [USEPA], 2008).

 Equation: $Q = K \times W \times d \times i \times Factor$

 where,

 Q = flow to achieve capture (various units, see table)
 K = hydraulic conductivity (feet per day [ft/day])
 W = width of plume (feet [ft])
 d = thickness of plume (ft)
 i = horizontal hydraulic gradient
 Factor = 1.5 to 2.0

 Assumptions:

 K = 10 ft/day
 W = 4,000 ft
 d = 10 ft
 i = 0.015

- Method (B): Flow model estimates of flux into the site as described in *DRAFT Groundwater Flow Model and Predictive Simulation Update Technical Memorandum* (NewFields, 2014).

				Range of Flows to Achieve Containment	
Parameter	Unit	Capture Zone Analysis: Method (A)	Flow Model Flux: Method (B)	Method (A) and Factor = 1.5	Method (B) and Factor = 2.0
Flow, Q	ft^3/day	6,000	12,652	9,000	25,304
	gpm	31	66	47	131
	gpd	44,880	94,556	67,320	189,112
	gal/yr	16,381,200	34,512,935	24,571,800	69,025,871
	MGY	16.4	34.5	24.6	69.0

Groundwater flow range of 16 to 69 million gallons per year (MGY); a**ssume 50 MGY for containment.**

Onsite and Offsite Groundwater: Achieve containment along northern site boundary and downgradient of the site, and remediate offsite plumes.

Assume three times the volume required or **3 x 50 MGY = 150 MGY**.

[1] Defined as "pump and treat," an abbreviation of groundwater extraction and treatment.

P&T—Treatment Cost of $0.05/gallon for Conventional Water Treatment Plant

The treatment unit cost of **$0.05 per gallon** is considered conservative and was selected for the Phase 1 evaluation based on the need to treat selenium (more costly than arsenic alone) and considering the cost information from similar treatment technologies as summarized in *Review of Available Technologies for the Removal of Selenium from Water* (CH2M HILL, 2010).

A summary of unit costs from this document is provided in the following chart:

Type of Treatment Technology	Flow Rate (gpm)	Capital Cost ($Millions)	O&M Cost ($ per year)	Cost Converted to ($/gal)
Conventional Reverse Osmosis	25	$5.5M	$450K/year	$0.03/gal
Mechanical evaporation/crystallization	25	Less than $10M	$950K/year	$0.07/gal
Ion Exchange	25	$3.7M	$550K/year	$0.04/gal
Iron Co-Precipitation	30	Less than $0.7M	$600K/year	$0.05/gal
Fluidized Bed Reactor	25	$1.4	$400K/year	$0.03/gal

Focused P&T—Treatment of Metals Using Semipassive Treatment System

The focused P&T alternative for the Phase 1 evaluation selected **$1M in capital cost and $50K annually for operations and maintenance (O&M) costs** based on the applicable costing information of a semipassive treatment system (Alternative 6) as described in the *Crystal Mine Operable Unit 5 Final Interim Record of Decision* [ROD] (USEPA, 2014).

In the Crystal Mine ROD, the groundwater source control measure (Alternative 6) is described as a semipassive treatment system for acid mine drainage prior to discharging to polishing wetlands and ultimate discharge into nearby surface waterbodies. The passive treatment technology consists of a five-stage process using sulfate reducing biochemical reactor, aeration systems, oxidation/settling ponds, a wetland polishing complex, and discharge system. Routine maintenance is not required with this alternative but some long-term maintenance would be needed. The initial stage consists of compost layers that would require rototilling every 5 years and replacement every 8 to 10 years. The secondary cells would have to be replaced every 10 to 15 years. Sludge from the clarification pond would need to be removed, dried, and transported to nearby repository (permitted landfill). Discharge from the Crystal Mine would be allowed to free-flow at natural rates into pipes connected to the treatment system.

Permeable Reactive Barrier

Unit cost of **$3,000 per lineal** feet of Permeable Reactive Barrier (PRB) system (includes wall and reactive barrier) obtained via reference paper *Technical/Regulatory Guidance Document—Permeable Reactive Barrier: Technology Update* (Interstate Technology & Regulatory Council [ITRC], 2011). The case study in Sunnyvale, California, used zinc as reactive media, installed by backhoe/sheet pile to depths from 24 to 33 ft below ground surface (bgs) to a length of 700 ft, with a unit cost of **$3,000 per lineal foot**. Note that this cost is on the high end and is considered conservative for PRB technology from other case studies presented in this research paper.

Slurry Wall (Hydraulic Enclosure of Source Area)

Assumes a slurry wall installed through saturated zone down to lower confining unit (i.e., tie into top of the ash/clay layer). The Phase 1-Tier II estimates assume unit costs for (1) surface preparation (for example, buildings, utilities, and surface pad) to facilitate installation of slurry wall, and (2) constructing the slurry wall in saturated zone.

Surface Preparation: Assume unit cost of **$47 per cubic yards (CY)** along length of slurry wall – which assumes a surface area of 20 feet wide by 7 feet deep to prep the surface, clear buildings, and deal with utilities along the same path as the dimensions of the slurry wall. See unsaturated zone 'source removal' (next section) for the $47 per CY cost unsaturated soil removal.

Slurry Wall Construction: Assume a unit cost of **$12 per vertical square foot (VSF),** which was developed based on actual costs for installing a slurry wall as part of the groundwater remedy at the Bunker Hill Superfund Site in Kellogg, Idaho (under Comprehensive Environmental Response, Compensation, and Liability Act regulations administered by USEPA). At the Bunker Hill site, a 2-mile-long slurry wall is being installed to depths of 30 to 40 feet bgs in unconsolidated sands and gravels and tying into the underlying confining unit (silt to silty clay unit). The unit cost for installing the slurry wall at the Bunker Hill site is $8 per VSF (via email and personal communication with Karen Dawson/CH2M HILL on 9/23/2014, lead geotechnical engineer); the Phase 1 cost assumptions are conservative and assume 1.5 times this unit cost to yield the **$12 per VSF** used in the evaluation.

Source Removal—Excavate and Remove Unsaturated and Saturated Zone Source Materials

Unit cost assumptions of **$47 per CY** for unsaturated soil removal and **$151 per CY** for saturated zone soil removal; unit cost obtained via **Table 4** of the site-specific *Summary of Soil Removal Alternatives Evaluation at the East Helena Former ASARCO Smelter Site* (CH2M HILL, 2013).

In-Situ Treatment—Dosing of Aquifer with Ferrous Sulfate or Iron Media

Installation of Injection Wells (to deliver media): Assume unit cost of $10K for installation of each new injection well with screen zone across saturated zone and depth of well to top of ash/clay layer.

Injection Events (assumes media and labor to inject): Assume unit cost of $75K for each injection event (multiple events anticipated/needed to optimize the technology).

Unit costs obtained via personal communication with Mark Henry/CH2M HILL, project manager for Fairchild Air Force Base environmental remediation sites SS-39 and Craig Road Landfill. Unit costs obtained from actual costs incurred in the SS-39 and Craig Road Pilot Studies, which consisted of installation of multiple injection wells spring in 2012 to depths ranging from 30 to 50 ft in alluvium, followed by multiple injection events of permanganate solution over the period from 2012 to 2013.

In-Situ Treatment—Solidification/Stabilization

Solidification/Stabilization (S/S): Assume unit cost of $100 per ton via *In-Situ Treatment Technologies for Contaminated Soil, Engineering Issue Forum Paper* (USEPA, 2006).

Excavation and Dewatering (associated with S/S technology): Assume $47 per CY for vadose zone soil removal and dewatering associated with the S/S activities (see 'Source Removal' above for this unit cost).

References

CH2M HILL. 2010. *Review of Available Technologies for the Removal of Selenium from Water*. Final Report. Prepared for North American Metals Council.

CH2M HILL. 2013. *Summary of Soil Removal Alternatives Evaluation at the East Helena Former ASARCO Smelter Site*.

Interstate Technology & Regulatory Council (ITRC). 2011. *Technical/Regulatory Guidance Document: Permeable Reactive Barrier: Technology Update*. PRB-5. June 2011.

Newfields. 2014. *DRAFT Groundwater Flow Model and Predictive Simulation Update Technical Memorandum*. Prepared for Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust. August 15, 2014.

U.S. Environmental Protection Agency (USEPA). 2006. *In-Situ Treatment Technologies for Contaminated Soil, Engineering Issue Forum Paper*. EPA 542/F-06/013. November 2006.

U.S. Environmental Protection Agency (USEPA). 2008. *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems. Final Project Report*. EPA/600/R-08/003. January 2008.

U.S. Environmental Protection Agency (USEPA). 2014. *Crystal Mine Operable Unit 5 Final Interim Record of Decision* [ROD].

Appendix B
Predictive Model Results: FINAL Predictive Fate and Transport Modeling, Interim Measures and Tier II Corrective Actions, East Helena Site (NewFields, 2015)

Technical Memorandum

To:	Lauri Gorton, METG	Project:	350.0024
From:	Cam Stringer and Joel Jacobson	cc:	Bob Anderson, Hydrometrics Jay Dehner, CH2MHill
Tel:	(406) 549-8270		
Date:	May 19, 2015		

Subject: FINAL Predictive Fate and Transport Modeling, Interim Measures and Tier II Corrective Actions, East Helena Site

1.0 INTRODUCTION

This memorandum describes the methods and results of predictive fate and transport modeling used to support evaluation of source control measures for the Corrective Measures Study (CMS) to address groundwater contamination associated with the former East Helena smelter located near the City of East Helena, Montana (**Figure 1.1**). The Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust (Custodial Trust), is performing the CMS in compliance with the RCRA Corrective Action requirements of the First Modification to the 1998 Resource Conservation and Recovery Act (RCRA) Consent Decree (Dreher et. al., 2012).

As part of the CMS work, and pursuant to EPA-approved work plans, the Custodial Trust is currently implementing three inter-related Interim Measures (IMs): South Plant Hydraulic Controls (SPHCs; draining Upper and Lower lakes, dewatering Wilson Ditch, and realigning Prickly Pear Creek, which includes construction of a temporary bypass channel), Source Removal (excavation of Tito Park soils), and the phased construction of an evapotranspiration (ET) Cover System over the former operating area of the site. Draining of Upper and Lower Lake, dewatering of Wilson Ditch, excavation of Tito Park soils, and installation of the Prickly Pear temporary bypass were implemented between 2012 and 2014, and the realignment of Prickly Pear Creek and completion of the ET Cover System are currently scheduled to be completed by the end of 2016.

In addition, the Custodial Trust is currently evaluating multiple source control measures to augment overall IM performance in the North Plant Site and West Selenium areas (**Figure 1.1**; other potential groundwater contaminant source areas may be evaluated in 2015 and 2016). Phase 1 of the Tier II Source Control/Groundwater Remedy Evaluation screened several source control measures that may be considered based on estimated effectiveness, implementability, and cost (CH2MHill, 2014a). The Phase 1 evaluation resulted in recommendations that several potential source control measures be carried forward for Phase 2 evaluation including source removal, permeable reactive barriers (PRBs), slurry walls, and focused pump and treat.

NewFields (2014d) presented a work plan for predictive fate and transport simulations to support evaluation of planned IMs and source control measures and meet modeling objectives set forth in multiple work plans (AMEC, 2012a; NewFields, 2014c; and Hydrometrics, 2010). NewFields designed and calibrated a fate and transport model that served as the base for predictive simulations (NewFields, 2015a). The model was constructed using MT3DMS software (Zheng and Wang, 1999) and simulates transport of arsenic and selenium from on-site sources. This memorandum describes implementation of the predictive fate and transport work plan.

The following subsections describe predictive simulation setup, results, sensitivity analysis, and conclusions. Figures, tables, and attachments are compiled at the end of the memorandum.

1.1 PREDICTIVE MODELING GOALS AND OBJECTIVES

The Phase II RFI Work Plan (Hydrometrics, 2010) set forth three objectives for groundwater modeling at the former smelter site, which included the following objective related to predictive analysis:

- Perform predictive simulations to evaluate potential effectiveness, aquifer response, and preliminary design considerations for various groundwater management and treatment scenarios that may be developed.

In addition, the fate and transport model work plan (NewFields, 2014c) included the following objectives related to predictive analysis:

- Evaluate effects on groundwater chemistry from currently planned IMs which include the SPHC project, excavation of Tito Park soils, and placement of an ET soil cover over the site.

- Evaluate effects of other potential IMs/Corrective Measures. Pending assessment of the effectiveness of currently planned IMs, either through the flow and transport model and/or through post-implementation groundwater monitoring, additional remedial measures may be warranted. In order to facilitate project planning and scheduling, the transport model will be used to predict the effects on groundwater quality of other potential remedial activities.

2.0 METHODS

The calibrated 2011 steady-state fate and transport model was used as the base case for comparison of predictive simulations (NewFields, 2015a). In general, hydraulic parameters and boundary conditions used in the calibrated model were also used in predictive simulations, with the exception of changes made to simulate IMs or source control measures (e.g., boundary conditions representing Prickly Pear Creek were adjusted to simulate the bypass and realignment).

Predictive simulations were developed in consultation with the groundwater team (consisting of staff from Hydrometrics, CH2MHill, and NewFields) based on completed or planned implementation of IMs and the Tier II Phase 2 source control evaluation. **Table 2.1** summarizes IMs and source control measures simulated with the fate and transport model. Simulations were performed in the order of completed or proposed implementation.

Simulations were developed to evaluate construction of both the Prickly Pear Creek bypass channel and realignment. The bypass simulation reflects conditions after dewatering of Wilson Ditch, removal of Upper Lake, excavation of Tito Park soils, and implementation of the Prickly Pear Creek bypass. The realignment simulation includes IMs simulated in the bypass scenario as well as complete removal of Lower Lake, installation of the ET Cover System, and implementation of the Prickly Pear Creek realignment. Calibrated arsenic and selenium concentrations from the 2011 simulation were used as initial concentrations for the IM simulations and results were compared to 2011 calibrated concentrations (see **Section 3.1**).

The realignment IM simulation served as the base for simulating Tier II Phase 2 source control measures. Boundary conditions were incorporated or adjusted in the realignment scenario to simulate proposed source control measures and three simulations were run for each source control measure to evaluate changes in concentrations based on ranges of potential effectiveness. Predicted arsenic and selenium concentrations from the realignment simulation were used as initial concentrations for the source control simulations and results were compared to the IM realignment simulation (see **Section 3.2**).

Steady-state groundwater flow fields, which represent average groundwater flow conditions, were used with transient fate and transport simulations that simulate changes in concentration over time. It was assumed that the respective IMs (either bypass or realignment) were implemented instantaneously beginning with 2011 conditions, and the Tier II Phase 2 source control measures were implemented instantaneously following the IM realignment simulation. This setup causes rapid changes in concentrations that are not representative of the time it would take concentrations to change. Predictive results presented below show changes in concentration that could be expected if an IM or source control were operational until concentrations reached equilibrium. In addition, equilibrium results are appropriate for evaluating IMs and source control measures on a comparative basis.

The following subsections describe setup of predictive simulations listed in **Table 2.1**.

2.1 INTERIM MEASURE SIMULATIONS

As discussed above, since 2012 the Custodial Trust has completed several IM components, including portions of the SPHC (draining of Upper and Lower Lake, dewatering of Wilson Ditch, and installation of the Prickly Pear temporary bypass), Source Removal (Tito Park Soils), and portions of the ET Cover System. The Prickly Pear Creek realignment (part of the SPHC IM) and remaining elements of the ET Cover System are currently planned to be completed in 2015 and 2016.

Transport simulations of arsenic and selenium were used to evaluate effects of IMs on groundwater quality. Steady-state flow fields were generated for each scenario and fate and transport simulations were run for 50 years to allow concentrations to reach steady-state (i.e., concentrations do not change with time). The following subsections describe boundary condition setup and parameterization of the IM simulations.

2.1.1 Prickly Pear Creek Temporary Bypass

To simulate long-term hydrologic effects of IMs, a steady-state groundwater flow simulation was generated representing average conditions anticipated to occur after implementation of elements of the IMs, including the Prickly Pear Creek bypass which was completed in 2013. Model inputs used to generate the flow field for this simulation were those used in the most recent refinement of the flow model, described in NewFields (2015a), which include:

- Hydraulic conductivity values (listed in NewFields, 2014b and 2015a);
- Well Package (specified flux) boundaries representing irrigation ditches and municipal well pumping (listed in AMEC, 2012 and NewFields, 2014b);
- Recharge Package (specified flux) boundaries representing net infiltration applying estimated average rates as described in AMEC (2012b) and used in the 2011 steady-state calibration;
- Drain Package (head-dependent) boundaries representing drainage ditches (listed in AMEC, 2012 and NewFields, 2014b);
- Evapotranspiration Package (head-dependent) boundaries with rates from the most recent calibration to 2011 data (NewFields, 2014a; 2014b); and
- River Package (head-dependent) boundary cells representing the Prickly Pear Creek bypass (Pioneer Technical, 2014a; **Figure 2.1**), Lower Lake, and Prickly Pear Creek described in NewFields (2014b). The distribution of cells representing the bypass accurately reflects as-built drawings provided by Pioneer Technical, (2014a; **Figure 2.1**). Stage values assigned to cells representing Prickly Pear Creek and the bypass channel are based on the average of stage measured at stations upstream and downstream of this reach in 2013 and 2014. River Package cells representing Upper Lake were removed to reflect dewatering of the lake in 2012.

Unsaturated source terms for arsenic and selenium were assigned based on the 2011 calibration (NewFields, 2015a). Mass flux for saturated source terms from the 2011 calibrated simulation were scaled proportionately based on the difference between the model-calculated groundwater flux through the cells representing source areas before and after implementation of elements of the IMs (**Attachment A**). In addition, Tito Park source terms were removed to reflect source removal actions completed in 2014.

These simulations include the assumption that the flux of arsenic and selenium mass from saturated source areas following implementation of elements of the IMs will decrease proportional to the decrease in saturated thickness. As in the transport model calibration, it was assumed that the overall vertical distribution of saturated source mass does not vary within the model layer it is assigned to. It was also assumed that no further source is left in Tito Park following soil removal.

2.1.2 Prickly Pear Creek Realignment

This simulation is similar to the bypass simulation (see **Section 2.1.1**) except that the distribution of River Package Cells representing Prickly Pear Creek were adjusted to match the design of the Prickly Pear Creek realignment (**Figure 2.1**). The distribution of River Package Cells was based on the distribution described in NewFields (2014b) representing the realignment simulation and supplemental information provided by Pioneer Technical (Pioneer Technical, 2014b). Stage values for cells representing the realignment were assigned based on the average of stage measurements at stations upstream and downstream of the planned realignment. In addition, recharge rates in the area of the planned ET Cover System were adjusted to match preliminary estimates of infiltration through the cover (**Figure 2.1**; CH2MHill, 2014b), and River Package cells representing Lower Lake were removed. All other flow model inputs and parameters were the same as the bypass simulation.

Unsaturated source terms for arsenic and selenium used in the realignment simulation were the same as those used in the bypass simulation, and mass flux rates for saturated source terms from the 2011 simulation were scaled proportionately based on the difference between the model calculated groundwater flux before and after implementation of the SPHCs (**Attachment A**).

2.2 TIER II PHASE 2 SOURCE CONTROL SIMULATIONS

Simulations were developed to evaluate potential effects of each source control measure considered in the Tier II Phase 2 evaluation (**Table 2.1**) using model inputs from the IM realignment simulation described in **Section 2.1.2.** Three scenarios were run for each source control measure, and results were used to evaluate potential changes in downgradient contaminant concentrations and plume geometry. The three scenarios for each source control measure simulate a different level of assumed effectiveness. Results of the IM realignment simulation were used as initial conditions for the source control scenarios and fate and transport simulations were run for 50 years to allow concentrations to reach steady-state (i.e., concentrations and plume geometry do not change with time). Tier II Phase 2 source control simulation results were compared to results of the IM realignment simulation.

The following subsections describe inputs developed for each source control simulation.

2.2.1 North Plant Site Area Permeable Reactive Barrier

Construction of a hypothetical PRB downgradient of the North Plant Site arsenic source area was simulated. Model cells representing the PRB were placed in Layers 1, 2, and 3. The PRB geometry was based on plume width, depth of the ash/clay layer, and a preliminary design provided by CH2MHill (**Figure 2.2**; CH2MHill, 2014c). The PRB was assigned a hydraulic conductivity of approximately 138 feet/day based material properties estimated from an existing PRB on site (Wilkin, et. at., 2008).

Removal of arsenic by a PRB was simulated using decay coefficients. A half-life of 0.001 days was assigned to the PRB to simulate 100 percent arsenic removal. To evaluate a range of potential effectiveness, additional simulations were run using half-lives of approximately 6.6 and 3.8 days to simulate 43 and 55 percent arsenic mass removal, respectively. Half-lives were determined based on estimated residence time in the PRB from the groundwater flow model. All other arsenic transport inputs remained consistent with the IM realignment simulation.

2.2.2 North Plant Site Area Slurry Wall

Construction of a hypothetical slurry wall around the North Plant Site arsenic source area was simulated. MODFLOW's Hydraulic Flow Barrier (HFB) Package was used to simulate the slurry wall encompassing the source area as shown in **Figure 2.2**. HFB boundaries were placed in Layers 1, 2, and 3 and distributed laterally based on a preliminary design from CH2MHill (**Figure 2.2**; CH2MHill, 2014c). The boundaries were assigned a thickness of 2 feet based on parameterization of existing slurry walls at the site in the calibrated flow model. Hydraulic conductivity values of 0.01, 0.1, and 1.0 foot/day were used to simulate the slurry wall to evaluate a range of potential effectiveness.

Mass loading rates were adjusted proportionally to the predicted reduction in groundwater flux through the source area for each simulation (**Attachment A**). This scenario assumes that the slurry wall will have uniform thickness and permeability and will be keyed into the ash/clay layer, with no leakage underneath it.

2.2.3 West Selenium Area Source Removal

Removal of saturated and unsaturated source material in the West Selenium area by excavation was simulated. Mass loading rates in the West Selenium Source area simulations were reduced by 50, 70, and 100 percent to evaluate a range of potential effectiveness.

2.2.4 West Selenium Area Permeable Reactive Barrier

Construction of a hypothetical PRB to remove selenium from groundwater in the West Selenium area was simulated. Geometry of the PRB was based on plume width, depth of the ash/clay layer, and preliminary designs from CH2MHill (**Figure 2.2**; CH2MHill, 2014c). Model cells in Layers 1, 2, and 3 were assigned a hydraulic conductivity of approximately 15 feet/day based on PRB material properties estimated for another project involving construction of a PRB for removal of selenium from groundwater (NewFields 2015b). Model cells representing the PRB were assigned half-lives of approximately 7.2, 4.2, and 0.01 days that simulate 67, 76, and 100 percent removal, respectively.

2.2.5 West Selenium Area Slurry Wall

Construction of a hypothetical slurry wall placed around the West Selenium source area was simulated. The slurry wall was simulated using HFB Package boundaries encompassing the source area as shown in **Figure 2.2**. HFB boundaries were placed in Layers 1, 2, and 3 and distributed horizontally based on a preliminary design from CH2MHill (**Figure 2.2**; CH2MHill, 2014c). The boundaries were assigned a thickness of 2 feet based on parameterization of existing slurry walls at the site in the calibrated model. Hydraulic conductivities of 0.01, 0.1, and 1.0 foot/day were used to simulate the slurry wall to evaluate a range of potential effectiveness.

Mass loading rates were adjusted proportionally to the predicted reduction in groundwater flux through the source area for each simulation (**Attachment A**). This scenario assumes that the slurry wall will have uniform thickness and permeability and will be keyed into the ash/clay layer, with no leakage underneath it.

2.2.6 West Selenium Area Focused Pump and Treat

Construction of a hypothetical pump and treat system to capture groundwater containing selenium originating from the West Selenium source area was simulated. Two MODFLOW Well Package cells were placed in Layer 3 a short distance downgradient of the source area (**Figure 2.2**) and pumping rates were adjusted incrementally until all groundwater with a selenium concentration above 0.05 milligrams per liter (mg/L) was captured. To test potential ranges of pumping rates, transmissivity was increased and decreased around the pumping wells by 50 percent and pumping rates were adjusted to maintain capture of groundwater with selenium concentration above 0.05 mg/L.

3.0 RESULTS

Predictive simulations were evaluated using qualitative and quantitative methods. Qualitative evaluation was performed by visually comparing changes in plume geometry for the 2011 calibrated model and IM and source control simulations. Quantitative evaluation was performed by comparing predicted changes in concentration at individual wells, volume of groundwater above the U.S. Environmental Protection Agency's (EPA) maximum contaminant level (MCL) for arsenic and selenium, and total mass of arsenic and selenium in groundwater. The volume of groundwater with arsenic or selenium above the MCL was calculated by multiplying the saturated thickness of cells with simulated groundwater concentrations above the MCL by the area of the cell and porosity. The total mass of arsenic or selenium in groundwater was calculated by multiplying the simulated groundwater concentration by the volume of groundwater (i.e., saturated thickness multiplied by area and porosity) in each model cell. Downgradient (north of the property boundary) volume and mass were calculated in order to evaluate predicted effects of the IMs and source control measures. On-site (south of the property boundary) volume and mass were also calculated but were not used to evaluate IMs or source control measures. IM and source control simulations were compared to results from the 2011 calibrated fate and transport model. In addition, the source control simulations were compared to results from the IM realignment simulation.

The following subsections summarize results of IM and source control simulation results. Simulated two-dimensional plume maps were generated by integrating simulated concentrations in the upper three model layers (i.e., above the ash/clay layer). Plots showing predicted changes in concentration at individual wells are not intended to depict the amount of time it would take to reach equilibrium concentrations. Instead, the graphs are meant to show changes in concentration that could be expected if an IM or source control measure were operational until concentrations reached equilibrium. The use of a steady-state flow field in this analysis, which simulates instantaneous changes in groundwater flow as a result of the implementation of remedial measures (as described in **Section 2.0**), likely leads the model to under-predict the time it would take for concentrations to reach equilibrium. A transient groundwater flow model would need to be constructed to more accurately simulate temporal changes in concentrations resulting from remedial measures.

3.1 INTERIM MEASURE SIMULATIONS

IMs were evaluated by comparing predictive simulations to results from the 2011 steady-state calibration, which represents baseline conditions.

3.1.1 Arsenic Plume Geometry, Volume, and Mass

In general, the model predicts that the overall size and shape of the arsenic plume (based on the 0.01 mg/L MCL isoconcentration contour) will not change significantly after implementation of the SPHC, Source Removal, and ET Cover System IMs. However, concentrations within specific areas of the plume are predicted to decrease and the total mass of arsenic in groundwater is predicted to decrease by 66 percent downgradient of the site.

Figure 3.1 compares simulated arsenic plume maps for the 2011 calibrated model, bypass, and realignment simulations, and includes a chart showing predicated changes in concentration at selected downgradient wells. The model predicts that concentrations of arsenic in groundwater in the Lower Lake and Acid Plant Sediment Drying areas decrease primarily as a result of source removal in Tito Park. Concentrations in the central plant site, around the North Plant Site arsenic source area decrease as a result of a decrease in groundwater flux through saturated source material. The model predicts arsenic concentrations will decrease between approximately 58 and 75 percent in wells DH-64 and EH-111, located directly downgradient (north) of the North Plant Site arsenic source area, as a result of decreased groundwater flux through saturated source material.

Tables 3.1a and **3.1b** present predicted changes in the volume of groundwater above U.S. EPA's arsenic MCL (0.01 mg/L) and changes in the total mass of arsenic dissolved in groundwater, respectively. The total volume of groundwater above the MCL increased by 5 percent and decreased by 6 percent for the bypass and realignment simulations, respectively. The volume of groundwater above the MCL downgradient of the site increased by 8 percent and 1 percent for the bypass and realignment simulations, respectively. These predicted changes are likely the result of small changes in groundwater flow direction within and downgradient of the site.

The total mass of arsenic in groundwater is predicted to decrease by 47 percent after implementation of the bypass compared to the 2011 simulation, with a 52 percent decrease in mass downgradient of the site. The total mass of arsenic in groundwater for the realignment simulation is predicted to decrease by 66 percent, with a 75 percent decrease downgradient of the site compared to the 2011 simulation. Decreases in mass correspond to reduced concentrations in the center of the plume (**Figure 3.1**).

3.1.2 Selenium Plume Geometry, Volume, and Mass

Predictive results show that implementation of IMs slightly decreases the downgradient extent of elevated selenium concentrations. In addition, the volume of groundwater above the MCL and the total mass of selenium in groundwater are predicted to decrease by 40 percent and 28 percent, respectively, for the realignment simulation.

Figure 3.2 compares simulated selenium plume maps for the 2011 calibrated model, bypass, and realignment simulations, and includes a chart showing predicated changes in concentration at selected downgradient wells. Selenium concentrations decrease in the Acid Plant area and the west and east lobes of the selenium plume begin to separate. The model predicts that selenium concentrations in well DH-67, located downgradient of the West Selenium area, decrease approximately 55 percent after implementation of the IMs. The concentration in well EH-118 is predicted to increase by approximately one order of magnitude (0.03 to 0.3 mg/L). The predicted increasing concentration in well EH-118 is caused by a westward shift in the selenium plume that is largely a result of dewatering Wilson Ditch.

The total volume of groundwater above U.S. EPA's selenium MCL (0.05 mg/L) is predicted to decrease by 18 percent and 40 percent for the bypass and realignment simulations, respectively (**Table 3.2a**). The volume of groundwater above the MCL downgradient of the site is predicted to decrease by 19 for the bypass simulation and 42 percent for the realignment simulation. The total and downgradient mass of selenium in groundwater is predicted to decrease by 16 percent for the bypass simulation and 39 percent for the realignment simulation (**Table 3.2b**). The mass of selenium in groundwater on-site is predicted to decrease by 15 and 28 percent for the bypass and realignment simulations, respectively. Decreases in volume and mass of selenium are the result of decreased groundwater flux through saturated source areas after IM implementation.

3.2 Tier II Phase 2 Source Control Simulations

Source control measures identified in the Tier II Phase 2 study were evaluated by comparing predictive simulations to the IM realignment simulation results because the realignment simulation represents baseline conditions (i.e., it was assumed for the predictive analysis that all IMs will be completed prior to implementation of source control measures).

3.2.1 North Plant Site Area Permeable Reactive Barrier

The model predicts that construction of a PRB downgradient of the North Plant Site arsenic source would not result in a substantial decrease in the extent of the arsenic plume (**Figure 3.3**). However, predicted concentrations within the plume downgradient of the site are lower. The 1 mg/L isoconcentration contour does not extend as far downgradient of the site after implementation of the PRB. In general, as PRB effectiveness increases, concentrations downgradient of the PRB decrease. Concentrations at wells DH-64 and EH-111, located downgradient of the North Plant Site area, decrease between approximately 47 and 98 percent depending on PRB effectiveness.

The volume of groundwater containing arsenic above the MCL is predicted to increase between 2 and 3 percent after implementation of the PRB compared to the IM realignment simulation (**Table 3.1a**). The increase in volume of groundwater above the MCL is likely the result of small increases in saturated thickness behind the PRB. The total mass of arsenic in groundwater is predicted to decrease between 15 and 37 percent relative to the IM realignment simulation depending on PRB effectiveness (**Table 3.1b**). The mass of arsenic in groundwater downgradient of the site is predicted to decrease between 26 and 58 percent compared to the IM realignment simulation.

3.2.2 North Plant Site Area Slurry Wall

A slurry wall encompassing the North Plant Site arsenic source area is predicted to have little effect on the overall extent of the arsenic plume (**Figure 3.4**). However, similar to the PRB simulations, construction of a slurry wall is predicted to result in decreased concentrations within the plume. Concentrations in well DH-64, downgradient of the slurry wall, are predicted to decrease between approximately 71 and 92 percent depending on slurry wall permeability.

The volume of groundwater above the MCL is predicted to increase by approximately 3 percent compared to the IM realignment simulation, which is likely related to changes in saturated thickness around the slurry wall (**Table 3.1a**). Similar to the PRB simulations, high concentration zones in the North Plant Site area are predicted to shrink and the total mass of arsenic in groundwater is predicted to be reduced between 40 and 47 percent after implementation of the slurry wall compared to the IM realignment simulation (**Table 3.1b**). The mass of arsenic in groundwater downgradient of the site is predicted to decrease between 43 and 53 percent compared to the IM realignment simulation.

The potential effect of the slurry wall on groundwater elevation and flow directions was also evaluated. **Figure 3.5** presents predicted changes in groundwater elevation in the North Plant Site area as a result of the slurry wall. Changes in groundwater elevation were calculated as the difference in head between the IM realignment and 0.1 foot/day permeability slurry wall simulations. Groundwater elevations are predicted to increase south and southeast of the slurry wall up to 3 feet, with the largest increases occurring directly upgradient of the wall. Groundwater elevations are predicted to decrease directly downgradient of the wall up to 0.75 feet.

Groundwater flow directions around the North Plant Site slurry wall were analyzed using particle tracking. **Figure 3.6** presents particle tracking results for the IM realignment and North Plant Site slurry wall (0.1 foot/day permeability) simulations. Particles were placed upgradient of the slurry wall in the upper three model layers (i.e., above the ash/clay) and traced through the flow field in the direction of groundwater flow. Based on the particle track results, groundwater flow directions shift to the west, towards the West Selenium source area after implementation of the North Plant Site slurry wall.

3.2.3 West Selenium Area Source Removal

Removal of source material in the West Selenium area is predicted to have significant effects on plume geometry, volume of groundwater above the MCL, and the total mass of selenium in groundwater. **Figure 3.7** presents predicted plumes for the IM realignment and source removal simulations and concentrations at individual wells. The downgradient extent of the selenium plume is predicted to be reduced as additional saturated source material is removed. The amount of decrease in selenium concentrations at downgradient wells is proportional to the percent of saturated source material removed (i.e., 50 percent source removal results in a 50 percent decrease in concentration). The total volume of groundwater above the MCL is predicted to decrease between 33 and 75 percent (**Table 3.2a**) and the total mass of selenium is predicted to decrease between 24 and 55 percent as a result of source removal (**Table 3.2b**). Downgradient of the site, the volume of groundwater above the MCL is predicted to decrease between 38 and 84 percent (**Table 3.2a**) and the mass of selenium is predicted to decrease between 37 and 54 percent (**Table 3.2b**) compared to the IM realignment simulation.

3.2.4 West Selenium Area Permeable Reactive Barrier

Similar to source removal simulations, implementation of a PRB downgradient of the West Selenium source area is predicted to reduce the downgradient extent of the selenium plume, the volume of groundwater above the MCL, and the total mass of selenium in groundwater. **Figure 3.8** presents predicted changes in plume geometry and concentrations at individual wells after PRB implementation. As PRB effectiveness increases, the extent of downgradient selenium contamination is reduced. Concentrations at downgradient wells are reduced proportional to the PRB effectiveness (i.e., a 67 percent effective PRB results in a 67 percent decrease in downgradient concentrations). In addition, the total volume of groundwater above the MCL is predicted to decrease between 58 and 74 percent (**Table 3.2a**) and the total mass of selenium in groundwater is predicted to decrease between 35 and 52 percent depending on PRB effectiveness (**Table 3.2b**). The volume of groundwater above the MCL downgradient of the site is predicted to decrease between 66 and 84 percent (**Table 3.2a**) and the mass of selenium downgradient of the site is predicted to decrease between 37 and 54 percent (**Table 3.2b**) compared to the IM realignment simulation.

3.2.5 West Selenium Area Slurry Wall

Figure 3.9 presents predicted plume geometry and concentrations at individual wells for West Selenium slurry wall simulations. Implementation of the slurry wall reduces the downgradient extent of the selenium plume. A simulated slurry wall permeability of 0.01 feet/day is predicted to eliminate off-site migration of selenium from the West Selenium area. Concentrations at downgradient wells decrease as a result of the slurry wall; however, the degree of reduction in selenium concentrations decreases as slurry wall permeability in reduced (i.e., further decreasing permeability does not improve groundwater quality proportionally).

Predictive simulations show that the volume of groundwater with selenium concentrations above the MCL is reduced between 38 and 74 percent (**Table 3.2a**) and the total mass of selenium in groundwater is reduced between 18 and 44 percent depending on slurry wall permeability (**Table 3.2b**). Downgradient of the site, the volume of groundwater above the MCL is predicted to decrease between 43 and 84 percent (**Table 3.2a**) and the mass of selenium in groundwater is predicted to decrease between 19 and 45 percent (**Table 3.2b**) compared to the IM realignment simulation.

Changes in groundwater elevation and flow as a result of slurry wall implementation were also evaluated. **Figure 3.10** presents predicted changes in groundwater elevation as a result of the slurry wall. Changes in groundwater elevation were calculated as the difference in head between the IM realignment and 0.1 foot/day permeability slurry wall simulations. Groundwater elevations are predicted to increase south and southwest of the slurry wall up to 2.36 feet, with the largest increases occurring directly upgradient of the slurry wall. Downgradient of the slurry wall, groundwater elevations are predicted to change less than 0.5 feet.

Figure 3.11 presents particle track results for the IM realignment and slurry wall simulations. Particles were placed upgradient of the slurry wall in the upper three model layers (i.e., above the ash/clay) and traced through the flow field in the direction of groundwater flow. Implementation of the slurry wall results in a westward shift in groundwater flow directions around the slurry wall.

3.2.6 West Selenium Area Focused Pump and Treat

Pumping rates ranged from 11.5 to 14.5 gallons per minute (gpm) per well for the West Selenium area pump and treat simulations depending on transmissivity (**Figure 3.12**). Plume geometry and volume of groundwater above the MCL do not vary appreciably for the three simulations. The model predicts that focused pump and treat downgradient of the West Selenium area reduces the total volume of groundwater above the MCL between 74 and 79 percent (**Table 3.2a**) and the total mass of selenium in groundwater between 38 and 56 percent (**Table 3.2b**). The volume of groundwater above the MCL downgradient of the site is predicted to decrease between 85 and 89 percent (**Table 3.2a**) and the mass of selenium is predicted to decrease between 40 and 58 percent (**Table 3.2b**).

In theory, each pump and treat simulation should result in identical plume geometry, volume of groundwater above the MCL, and total mass of selenium in groundwater because pumping rates were adjusted to achieve capture based on the same criteria (i.e., no downgradient selenium concentrations above the MCL). Differences are the result of the degree to which pumping rates and selenium concentrations were optimized. Pumping rates were optimized to 0.5 gpm and selenium capture was considered achieved if downgradient concentrations were below the MCL. Thus, a change in the pumping rate of less than 0.5 gpm could result in selenium capture but produce varying amounts of selenium downgradient of the site which would cause differences in the total mass of selenium in groundwater. Predicted changes in volume and mass would likely be closer if further optimization of pumping rates was performed.

3.3 Summary of Predictive Results

Predictive results show implementation of IMs and source control measures improve groundwater quality for arsenic and selenium downgradient of the site. The extent and volume of groundwater with arsenic concentrations above the MCL are not predicted to be affected greatly by IMs or source control measures however the total mass of arsenic is predicted to decrease from the 2011 baseline in all simulations. The extent of the downgradient selenium plume, volume of groundwater with concentrations above the selenium MCL, and the total mass of selenium in groundwater are predicted to decrease as a result of IMs and source control measures.

Figure 3.13 and **Tables 3.1a** and **3.1b** present predicted changes in the volume of groundwater above the arsenic MCL and total mass of arsenic in groundwater for the IMs and North Plant Site source control measures. **Figure 3.13** illustrates that the volume of groundwater above the MCL does not change appreciably with implementation of IMs or source control measures. In both the conceptual and numerical models, it is assumed that northward migration of arsenic is limited by changing redox conditions that creates high concentration gradients. In the numerical model the area of high concentration gradients is simulated with a decay coefficient, which removes mass and thus does not allow arsenic to migrate farther northward.

The model predicts that implementation of the IMs will result in a greater than 50 percent reduction of the total mass of arsenic in groundwater downgradient of the site. Based on these results, the model predicts that implementation of IMs would have the greatest reduction in downgradient arsenic concentrations. Source control measures would result in additional improvement, with a 100 percent effective PRB predicted to reduce the total mass of arsenic in groundwater by 25 percent compared to the IM realignment simulation.

Figure 3.14 and **Tables 3.2a** and **3.2b** present predicted changes in the volume of groundwater above the selenium MCL and total mass of selenium in groundwater for IMs and West Selenium area source control measures. The model predicts that implementation of IMs would decrease the volume of groundwater above the MCL by 42 percent and the mass of selenium by 39 percent downgradient of the site compared to the 2011 simulation. Source control measures in the West Selenium area would result in an additional decrease in the volume of groundwater above the MCL between 38 to 89 percent and a decrease in the mass of selenium between 19 and 58 percent downgradient of the site compared to the IM realignment simulation.

4.0 MODEL SENSITIVITY

A degree of uncertainty is inherent in any modeling effort. The purpose of sensitivity analysis is to quantify the uncertainty in model simulations caused by uncertainty in estimates of model parameters (Anderson and Woessner, 1992). During sensitivity analysis, model input parameters are systematically changed one at a time within reasonable ranges to determine the effect on model results of changing model input parameters.

NewFields (2015a) describes sensitivity analyses that was used identify sensitive parameters in the fate and transport calibration, which included changes in the mass loading rate for saturated source terms, the lateral position of saturated source terms, and attenuation parameters for selenium.

The sensitivity analysis described below evaluates the sensitivity of model predictions to model parameters selected by the groundwater team, including:

- Stream bed conductance for the bypass and realignment;
- Unsaturated source concentration and recharge rate;
- Effective porosity; and
- Arsenic attenuation parameters.

During the sensitivity analysis, these parameters were adjusted systematically within plausible ranges to determine the effect on model predictions. The effect of changes in parameter values on model predictions was evaluated qualitatively and quantitatively. Qualitative evaluation was performed by visually comparing changes in plume geometry for the base predictive simulations and sensitivity simulations. Quantitative evaluation was performed by comparing changes in concentrations at individual wells, volume of groundwater above the U.S. EPA's MCL for arsenic and selenium, and total mass of arsenic and selenium in groundwater for model adjustments.

4.1 BYPASS AND REALIGNMENT STREAMBED CONDUCTANCE

Streambed conductance terms for the bypass and realignment were increased and decreased 50 percent by adjusting hydraulic conductivity (initial hydraulic conductivity for the bypass and realignment was 1,200 feet/day and 1 foot/day, respectively). Mass loading rates were decreased proportionally to predicted changes in groundwater flux through saturated source areas for the analysis. **Figures 4.1** and **4.2** present predicted arsenic plume geometry for the bypass and realignment simulations, respectively. Similar to results from the predictive simulations, the overall extent of the arsenic plume does not vary significantly with changes to conductance. In addition, the volume of groundwater above the arsenic MCL and the total mass of arsenic in groundwater changes less than 5 percent as a result of the sensitivity analysis (**Table 4.1a** and **4.1b).**

Figures 4.3 and **4.4** present predicted selenium plume geometry for the bypass and realignment simulations, respectively. There are no appreciable differences in plume geometry as a result of adjusting bypass or realignment conductance. In addition, the volume of groundwater above the selenium MCL and the total mass of selenium in groundwater changes less than 5 percent (**Table 4.2a** and **Table 4.2b**). In general, predicted transport of arsenic and selenium is not sensitive to changes in conductance for the bypass or realignment.

4.2 UNSATURATED SOURCE TERMS

The IM realignment simulation was used to evaluate sensitivity of model predictions to unsaturated source terms. Two simulations were used for the analysis, which included: 1) increasing unsaturated source concentrations by one order of magnitude; and 2) increasing unsaturated source concentrations by one order of magnitude and increasing the recharge rate to 10 percent of annual precipitation (about 1.2 inches/year) in the central plant site. Unsaturated arsenic source terms contribute a relatively small amount of mass to groundwater (<1 percent; NewFields, 2015a) and therefore, arsenic was not simulated for this analysis. **Figure 4.5** presents changes in plume geometry for the unsaturated source sensitivity simulations. Increasing source concentrations increases concentrations in groundwater in the Slag Pile area but has little effect on concentrations in the West Selenium area and downgradient of the site. The volume of groundwater above the selenium MCL and the total mass of selenium in groundwater increase for both sensitivity simulations (**Tables 4.2a** and **4.2b**). However, the most significant changes occurred on-site and the total mass of selenium downgradient of the site increases by less than 3 percent. These results indicate that predicted selenium concentrations are sensitive to changes in unsaturated source terms in the Slag Pile area but are not sensitive in the West Selenium area or downgradient of the site. Sensitivity analysis performed on the model calibration by NewFields (2015a) indicates that downgradient selenium concentrations and plume geometries are sensitive to the mass loading rate for the West Selenium saturated source boundary.

4.3 EFFECTIVE POROSITY

Sensitivity analysis performed during fate and transport model calibration determined that equilibrium calibration to arsenic and selenium concentrations is not sensitive to effective porosity (NewFields, 2015a). However, effective porosity can affect the time it takes for changes in concentration to occur. To evaluate temporal sensitivity, effective porosity values in the IM realignment simulation were increased and decreased by 50 percent, and changes in concentration at individual wells were evaluated. **Figure 4.6** presents predicted changes in arsenic and selenium concentrations for wells downgradient of the site. In general, as effective porosity is increased, the time it takes to reach equilibrium concentrations increases. These results reflect the inverse relationship between effective porosity and groundwater velocity; as effective porosity is reduced, groundwater velocity increases, resulting in increased solute travel times. As discussed above, because of assumptions made during the modeling process (e.g., instantaneous implementation of remedies), results of this sensitivity analysis are not representative of the time it would take concentrations to reach equilibrium, rather, the results are meant to help quantify model sensitivity of this parameter on a comparative basis.

4.4 ARSENIC ATTENUATION PARAMETERS

The 2011 fate and transport model was calibrated to arsenic concentrations using a combination of retardation and decay coefficients to simulate sorption and precipitation, respectively. Decay coefficients were used in the calibrated model to create the high concentration gradients observed at the downgradient edge of the arsenic plume. Using decay coefficients assumes that arsenic precipitates from groundwater and that this reaction is irreversible (i.e., arsenic cannot remobilize in groundwater). It is important to understand the long-term effects of this assumption and evaluate the possibility of arsenic continuing to migrate downgradient. To test this, decay coefficients were replaced with retardation coefficients. Retardation simulates sorption of arsenic to aquifer materials by slowing the movement of arsenic relative to groundwater. Retardation coefficients added in place of decay coefficients were simulated with a linear isotherm and adjusted in order to reasonably reproduce observed concentrations in the 2011 calibration simulation. Based on these results, retardation coefficients were then updated in the IM realignment simulation to evaluate arsenic transport over 50 years.

Within the site boundary, retardation coefficients used to replace decay coefficients were generally similar to those used in the original model calibration (NewFields, 2015a). One exception was an area within the site boundary, directly north of the North Plant Site source area that was simulated with a retardation coefficient 30 times greater than in the calibrated model. North of the site at the downgradient edge of the arsenic plume, retardation coefficients used were 100 times greater than those used in the calibrated model.

Figure 4.7 presents results of the attenuation sensitivity simulation. The downgradient extent of the arsenic plume increases by approximately 350 feet and the lateral extent increases by approximately 100 feet. These results suggest that the arsenic plume could migrate further downgradient if the primary attenuation factor is sorption instead of precipitation, although movement would be relatively slow compared to selenium transport.

4.5 SENSITIVITY ANALYSIS SUMMARY

Results of the sensitivity analysis show that, in general, predicted arsenic and selenium concentrations are not sensitive to bed conductance values for the bypass or realignment. Predicted selenium concentrations are sensitive to changes in unsaturated source concentrations and recharge rates in the Slag Pile area but are not sensitive to changes in these parameters in the West Selenium area or downgradient of the site.

Predictions of the time required to reach equilibrium concentrations is somewhat sensitive to changes in effective porosity values. However, predictions of temporal changes in groundwater concentrations are likely more sensitive to the use of a steady-state flow field in this analysis.

Replacing decay coefficients with retardation coefficients effects predicted downgradient arsenic migration. Results suggest that the arsenic plume could migrate further downgradient if the primary attenuation factor is sorption instead of precipitation, although movement would be relatively slow compared to selenium transport.

5.0 MODEL LIMITATIONS

Models are simplifications of complex systems and in all modeling exercises some model parameters are not well quantified due to a lack of data which ultimately leads to uncertainty in model predictions. The primary objective of the modeling exercise described in this memorandum was to evaluate the potential effects of IMs and proposed source control measures on arsenic and selenium groundwater concentrations.

NewFields (2015a) discussed model uncertainty related to monitoring well location and a lack of site specific data related to transport parameters such as dispersivity, effective porosity, and decay. Calibration results demonstrate that the model is capable of simulating fate and transport of arsenic and selenium within the model area under steady-state conditions and sensitivity results were used to evaluate the effects of parameter uncertainty on model predictions. The ability of the model to predict changes in concentration over short distances at the scale of tens of feet or less may be limited, particularly in areas with complex flow dynamics and geochemistry. In addition, the model likely under-predicts the time it would take for concentrations to reach equilibrium after IMs and source control measures are implemented. This is a result of using a steady-state flow field, which assumes that changes to groundwater elevations and flow occur instantaneously, with a transient transport model. In reality, changes in groundwater elevation and flow directions may take longer to reach equilibrium and as a result, changes in groundwater quality would take longer to reach equilibrium. In order to evaluate temporal changes in groundwater quality, a transient groundwater flow model would need to be constructed.

The model is limited by assumptions used for the predictive simulations, which include parameterization of the bypass and realignment, assumptions used for placement and parameterization of source control measures, and uncertainty in the location and mass loading rates/concentrations of source terms. However, based on calibration and sensitivity results (NewFields, 2015a) the model is appropriate for evaluating IM and source control effectiveness on a comparative basis. In addition, further field investigation of source areas is planned for 2015 and results may be included in the model update (see **Section 6.0**).

6.0 CONCLUSIONS

Predictive results are being used to support CMS evaluation of alternative source control measures. Results indicate that implementation of the planned IMs and potential source control measures improve groundwater quality for arsenic and selenium downgradient of the site. The overall extent of groundwater with arsenic concentrations above the MCL is not predicted to be significantly affected by IMs or source control measures however the total mass of arsenic is predicted to decrease from baseline conditions in all predictive simulations. The extent of the downgradient selenium plume, volume of groundwater with concentrations above the selenium MCL, and the total mass of selenium in groundwater are predicted to decrease as a result of the IMs and source control measures. Differences in results for arsenic and selenium reflect differences in chemical behavior in groundwater.

The next phase of modeling will include continued support of CMS evaluations by updating the flow and transport conceptual and numerical models to current conditions. This will include further incorporation of data collected in late 2014 as part of the source investigation study (Hydrometrics, 2015) and results of field work planned for 2015 (if warranted). The model will be refined based on collected data and the proposed source control measures will be further evaluated.

7.0 REFERENCES

AMEC Environment & Infrastructure, Inc. (AMEC), 2012a. Groundwater Flow and Fate and Transport Model Work Plan East Helena Site. East Helena, Lewis and Clark County Montana. Prepared for: Montana Environmental Trust Group, LLC. April.

AMEC Environment & Infrastructure, Inc. (AMEC), 2012b. Draft Initial Flow Model Design and Calibration, East Helena Site. East Helena, Lewis and Clark County, Montana. Prepared for: Montana Environmental Trust Group, LLC. October.

Anderson, M.P. and Woessner, W.W., 1992. Applied Groundwater Modeling, Simulation of Flow and Advective Transport. Academic Press, San Diego.

CH2MHill, 2014a. Draft Tier II Source Control Measure/Groundwater Remedy Evaluation - Phase I Results and Recommendations. Prepared for: Montana Environmental Trust Group, LLC. November.

CH2MHill, 2014b. East Helena Former ASARCO Smelter Site. ET Cover System Design. November.

CH2MHill, 2014c. ET Cover System, ICS2 and, Demolition Phase 3, Former ASARCO East Helena Facility. December.

Dreher, R.G., Rockler, M.W., Johnson, L./United States District Court for the District of Montana. 2012. First Modification to the 1998 Consent Decree. Civil Action No. CV 98-H-CCL. Case 6:98-cv-00003-CCL. Document 38. Filed January 17, 2012.

Hydrometrics, 2010. Phase II RCRA Facility Investigation Site Characterization Work Plan East Helena Facility. Prepared for: Montana Environmental Trust Group, LLC. May.

Hydrometrics, 2015. 2014 Supplemental Contaminant Source Area Investigation at the Former East Helena Smelter. Final. Prepared for Montana Environmental Trust Group, LLC. February.

NewFields, 2014a. Technical Memorandum, Groundwater Flow Model Calibration Refinement, Transient Verification, and Interim Measures Support, East Helena Site. Prepared for: Montana Environmental Trust Group, LLC. February.

NewFields, 2014b. Draft Technical Memorandum, Groundwater Flow Model and Predictive Simulation Update. Prepared for: Montana Environmental Trust Group, LLC. August.

NewFields, 2014c. Work Plan for Solute Transport Model Development, Former East Helena Smelter. Prepared for: Montana Environmental Trust Group, LLC. Revised June 25, 2014.

NewFields, 2014d. Draft Work Plan Addendum for Fate and Transport Predictive Simulation, Former East Helena Smelter. Prepared for: Montana Environmental Trust Group, LLC. November.

NewFields, 2015a. DRAFT Fate and Transport Model Design and Calibration, East Helena Site. Prepared for: Montana Environmental Trust Group, LLC. April.

NewFields, 2015b. Remedial Action Plan, Horseshoe Overburden Area Caribou County, Idaho. Prepared for: P4 Production, LLC. Revised February 2015.

Pioneer Technical, 2014a. As-Built Survey Drawings and Shapefiles. April.

Pioneer Technical, 2014b. Prickly Pear Creek Realignment: Final Grading Plan. Six Figures. October.

Wilkin, R.T., Acree, S.D., Beak, D.G., Ross, R.R., Lee, T.R., and Paul, C.J., 2008. Field Application of a Permeable Reactive Barrier for Treatment of Arsenic in Groundwater. U.S. Environmental Protection Agency Office of Research and Development, Ground Water and Ecosystems Restoration Division. EPA 600/R-08/093. September.

Zheng, P and P. Wang, 1999. MT3DMS: A Modular Three-Dimensional, Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems. Prepared for: Headquarters, U.S. Army Corps of Engineers.

TABLES

Table 2.1. Predictive fate and transport simulations.

Interim Measures		
Area	**Simulated Contaminant**	**Source Control Measure/ Remedy**
Site Wide	Arsenic and Selenium	SPHCs including Upper and Lower Lake Removal, Wilson Ditch Dewatering, and Prickly Pear Creek Bypass and Realignment
Tito Park	Arsenic and Selenium	Soil Removal
Plant Site	Arsenic and Selenium	ET Cover System
Tier II Phase 2 Source Control Measures		
Area	**Simulated Contaminant**	**Source Control Measure/ Remedy**
West Selenium Plume	Selenium	Source Removal
	Selenium	Permeable Reactive Barrier
	Selenium	Slurry Wall
	Selenium	Focused Pump and Treat
North Plant Site Area	Arsenic	Permeable Reactive Barrier
	Arsenic	Slurry Wall

Table 3.1a - Change in Volume of Groundwater with Arsenic Concentrations Above the MCL[a].

Simulation	Downgradient (acre-feet)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation	On-Site (acre-feet)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation	Total (acre-feet)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation
2011 Calibrated Model	375	NA	NA	407	NA	NA	783	NA	NA
Bypass	407	-8%	NA	416	-2%	NA	823	-5%	NA
Realignment	381	-1%	NA	357	12%	NA	737	6%	NA
PRB 43% Effectiveness	393	-5%	-3%	363	11%	-2%	756	3%	-3%
PRB 55% Effectiveness	392	-5%	-3%	363	11%	-2%	756	3%	-2%
PRB 100% Effectiveness	389	-4%	-2%	360	12%	-1%	748	4%	-2%
Slurry Wall High Permeability	392	-4%	-3%	365	10%	-2%	757	3%	-3%
Slurry Wall Base Case	390	-4%	-2%	368	10%	-3%	758	3%	-3%
Slurry Wall Low Permeability	389	-4%	-2%	370	9%	-4%	759	3%	-3%

Note: NA = Not Applicable. A negative value indicates an increase.

[a]U.S. EPA MCL for arsenic is 0.01 mg/L.

Table 3.1b - Change in Total Mass of Arsenic in Groundwater.

Simulation	Downgradient (kilograms)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation	On-Site (kilograms)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation	Total (kilograms)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation
2011 Calibrated Model	1,445	NA	NA	1,526	NA	NA	2,971	NA	NA
Bypass	700	52%	NA	883	42%	NA	1,583	47%	NA
Realignment	377	74%	NA	647	58%	NA	1,024	66%	NA
PRB 43% Effectiveness	281	81%	26%	590	61%	9%	870	71%	15%
PRB 55% Effectiveness	250	83%	34%	564	63%	13%	815	73%	20%
PRB 100% Effectiveness	157	89%	58%	488	68%	25%	644	78%	37%
Slurry Wall High Permeability	215	85%	43%	401	74%	38%	616	79%	40%
Slurry Wall Base Case	189	87%	50%	380	75%	41%	569	81%	44%
Slurry Wall Low Permeability	176	88%	53%	364	76%	44%	540	82%	47%

Note: NA = Not Applicable.

Table 3.2a - Change in Volume of Groundwater with Selenium Concentrations Above the MCL[a].

Simulation	Downgradient (acre-feet)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation	On-Site (acre-feet)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation	Total (acre-feet)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation
2011 Calibrated Model	1,865	NA	NA	186	NA	NA	2,050	NA	NA
Bypass	1,502	19%	NA	170	8%	NA	1,672	18%	NA
Realignment	1,079	42%	NA	158	15%	NA	1,237	40%	NA
50% Source Removal	668	64%	38%	158	15%	0%	826	60%	33%
70% Source Removal	366	80%	66%	158	15%	0%	524	74%	58%
100% Source Removal	170	91%	84%	145	22%	8%	315	85%	75%
PRB 67% Effectiveness	363	81%	66%	159	14%	0%	522	75%	58%
PRB 76% Effectiveness	273	85%	75%	158	15%	0%	432	79%	65%
PRB 100% Effectiveness	173	91%	84%	155	17%	2%	328	84%	74%
Slurry Wall High Permeability	619	67%	43%	155	17%	2%	773	62%	38%
Slurry Wall Base Case	193	90%	82%	155	16%	2%	348	83%	72%
Slurry Wall Low Permeability	172	91%	84%	153	18%	4%	325	84%	74%
Pump and Treat High Transmissivity	119	94%	89%	141	24%	11%	261	87%	79%
Pump and Treat Base Case	137	93%	87%	148	20%	7%	285	86%	77%
Pump and Treat Low Transmissivity	160	91%	85%	158	15%	0%	318	84%	74%

Note: NA = Not Applicable.

[a]U.S. EPA MCL for selenium is 0.05 mg/L.

Table 3.2b - Change in Total Mass of Selenium in Groundwater.

Simulation	Downgradient (kilograms)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation	On-Site (kilograms)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation	Total (kilograms)	Percent Change from 2011 Calibrated Model	Percent Change from Realignment Simulation
2011 Calibrated Model	3,304	NA	NA	141	NA	NA	3,444	NA	NA
Bypass	2,791	16%	NA	119	15%	NA	2,910	16%	NA
Realignment	2,008	39%	NA	101	28%	NA	2,108	39%	NA
50% Source Removal	1,507	54%	25%	85	40%	16%	1,592	54%	24%
70% Source Removal	1,233	63%	39%	79	44%	22%	1,312	62%	38%
100% Source Removal	887	73%	56%	69	51%	31%	957	72%	55%
PRB 67% Effectiveness	1,272	61%	37%	103	27%	-3%	1,376	60%	35%
PRB 76% Effectiveness	1,162	65%	42%	102	27%	-2%	1,264	63%	40%
PRB 100% Effectiveness	923	72%	54%	99	29%	1%	1,022	70%	52%
Slurry Wall High Permeability	1,635	51%	19%	92	35%	9%	1,726	50%	18%
Slurry Wall Base Case	1,135	66%	43%	76	46%	25%	1,211	65%	43%
Slurry Wall Low Permeability	1,099	67%	45%	73	48%	27%	1,172	66%	44%
Pump and Treat High Transmissivity	1,149	65%	43%	69	51%	31%	1,218	65%	42%
Pump and Treat Base Case	845	74%	58%	78	44%	22%	923	73%	56%
Pump and Treat Low Transmissivity	1,209	63%	40%	98	30%	3%	1,307	62%	38%

Note: NA = Not Applicable. A negative value indicates an increase.

Table 4.1a - Change in Volume of Groundwater with Arsenic Concentrations Above the MCL[a].

Simulation	Downgradient (acre-feet)	Percent Change from Bypass or Realignment Base Simulation	On-Site (acre-feet)	Percent Change from Bypass or Realignment Base Simulation	Total (acre-feet)	Percent Change from Bypass or Realignment Base Simulation
Bypass Base Simulation	407	NA	416	NA	823	NA
Bypass High Conductance	407	0%	416	0%	824	0%
Bypass Low Conductance	407	0%	416	0%	823	0%
Realignment Base Simulation	381	NA	357	NA	738	NA
Realignment High Conductance	362	5%	357	0%	719	3%
Realignment Low Conductance	370	3%	370	-4%	741	0%

Note: NA = Not Applicable. A negative value indicates an increase.

[a]U.S. EPA MCL for arsenic is 0.01 mg/L.

Table 4.1b - Change in Total Mass of Arsenic in Groundwater.

Simulation	Downgradient (kilogram)	Percent Change from Bypass or Realignment Base Simulation	On-Site (kilogram)	Percent Change from Bypass or Realignment Base Simulation	Total (kilogram)	Percent Change from Bypass or Realignment Base Simulation
Bypass Base Simulation	700	NA	883	NA	1,583	NA
Bypass High Conductance	701	0%	883	0%	1,584	0%
Bypass Low Conductance	700	0%	883	0%	1,584	0%
Realignment Base Simulation	377	NA	647	NA	1,024	NA
Realignment High Conductance	378	0%	649	0%	1,027	0%
Realignment Low Conductance	370	2%	647	0%	1,016	1%

Note: NA = Not Applicable. A negative value indicates an increase.

Table 4.2a - Change in Volume of Groundwater with Selenium Concentrations Above the MCL[a].

Simulation	Downgradient (acre-feet)	Percent Change from Bypass or Realignment Base Simulation	On-Site (acre-feet)	Percent Change from Bypass or Realignment Base Simulation	Total (acre-feet)	Percent Change from Bypass or Realignment Base Simulation
Bypass Base Simulation	1,502	NA	170	NA	1,672	NA
Bypass High Conductance	1,525	-2%	172	-1%	1,698	-2%
Bypass Low Conductance	1,445	4%	167	2%	1,612	4%
Realignment Base Simulation	1,079	NA	158	NA	1,237	NA
Realignment High Conductance	1,080	0%	159	0%	1,239	0%
Realignment Low Conductance	1,056	2%	156	1%	1,212	2%
Increased Unsaturated Concentration	1,113	-3%	174	-10%	1,287	-4%
Increased Recharge Rate	1,181	-9%	186	-18%	1,367	-11%

Note: NA = Not Applicable. A negative value indicates an increase.

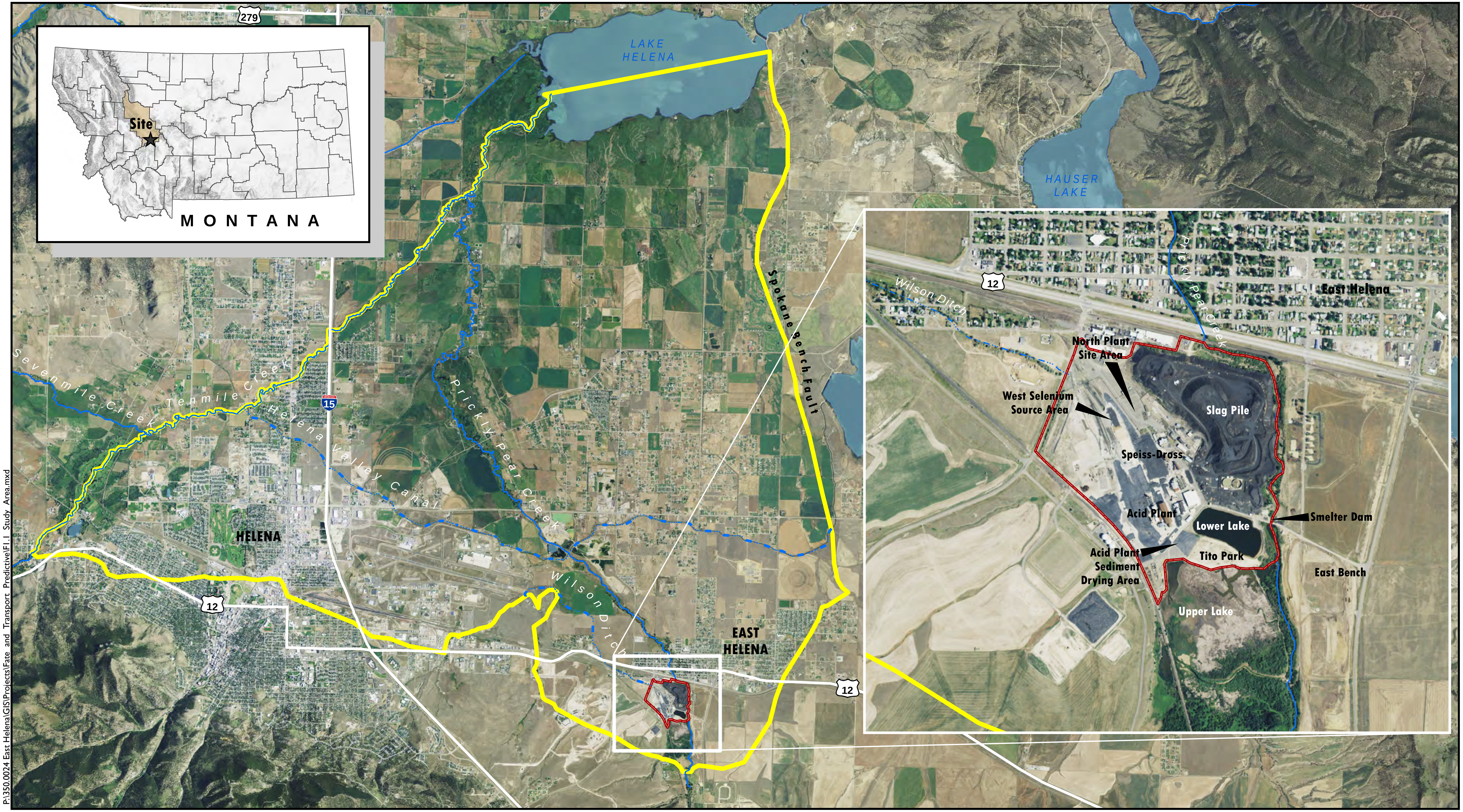
[a]U.S. EPA MCL for selenium is 0.05 mg/L.

Table 4.2b - Change in Total Mass of Selenium in Groundwater.

Simulation	Downgradient (kilogram)	Percent Change from Bypass or Realignment Base Simulation	On-Site (kilogram)	Percent Change from Bypass or Realignment Base Simulation	Total (kilogram)	Percent Change from Bypass or Realignment Base Simulation
Bypass Base Simulation	2,791	NA	119	NA	2,910	NA
Bypass High Conductance	2,803	0%	119	0%	2,922	0%
Bypass Low Conductance	2,763	1%	119	0%	2,883	1%
Realignment Base Simulation	2,008	NA	101	NA	2,108	NA
Realignment High Conductance	2,051	-2%	99	2%	2,150	-2%
Realignment Low Conductance	1,986	1%	105	-4%	2,091	1%
Increased Unsaturated Concentration	2,066	-3%	116	-15%	2,182	-3%
Increased Recharge Rate	2,055	-2%	134	-33%	2,189	-4%

Note: NA = Not Applicable. A negative value indicates an increase.

FIGURES



Source: NAIP, 2011; METG, 2011

N

0 Feet 6,000

NewFields

Ditch

Facility Boundary

Model Domain

Study Area and Facility Features
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 1.1

P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F2.1 IM Simulations.mxd

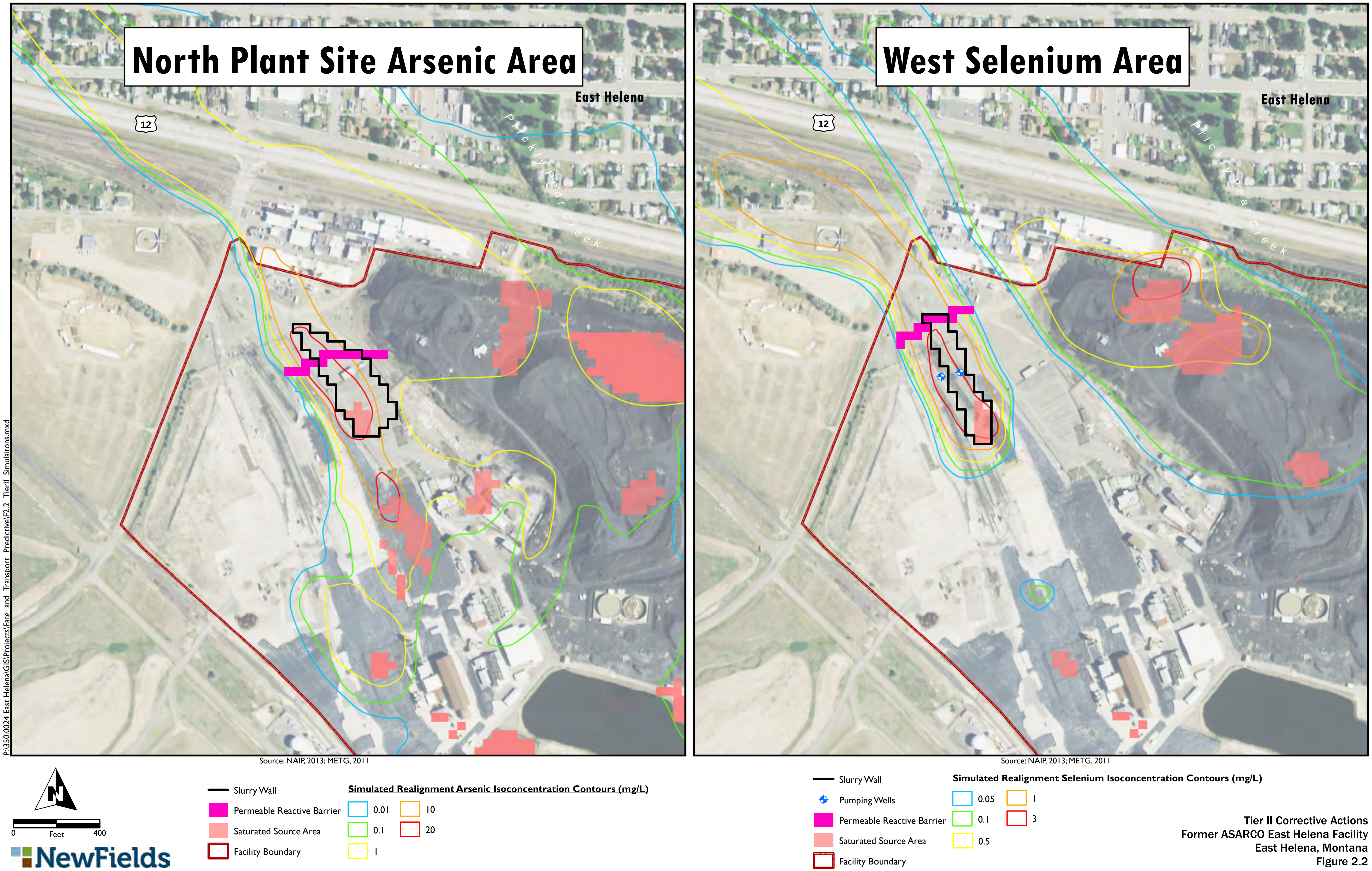
Source: NAIP, 2013; METG, 2011

Feet 0 800

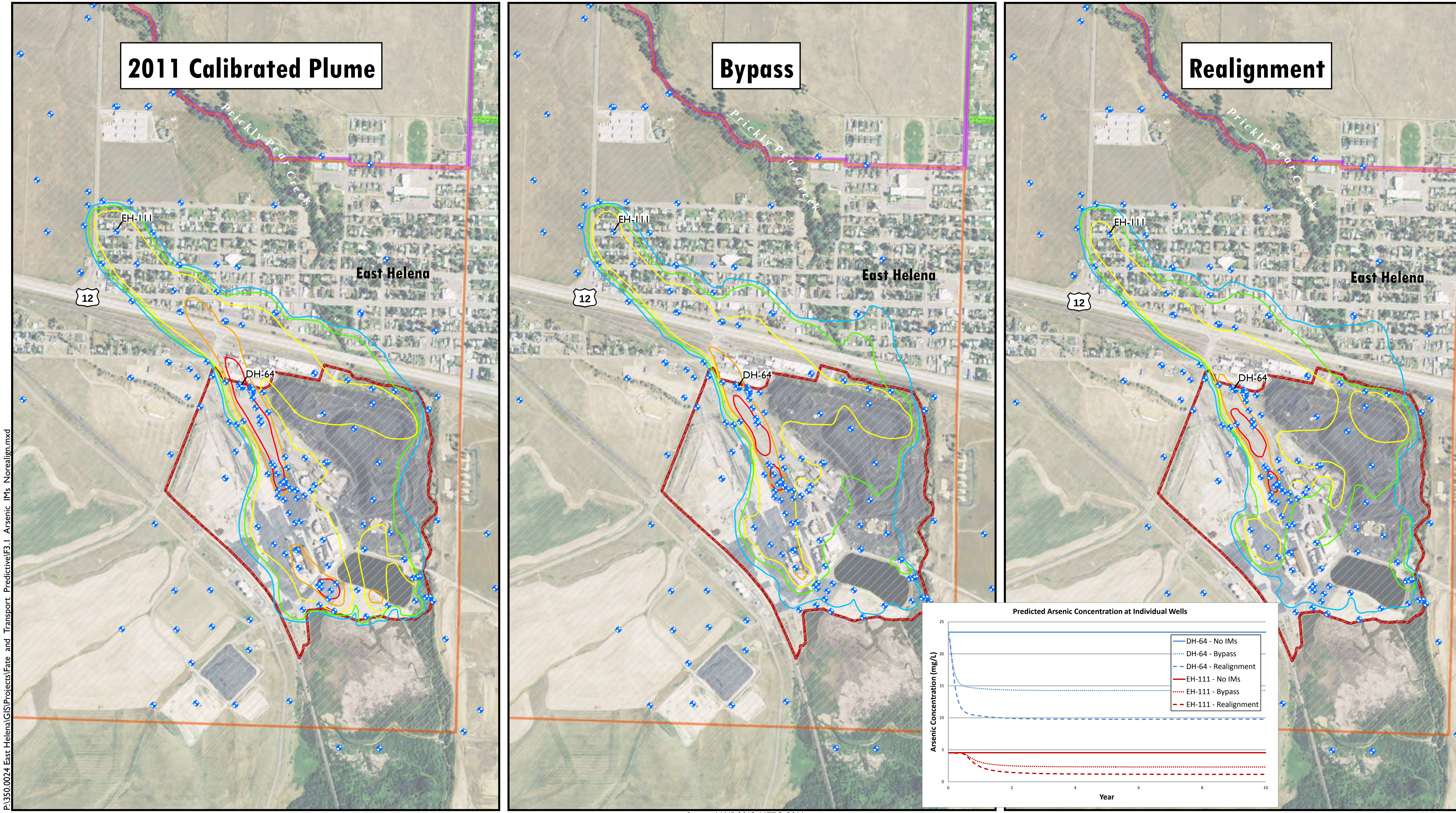
NewFields

- Prickly Pear Creek Realignmnet
- Prickly Pear Creek Bypass
- Prickly Pear Creek
- ET Cover System
- Facility Boundary

Interim Measures
Former ASARCO East Helena Facility
East Helena, Montana
Figure 2.1



Tier II Corrective Actions
Former ASARCO East Helena Facility
East Helena, Montana
Figure 2.2



Source: NAIP, 2013; METG, 2011

0 Feet 1,000

NewFields

Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predictive results depict concentrations after model has reached steady-state.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

- 0.01
- 0.1
- 1
- 10
- > 20

Monitoring Well

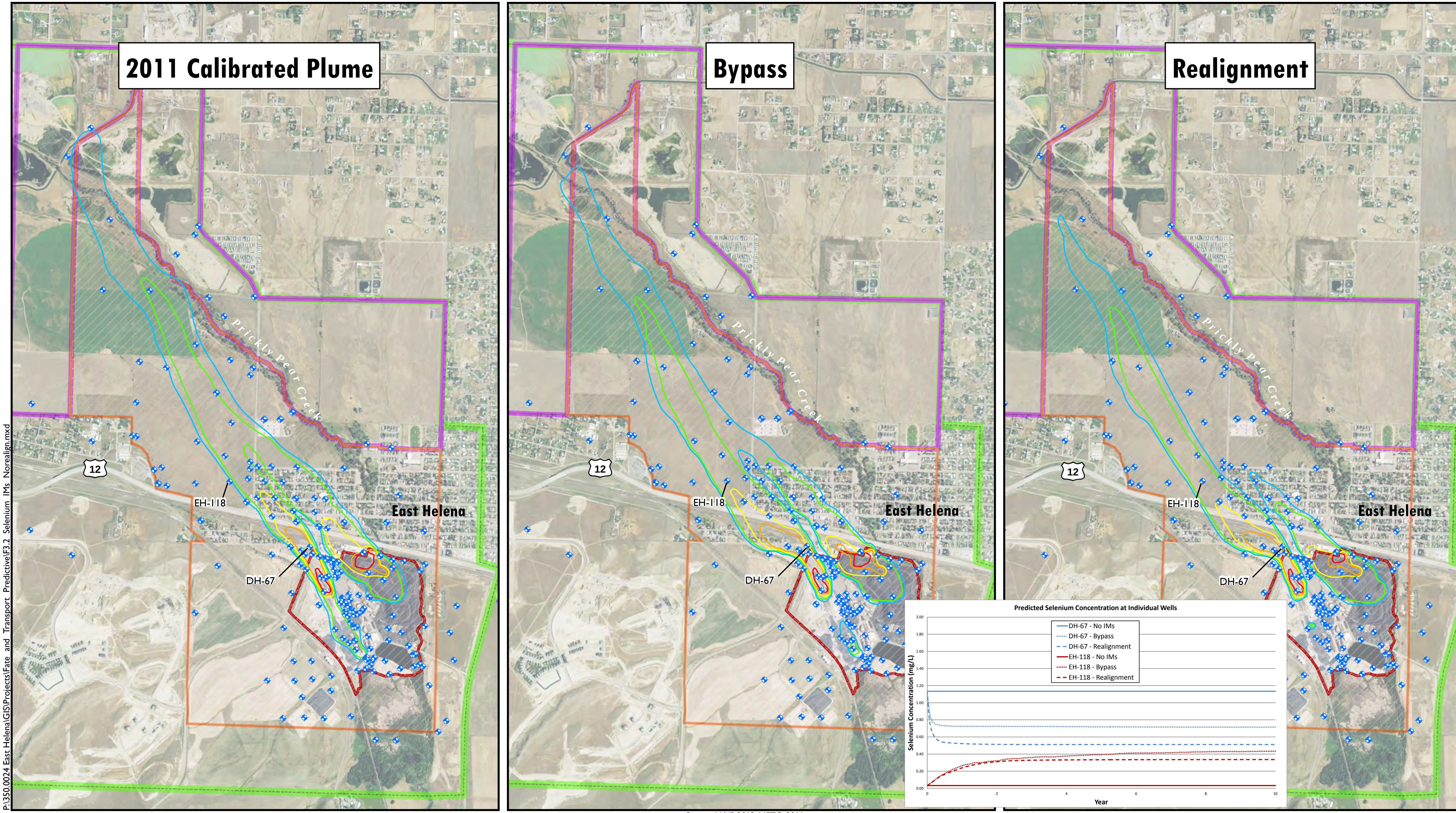
Facility Boundary

Permanent CGWA - Subarea1

Permanent CGWA - Subarea 2

Temporaty CGWA

Predicted Isoconcentration Contrours
Arsenic IM Simulations
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.1



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.2 Selenium IMs Norealign.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 2,000

NewFields

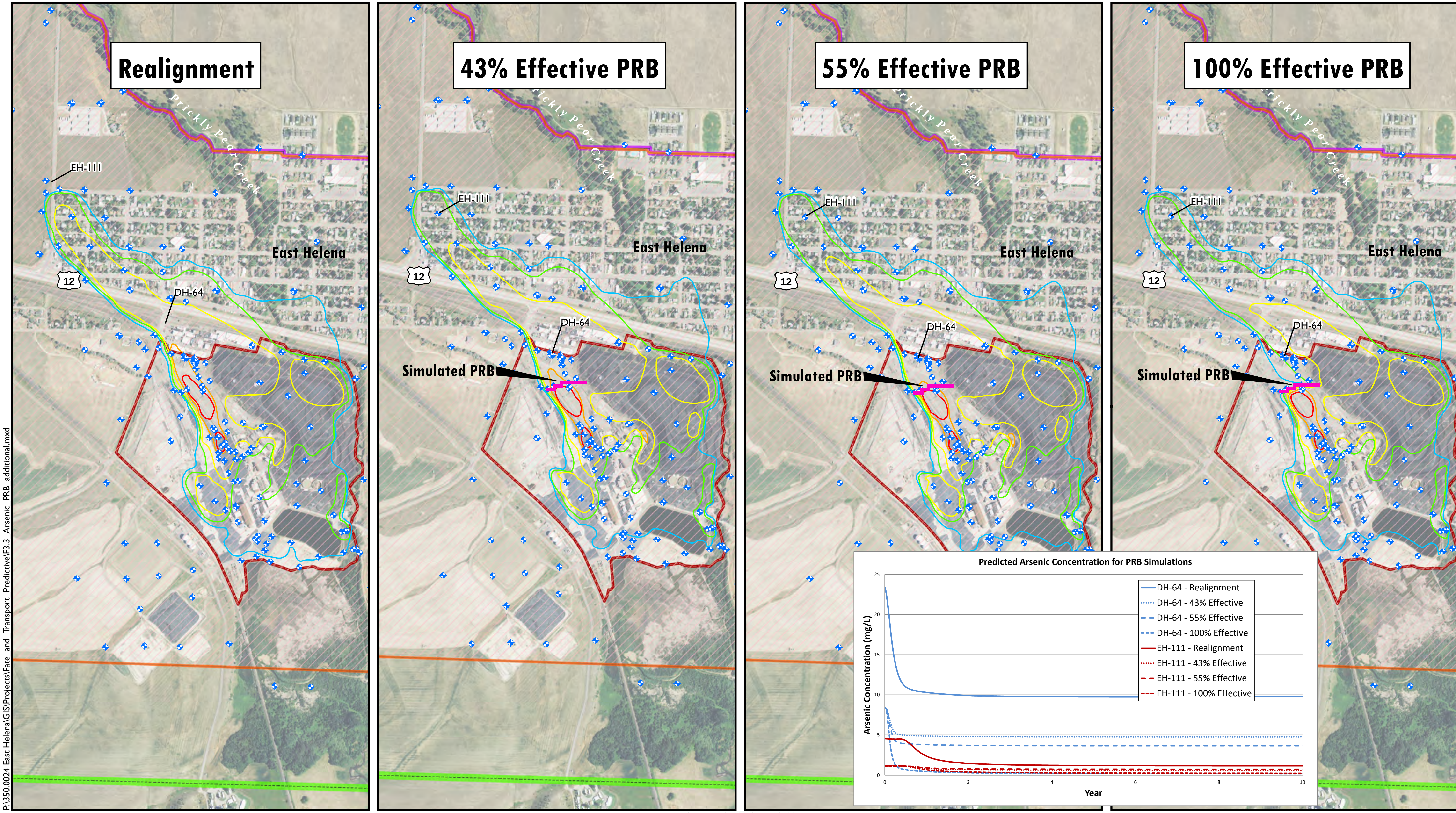
Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predictive results depict concentrations after model has reached steady-state.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

- 0.05
- 0.1
- 0.5
- 1
- > 3

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Predicted Isoconcentration Contrours
Selenium IM Simulations
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.2



Source: NAIP, 2013; METG, 2011

P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.3 Arsenic PRB additional.mxd

0 Feet 1,100

NewFields

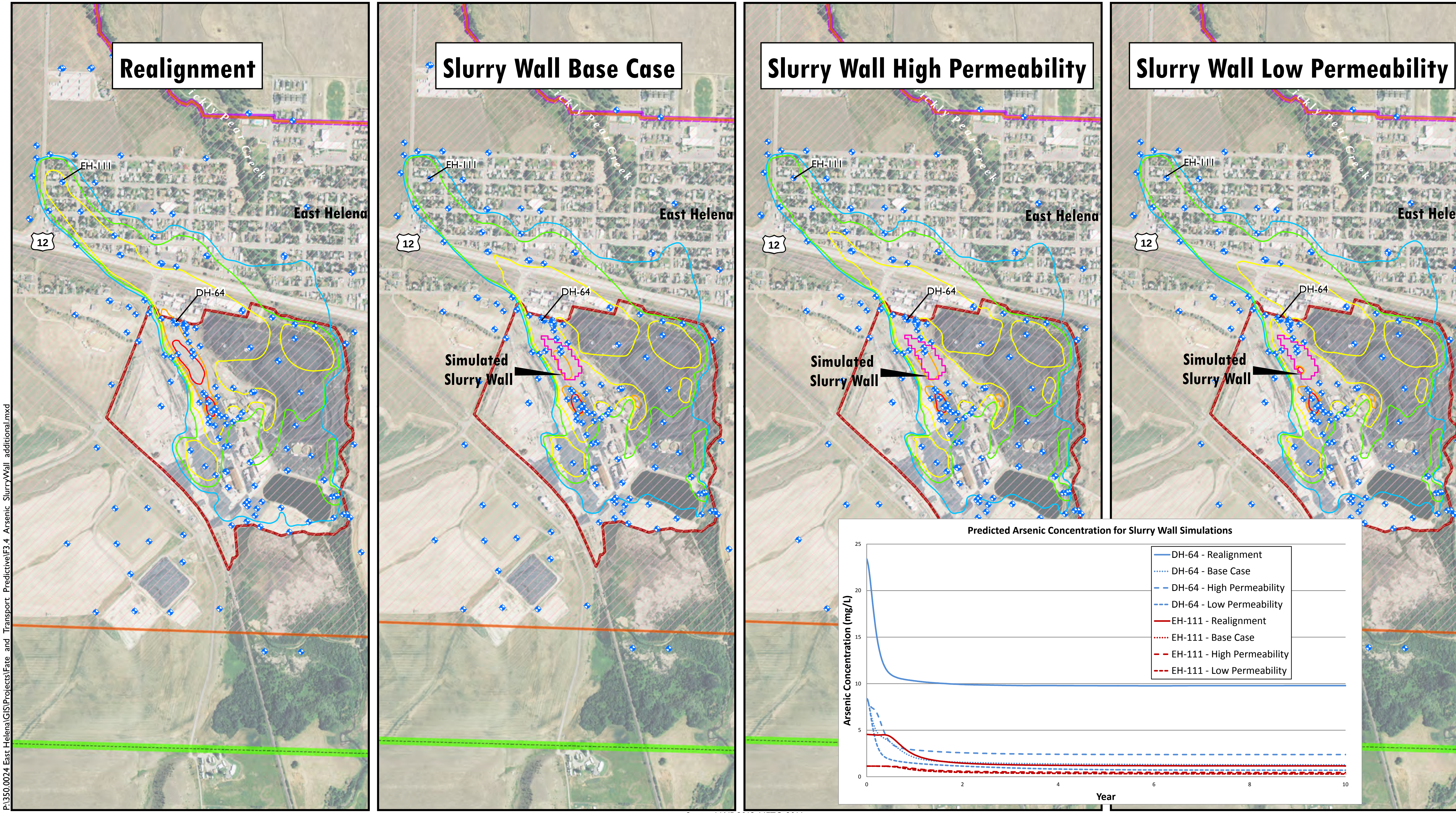
Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predictive results depict concentrations after model has reached steady-state.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

- 0.01
- 0.1
- 1
- 10
- > 20

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Predicted Isoconcentration Contrours
Arsenic PRB Simulations
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.3



Source: NAIP, 2013; METG, 2011

P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.4 Arsenic SlurryWall additional.mxd

0 Feet 1,100

NewFields

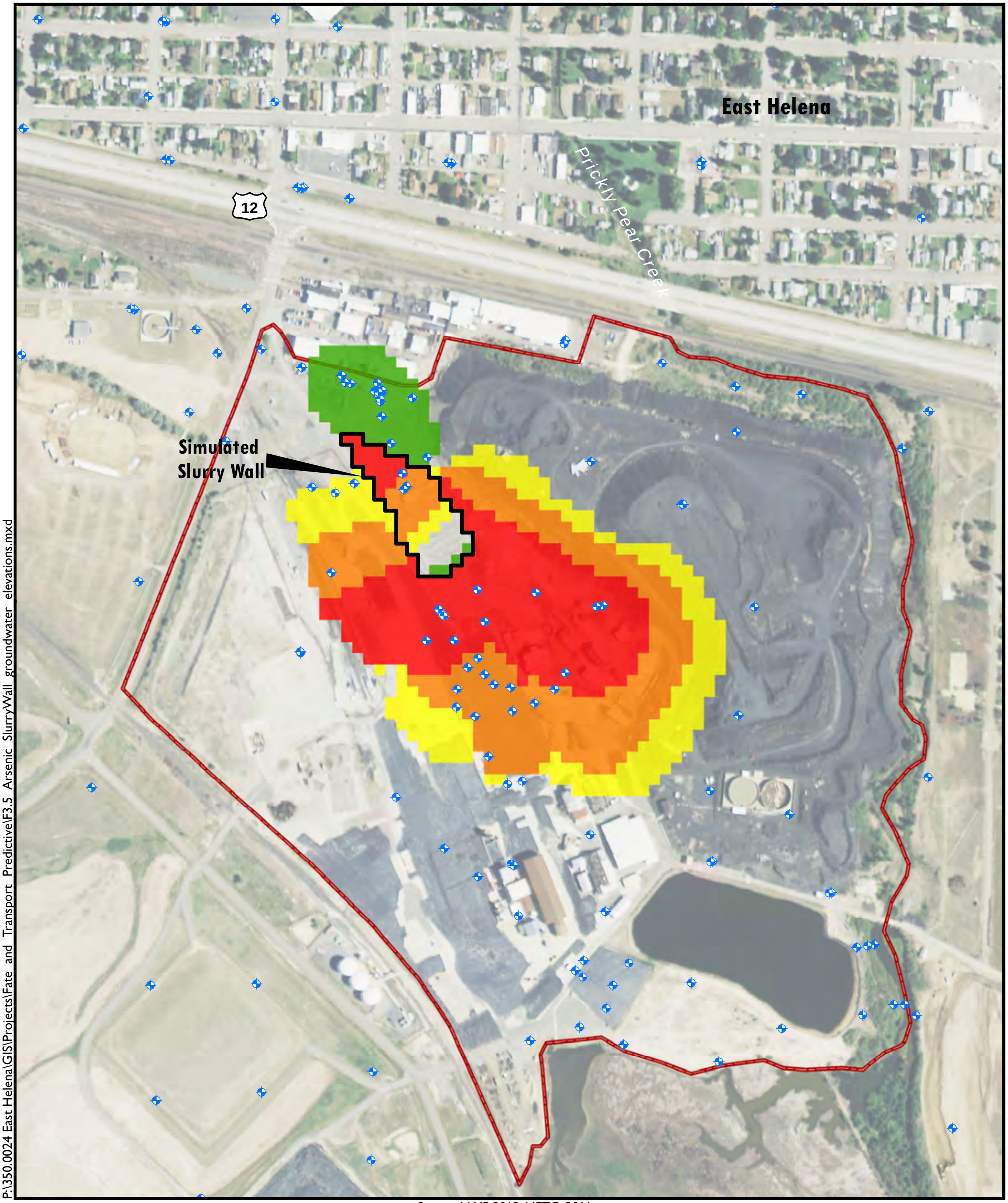
Note: Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predictive results depict concentrations after model has reached steady-state.
The slurry wall base case has a hydraulic conductivity of 0.1 feet/day and a thickness of 2 feet.
Slurry wall permeability was increased and decreased by one order-of-magnitude.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

- 0.01
- 0.1
- 1
- 10
- > 20

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Predicted Isoconcentration Contours
Arsenic Slurry Wall Simulations
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.4



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.5 Arsenic SlurryWall groundwater elevations.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 500

NewFields

Monitoring Well

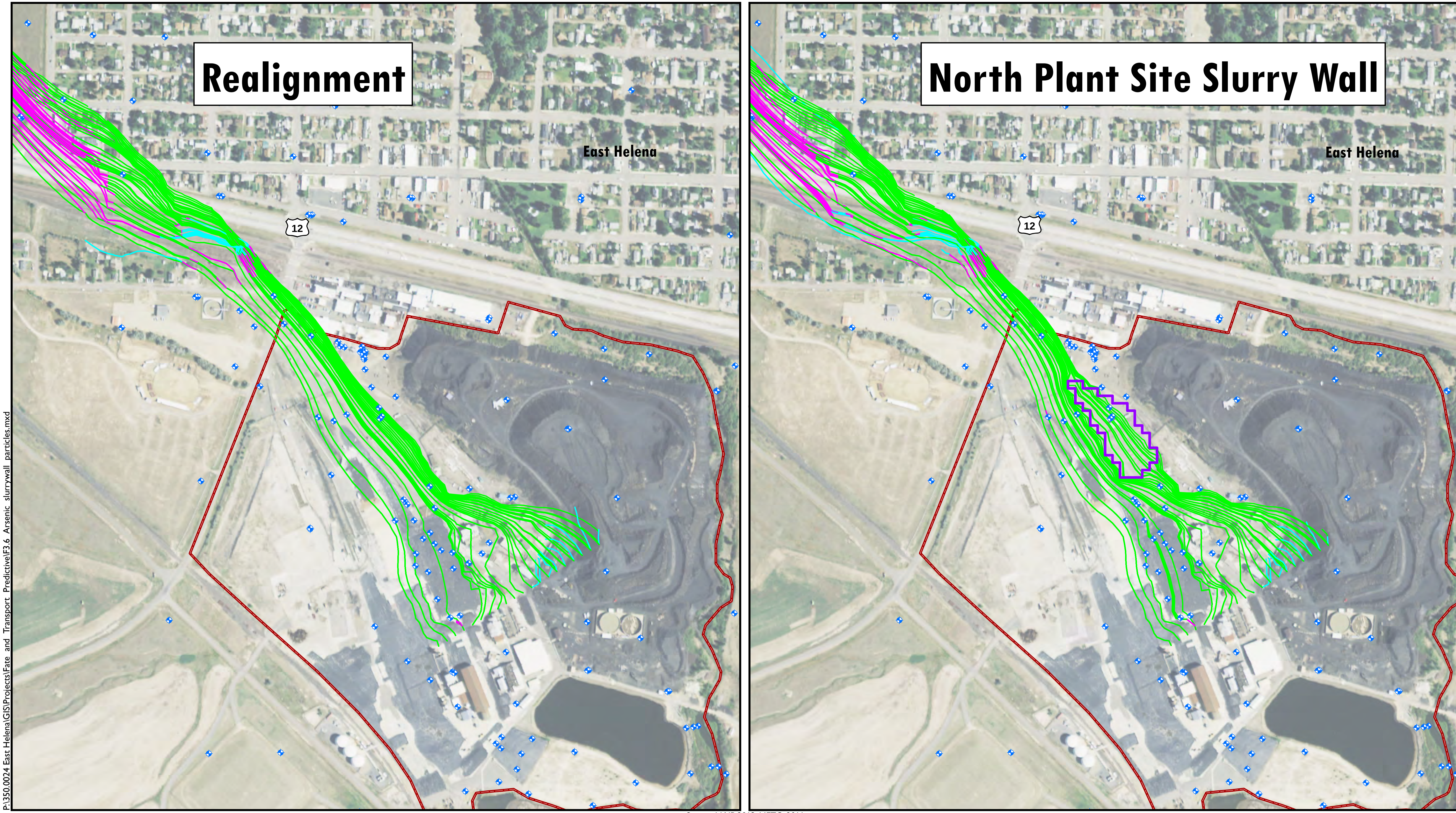
Facility Boundary

Note: Change in groundwater elevation is the difference between the slurry wall and realignment simulations.

Change in Groundwater Elevation (feet)

- -0.76 to -0.25
- 0.25 to 0.5
- 0.5 to 1.0
- >1.0

Predicted Change in Groundwater Elevations
Arsenic Slurry Wall Simulation
Former ASARCO East Helena Facility
East Helena, Montana
Figure 3.5



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.6 Arsenic slurrywall particles.mxd

Source: NAIP, 2013; METG, 2011

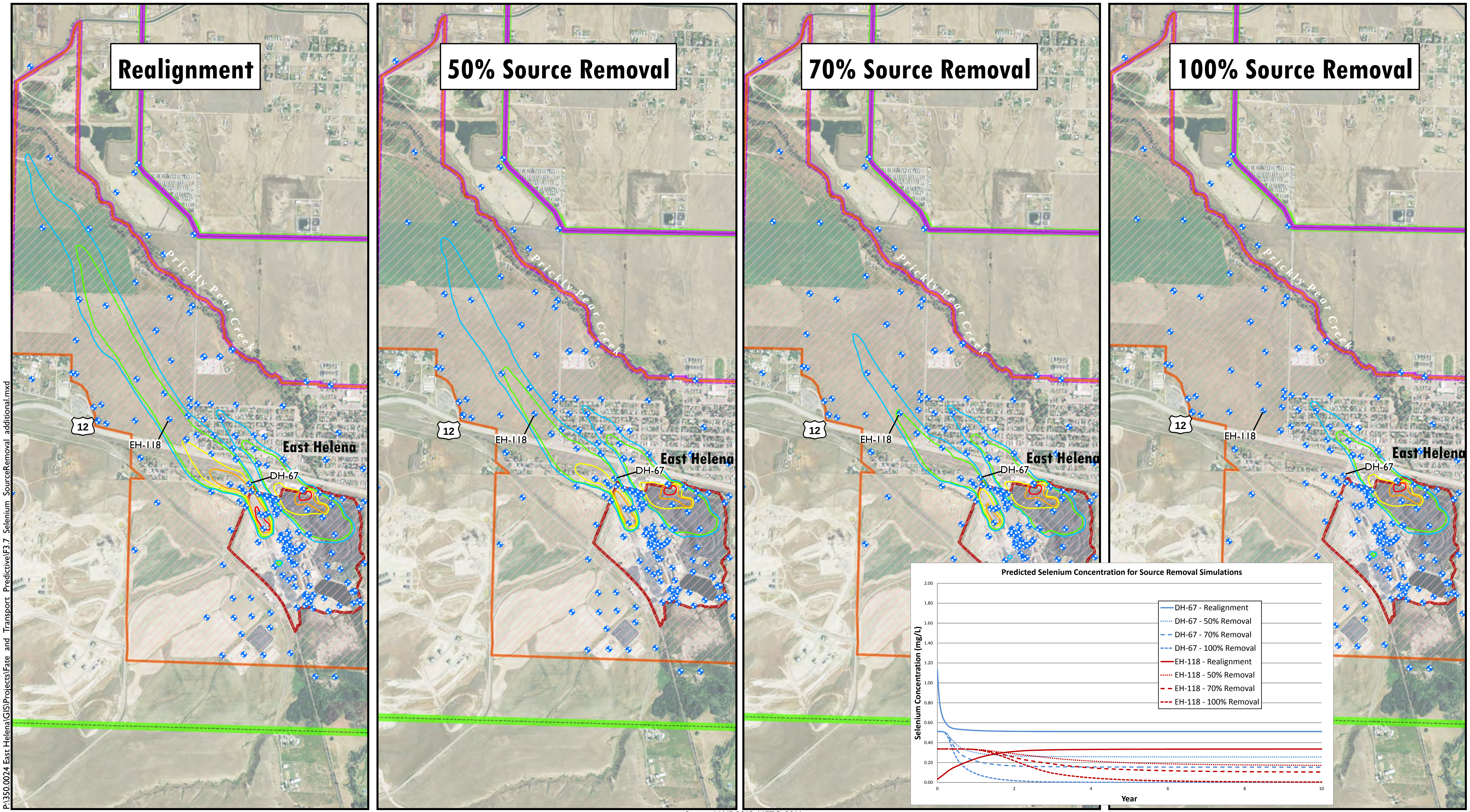
0 Feet 500

Monitoring Well
North Plant Site Slurry Wall
Facility Boundary

Particle Track Layer
1
2
3

NewFields

North Plant Site Particle Tracks
Former ASARCO East Helena Facility
East Helena, Montana
Figure 3.6



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.7 Selenium SourceRemoval additional.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 2,000

NewFields

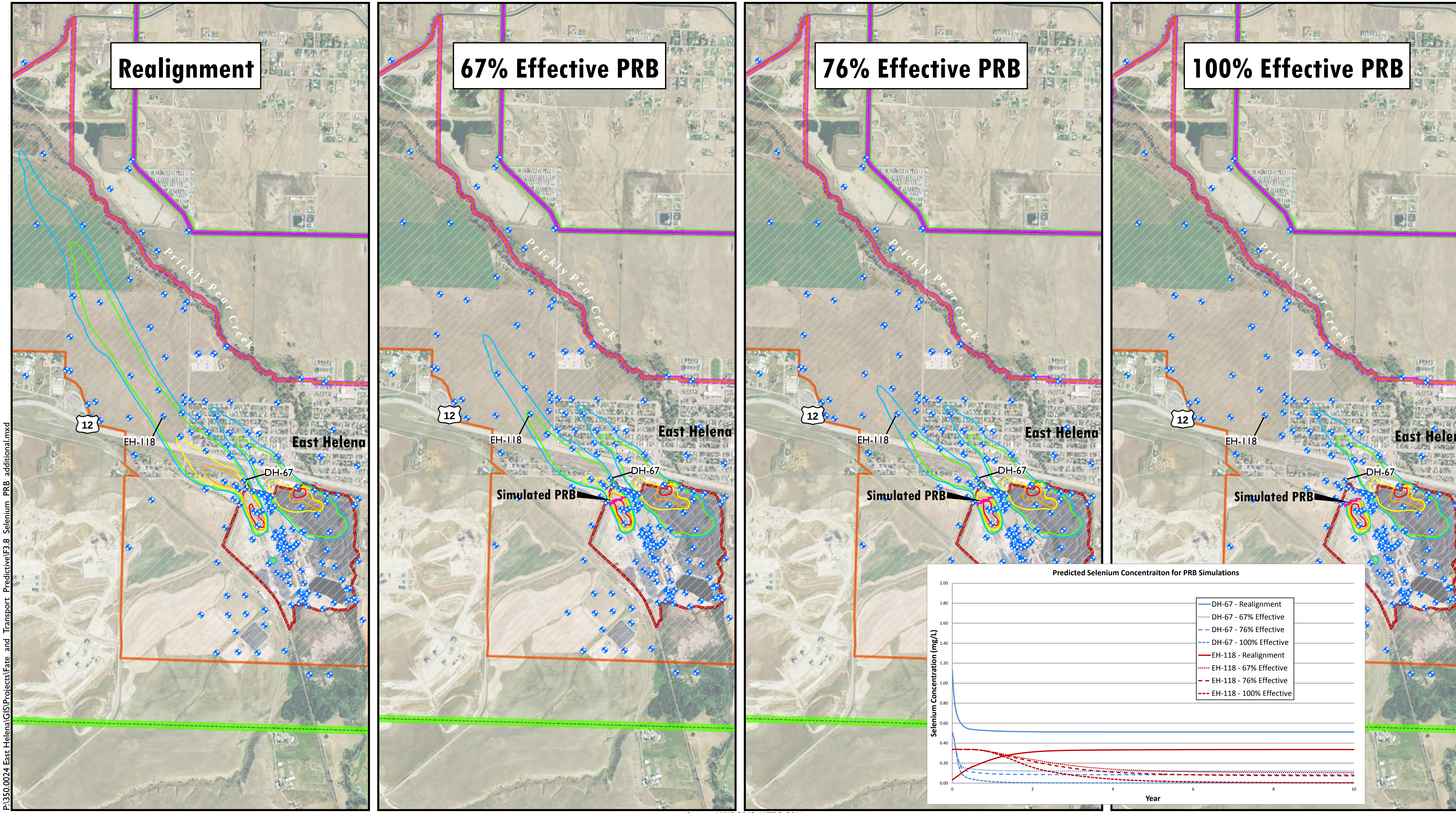
Note: Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predictive results depict concentrations after model has reached steady-state.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

- 0.05
- 0.1
- 0.5
- 1
- > 3

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Predicted Isoconcentration Contrours
Selenium Source Removal Simulations
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.7



Source: NAIP, 2013; METG, 2011

P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.8 Selenium PRB additional.mxd

0 Feet 2,000

NewFields

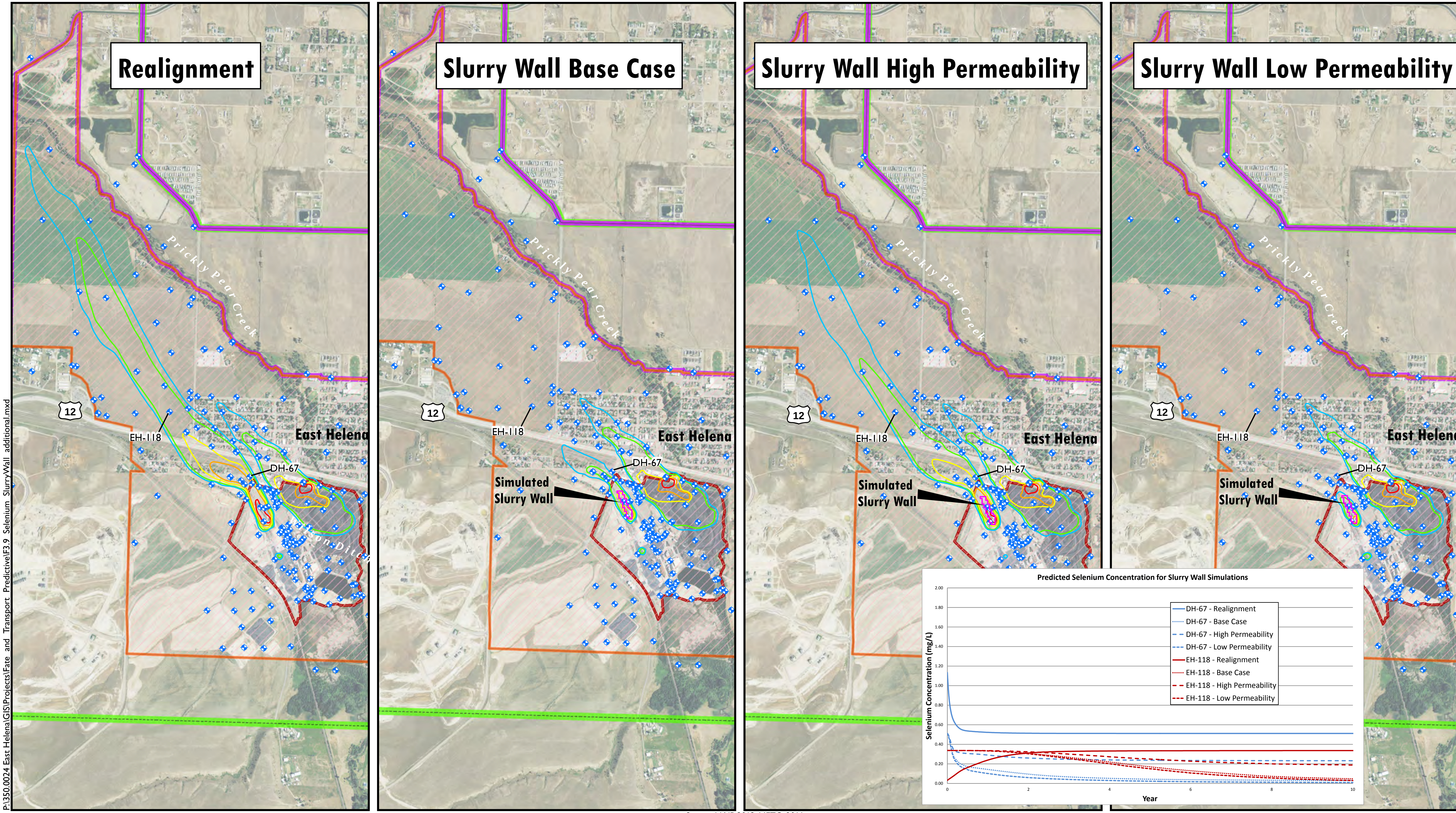
Note: Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predictive results depict concentrations after model has reached steady-state.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

- 0.05
- 0.1
- 0.5
- 1
- > 3

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Predicted Isoconcentration Contrours
Selenium PRB Simulations
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.8



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.9 Selenium SlurryWall additional.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 2,000

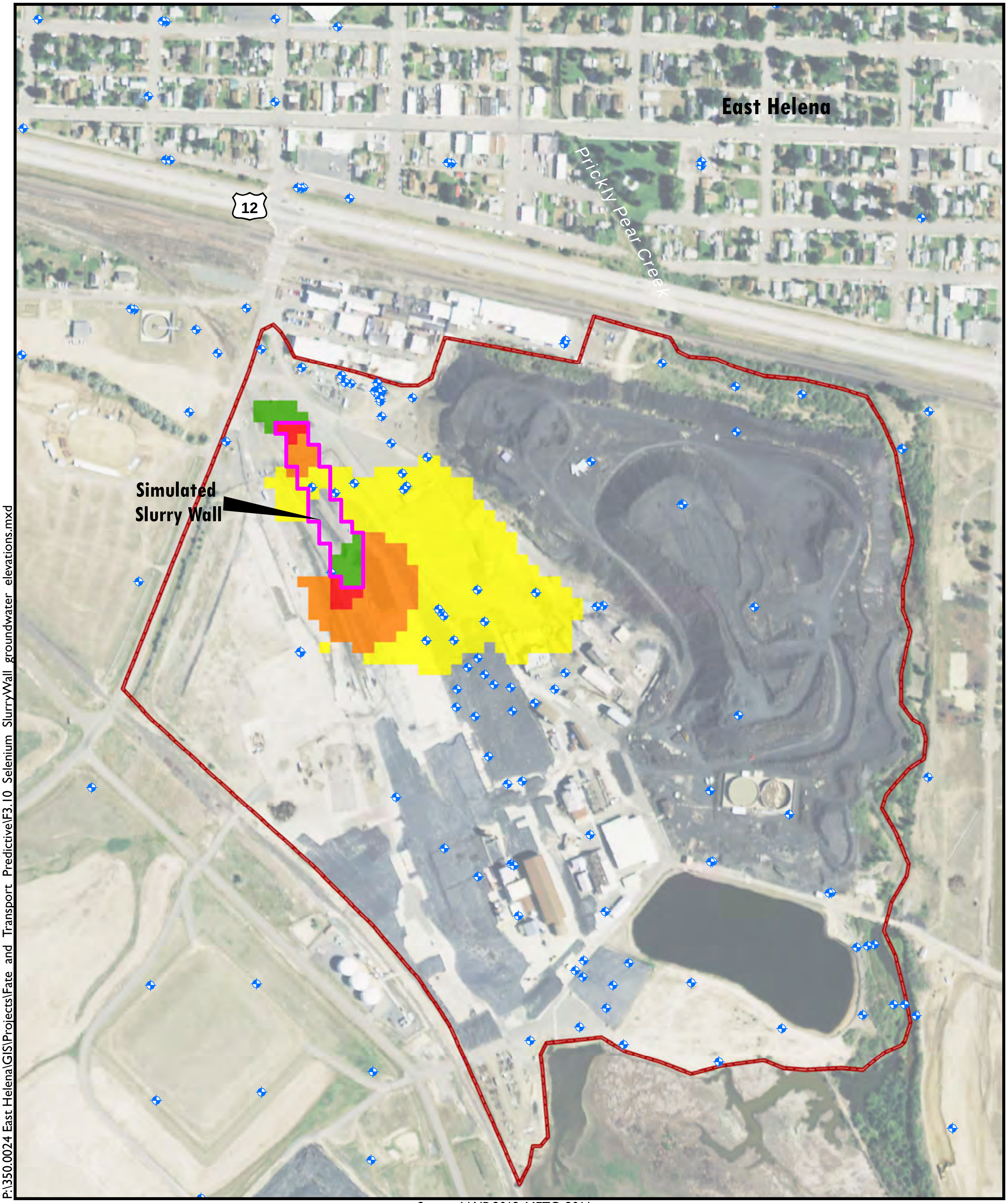
NewFields

Note: Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predictive results depict concentrations after model has reached steady-state.
The slurry wall base case has a hydraulic conductivity of 0.1 feet/day and a thickness of 2 feet.
Slurry wall permeability was increased and decreased by one order-of-magnitude.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)
- 0.05
- 0.1
- 0.5
- 1
- > 3

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporary CGWA

Predicted Isoconcentration Contrours
Selenium Slurry Wall Simulations
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.9



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.10 Selenium SlurryWall groundwater elevations.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 500

NewFields

Monitoring Well

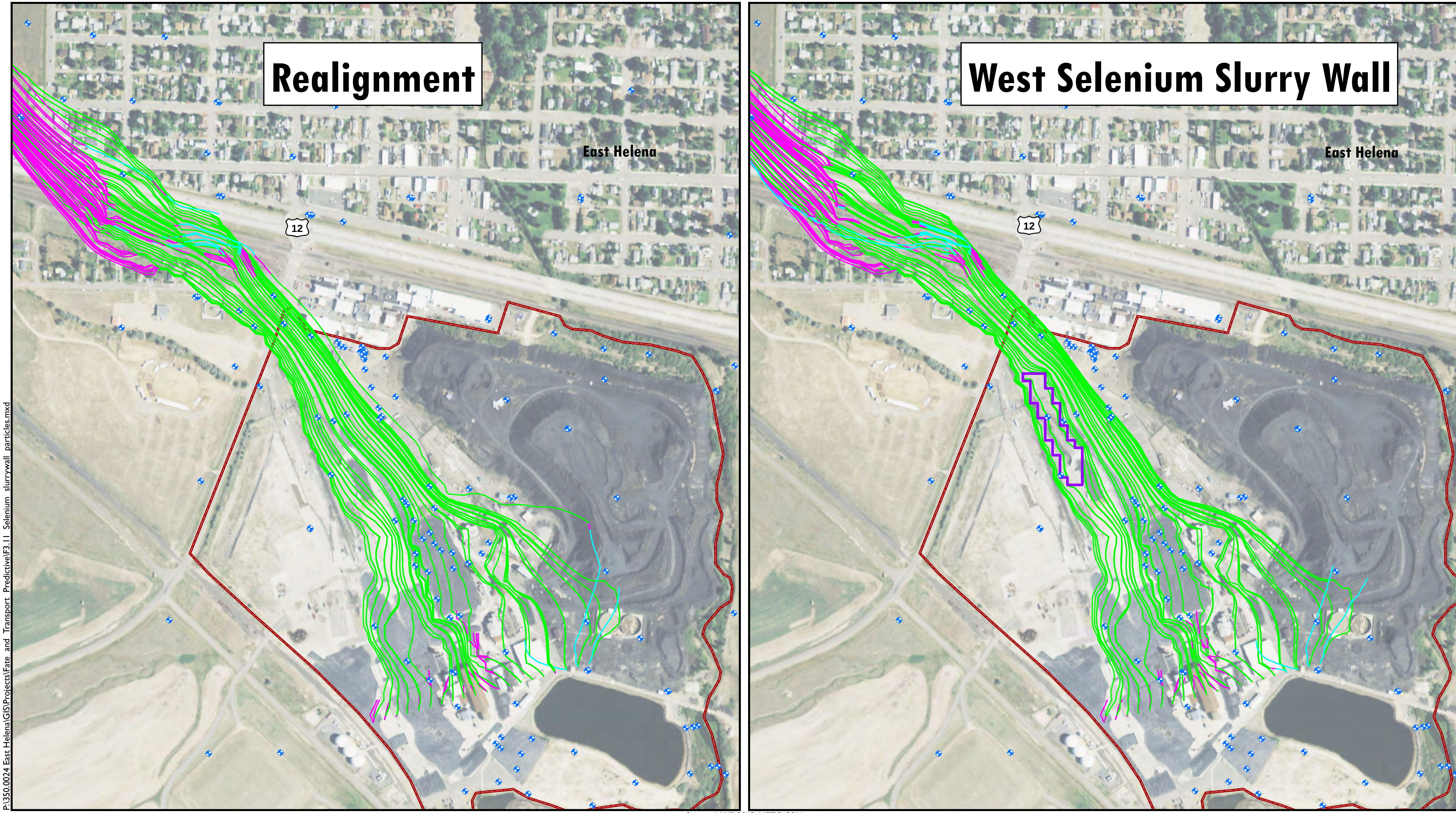
Facility Boundary

Note: Change in groundwater elevation is the difference between the slurry wall and realignment simulations.

Change in Groundwater Elevation (feet)

- -0.76 to -0.25
- 0.25 to 0.5
- 0.5 to 1.0
- >1.0

Predicted Change in Groundwater Elevations
Selenium Slurry Wall Simulation
Former ASARCO East Helena Facility
East Helena, Montana
Figure 3.10



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.11 Selenium slurrywall particles.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 500

NewFields

Monitoring Well

West Selenium Slurry Wall

Facility Boundary

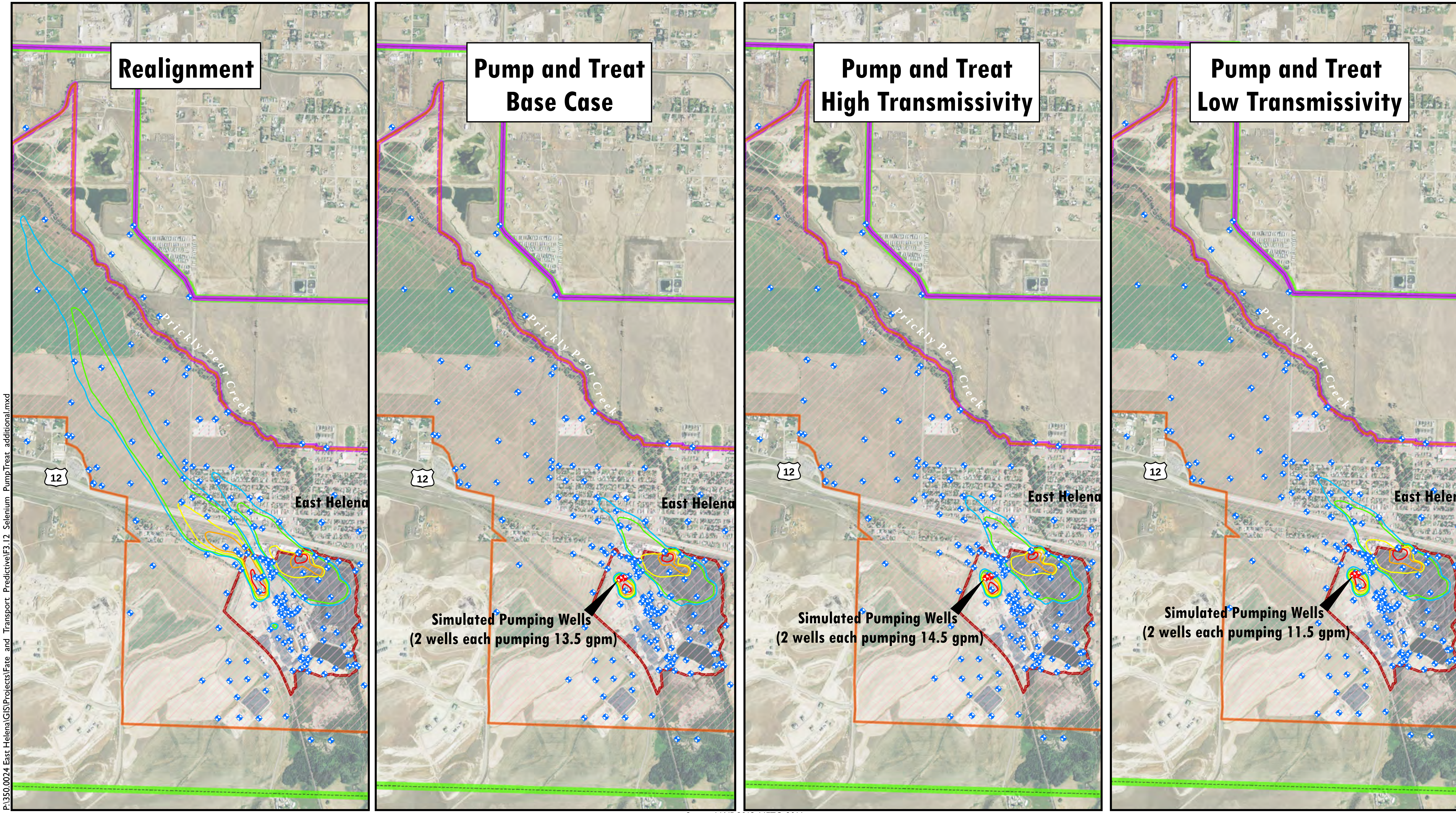
Particle Track Layer

1

2

3

West Selenium Area Particle Tracks
Former ASARCO East Helena Facility
East Helena, Montana
Figure 3.11



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.12 Selenium PumpTreat additional.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 2,000

NewFields

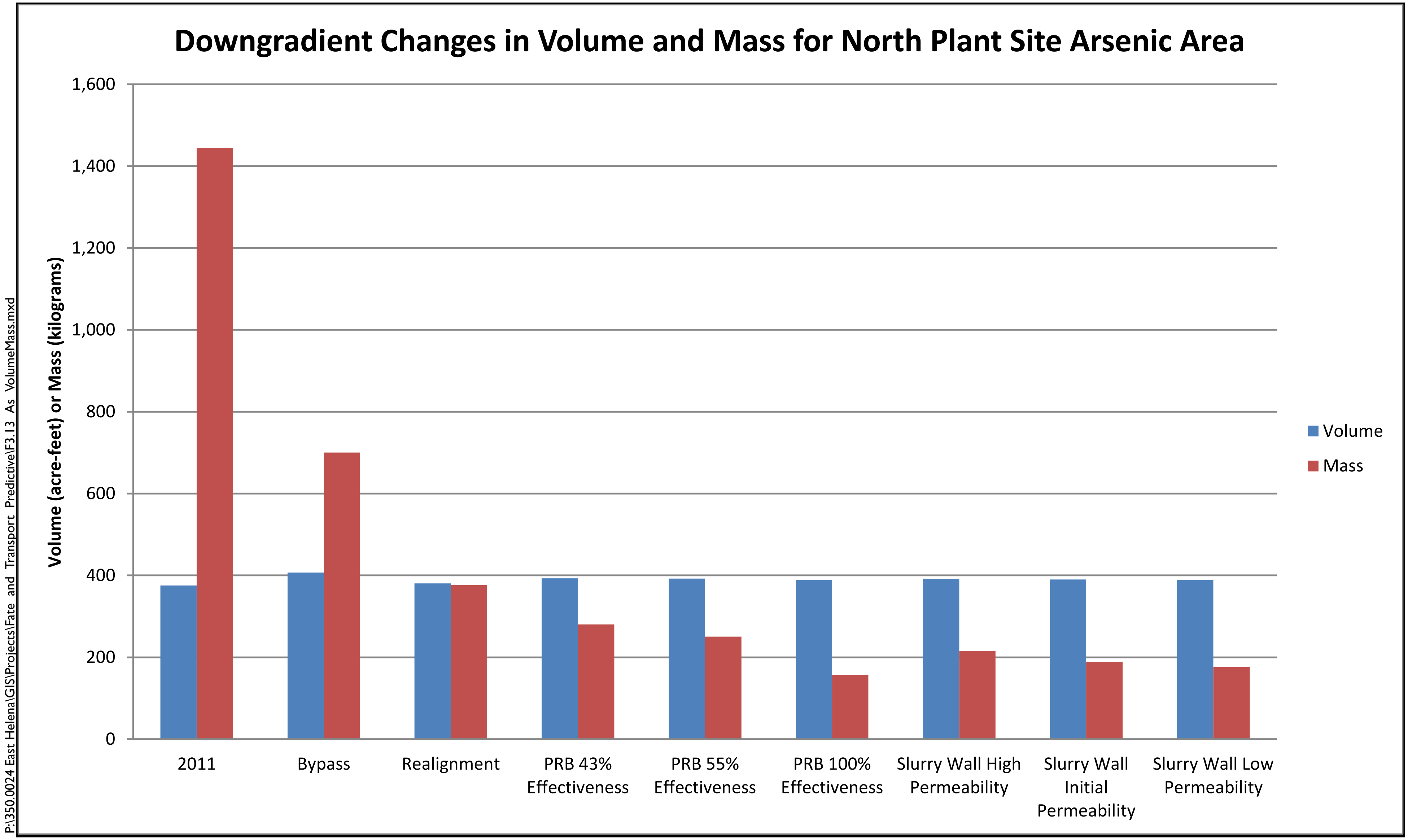
Note: Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predictive results depict concentrations after model has reached steady-state.
Hydraulic conductivity around the pumping wells was increased and decreased by 50 percent.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

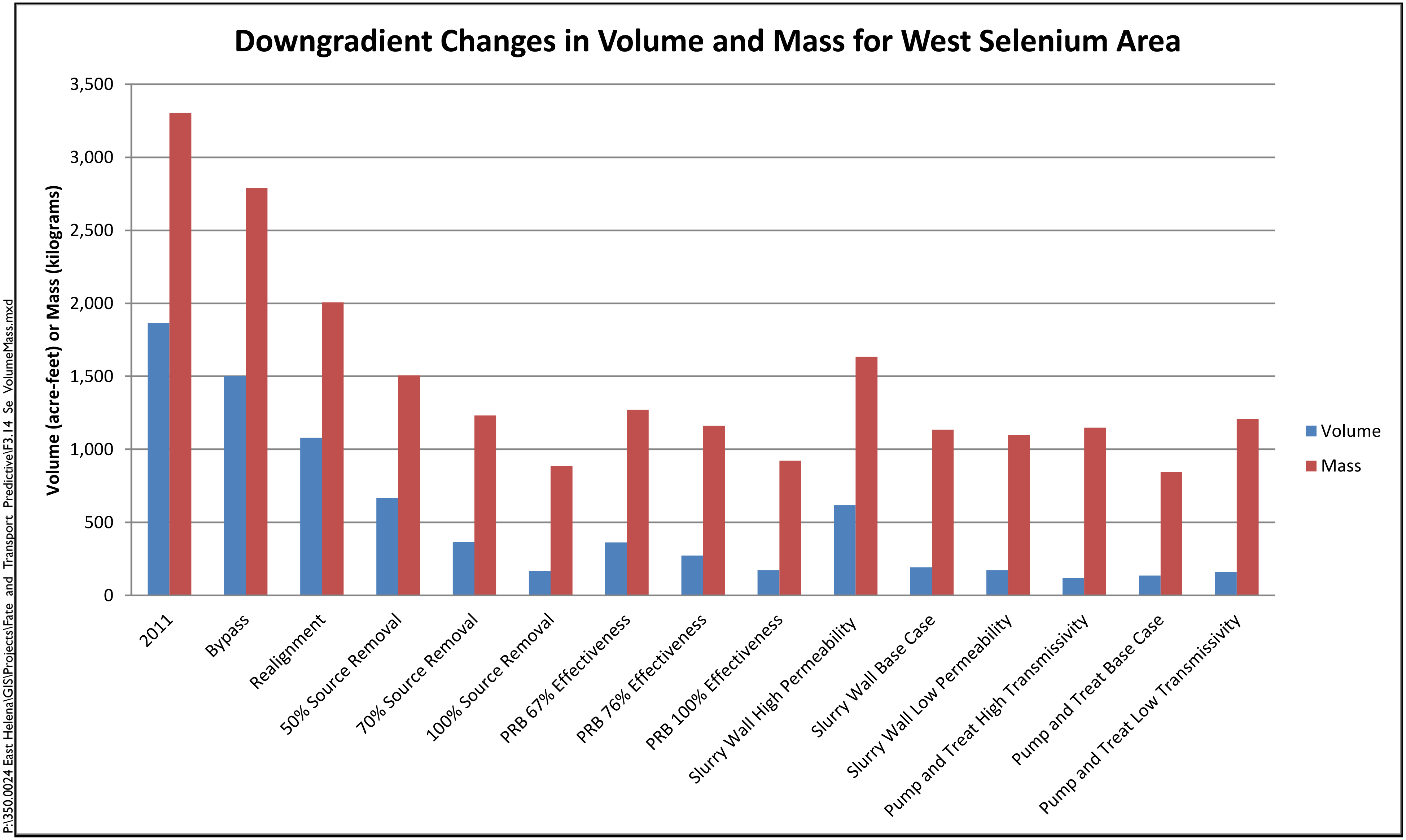
0.05 | 1
0.1 | > 3
0.5

Monitoring Well
Facility Boundary
Permanent CGWA - Subarea1
Permanent CGWA - Subarea 2
Temporaty CGWA

Predicted Isoconcentration Contrours
Selenium Pump and Treat Simulations
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.12



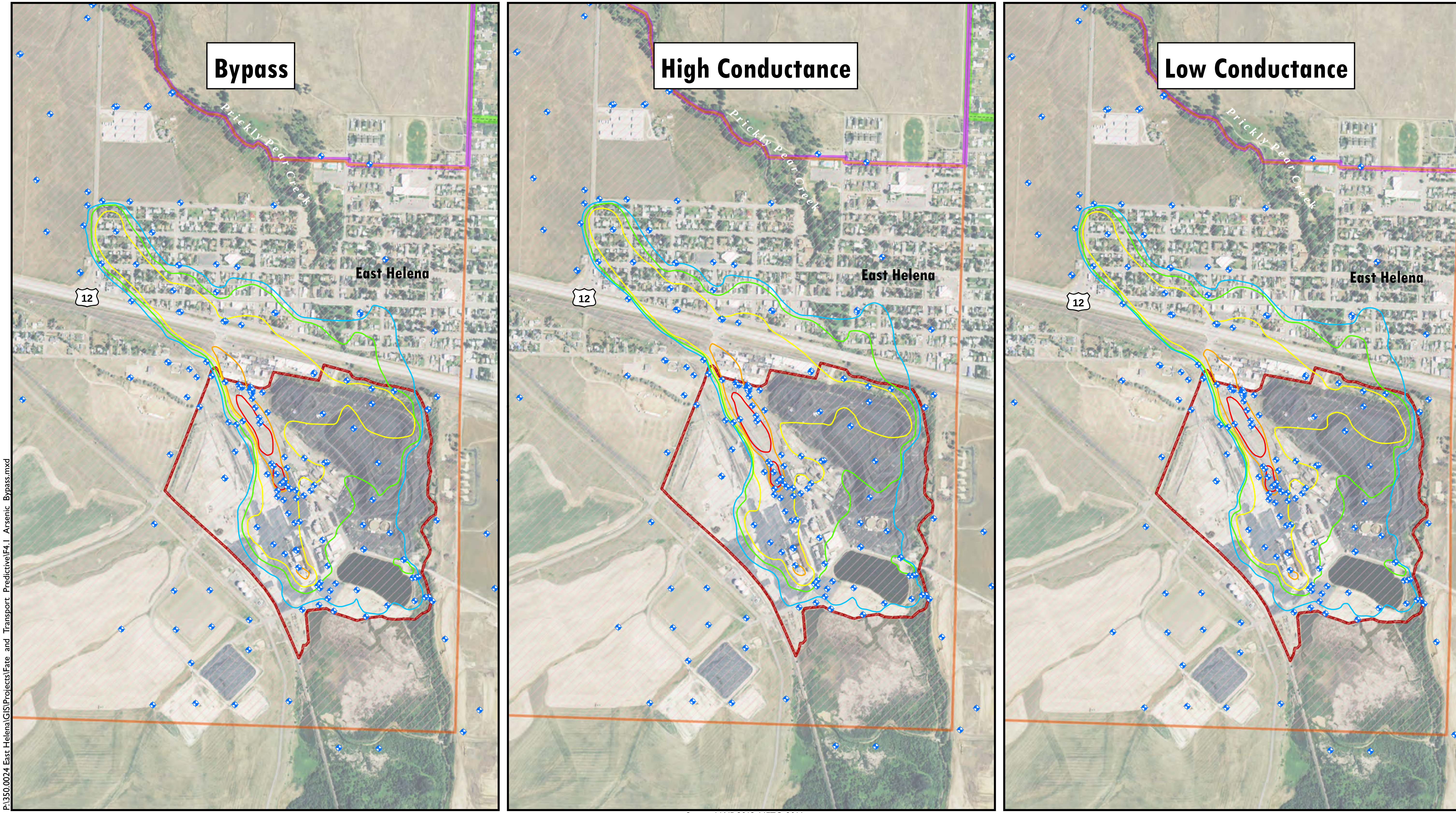
Changes in Arsenic Volume/Mass for IM and Corrective Acitons
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.13



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F3.14 Se VolumeMass.mxd

NewFields

Changes in Selenium Volume/Mass for IMs and Corrective Actions
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 3.14



Source: NAIP, 2013; METG, 2011

0 Feet 1,000

NewFields

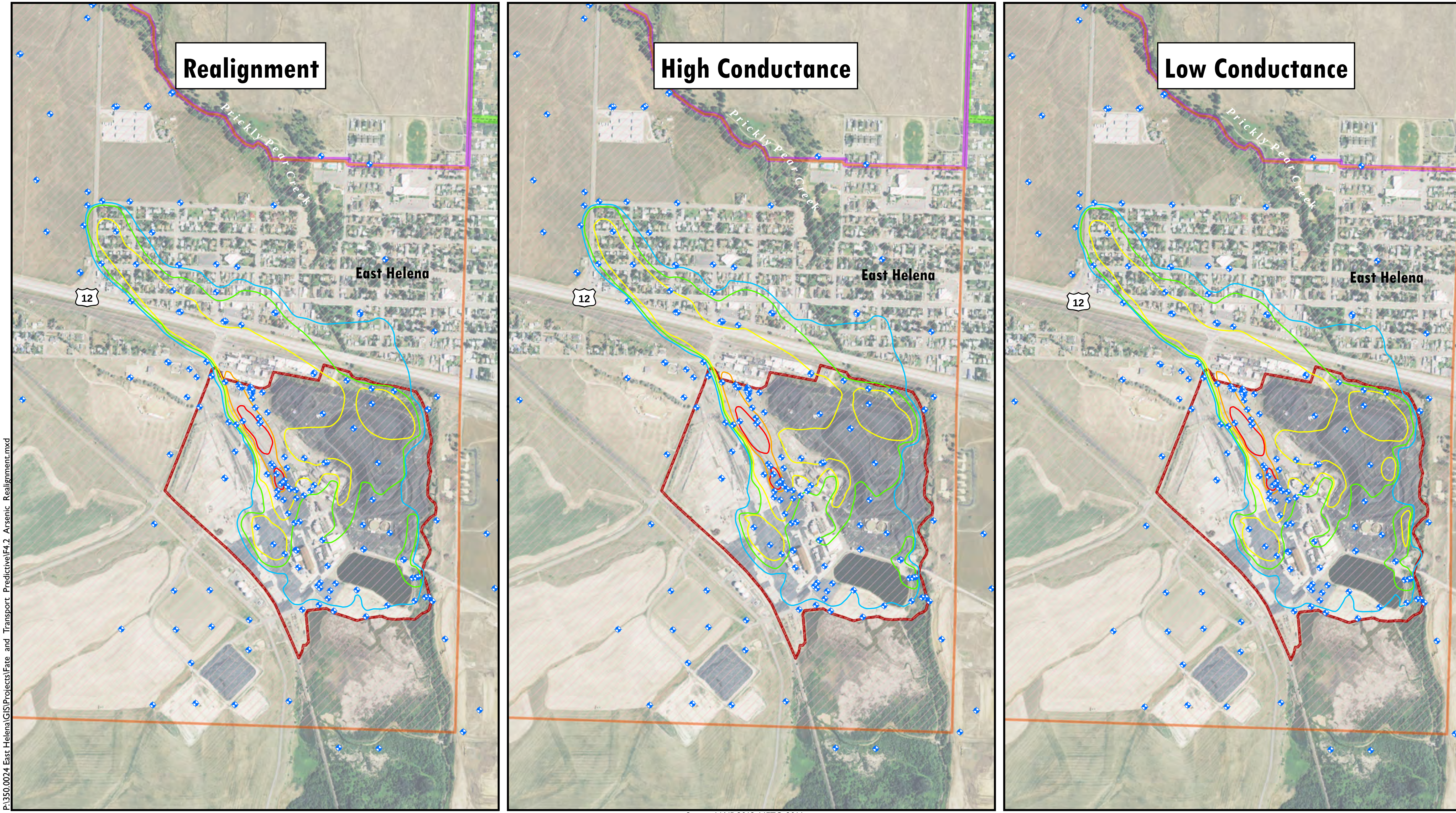
Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predicted results depict concentratins after model has reached steady-state.
Bypass conductance was increased and decreased by 50 percent.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

- 0.01
- 0.1
- 1
- 10
- > 20

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Arsenic Sensitivity Analysis for Bypass Conductance
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 4.1



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F4.2 Arsenic Realignment.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 1,000

NewFields

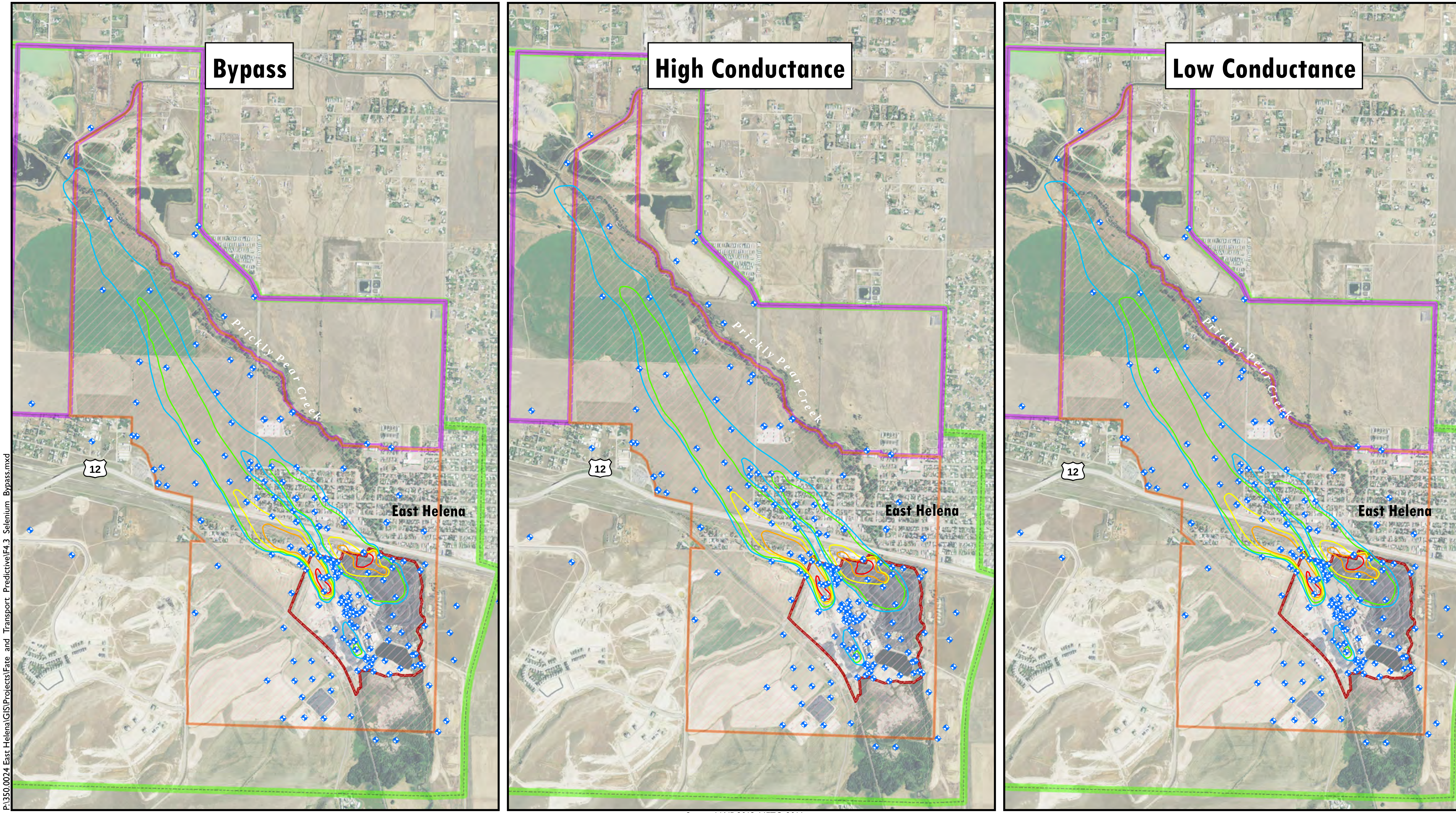
Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predicted results depict concentrations after model has reached steady-state.
Realignment conductance was increased and decreased by 50 percent.
CGWA = Controlled Groundwater Area.

Isoconcentration Contour (mg/L)

- 0.01
- 0.1
- 1
- 10
- > 20

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Arsenic Sensitivity Analysis for Realignment Conductance
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 4.2



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F4.3 Selenium Bypass.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 2,000

NewFields

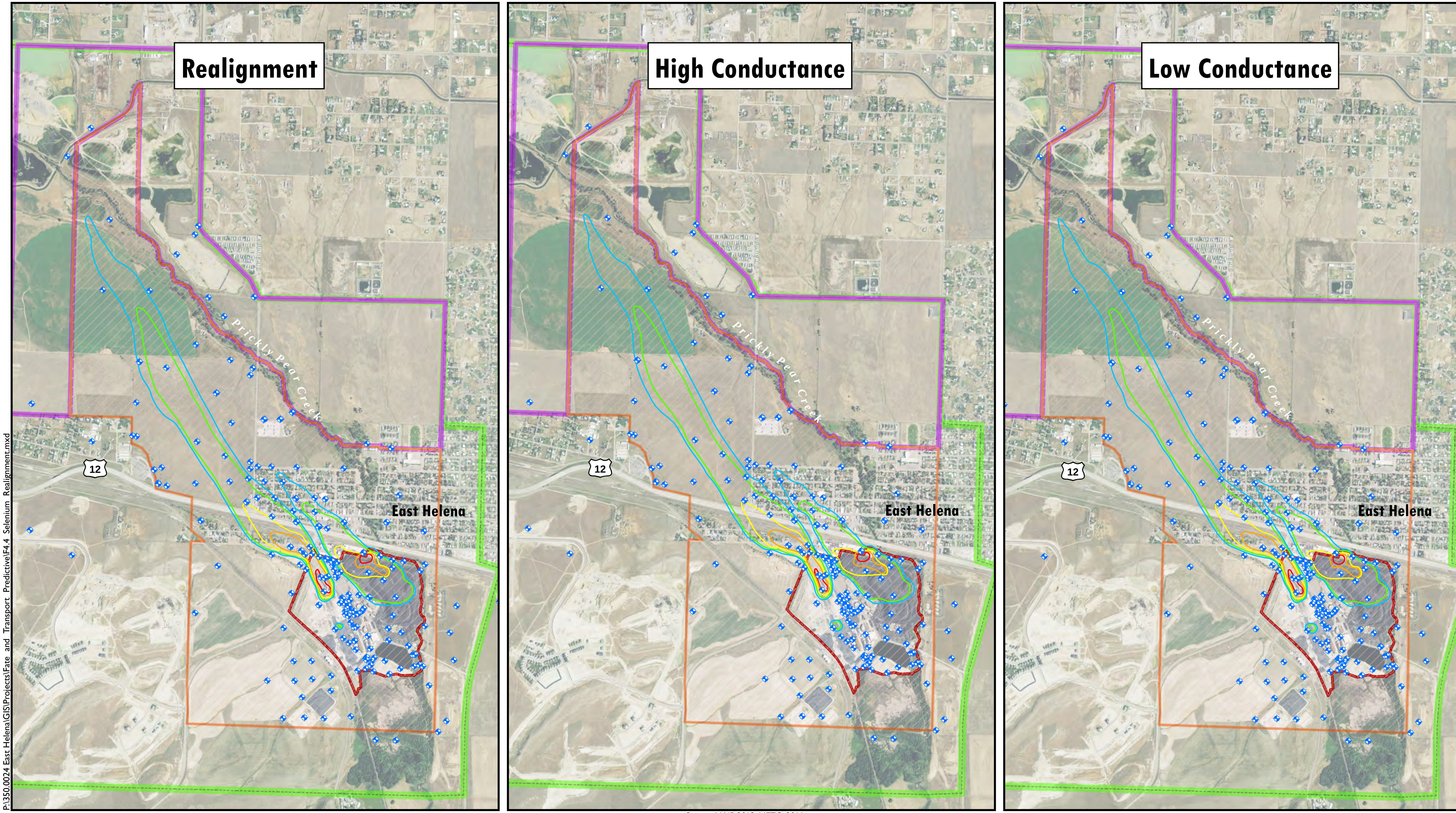
Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predicted results depict concentratins after model has reached steady-state.
Bypass conductance was increased and decreased by 50 percent.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

- 0.05
- 0.1
- 0.5
- 1
- > 3

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Selenium Sensitivity Analysis for Bypass Conductance
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 4.3



P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F4.4 Selenium Realignment.mxd

Source: NAIP, 2013; METG, 2011

0 Feet 2,000

NewFields

Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predicted results depict concentratins after model has reached steady-state.
Realignment conductance was increased and decreased by 50 percent.
CGWA = Controlled Groundwater Area

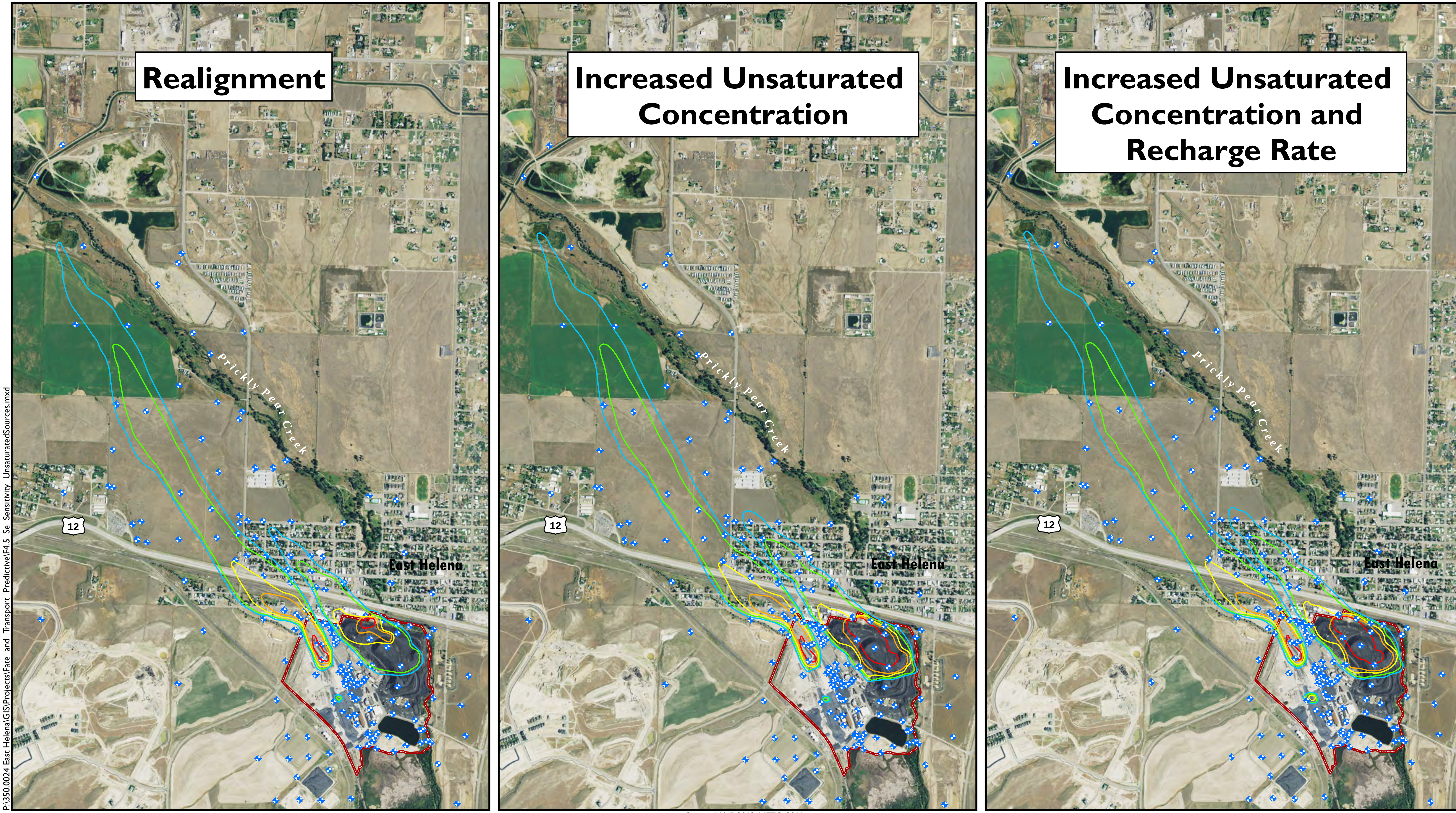
Isoconcentration Contour (mg/L)

- 0.05
- 0.1
- 0.5
- 1
- > 3

- Monitoring Well
- Facility Boundary
- Permanent CGWA - Subarea1
- Permanent CGWA - Subarea 2
- Temporaty CGWA

Selenium Sensitivity Analysis for Bypass Conductance
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 4.4

P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F4.5 Se Sensitivity UnsaturatedSources.mxd



Source: NAIP, 2013; METG, 2011

N

0 Feet 1,800

NewFields

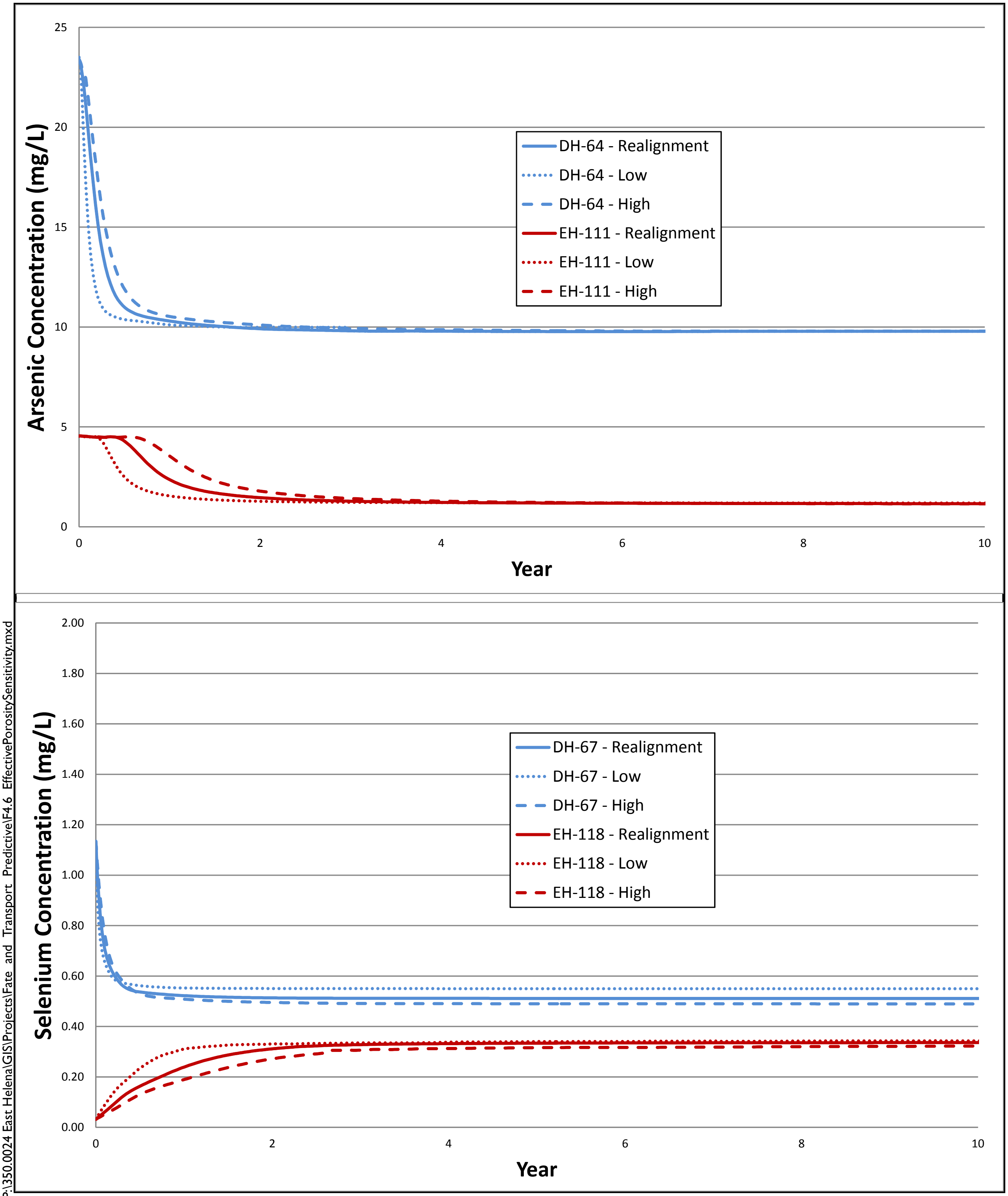
Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predicted results depict concentratins after model has reached steady-state.
Unsaturated source area concentrations were increased by one order-of-magnitude.
The recharge rate in the central plant site area was increased to 10 percent of annual precipitation.
CGWA = Controlled Groundwater Area

Isoconcentration Contour (mg/L)

- 0.05
- 0.1
- 0.5
- 1
- > 3

- Monitoring Well
- Facility Boundary

Selenium Sensitivity Analysis for Unsaturated Sources
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 4.5

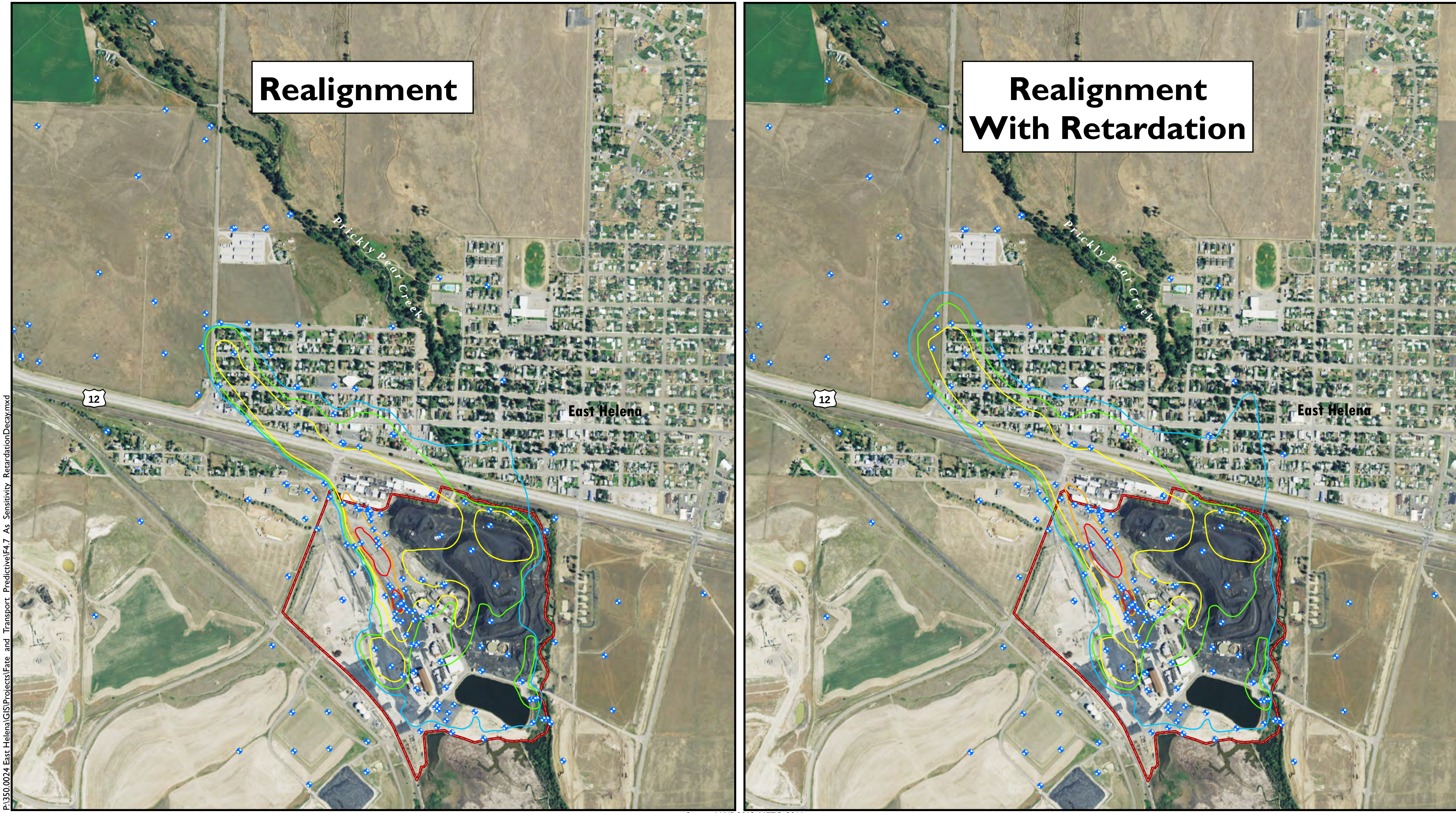


P:\350.0024 East Helena\GIS\Projects\Fate and Transport Predictive\F4.6 EffectivePorositySensitivity.mxd

Note: Effective porosity was increased and decreased by 50 percent.

Sensitivity Analysis for Effective Porosity
Former ASARCO East Helena Facility
East Helena, Montana
Figure 4.6

NewFields



Source: NAIP, 2013; METG, 2011

0 Feet 1,000

NewFields

Note: Simulated plumes represent a composite of model layers 1, 2, and 3.
Predictive results depict concentrations after model has reached steady-state.
Sorption was simulated with sorption coefficient of 5 liters per kilogram and a linear isotherm.

Isoconcentration Contour (mg/L)

- 0.01
- 0.1
- 1
- 10
- > 20

- Monitoring Well
- Facility Boundary

Arsenic Sensitivity Analysis for Attenuation
Former ASARCO East Helena Facility
East Helena, Montana
FIGURE 4.7

ATTACHMENT A

SIMULATED SATURATED MASS LOADING RATES

Attachment A - Arsenic
Simulated Saturated Source Mass Loading Rates (mg/day)
Former ASARCO East Helena Facility, East Helena, Montana

Source Area	Model Layer	Calibrated Model	Bypass Simulation	Reduction from 2011 Model	Realignment Simulation	Reduction from 2011 Model
Tito Park	1	267,544	Removed	NA	Removed	NA
Ore Storage Area	1	38,000	Removed	NA	Removed	NA
APSD Slurry Wall	1	158,595	Removed	NA	Removed	NA
Acid Plant	1	182,400	Dry	NA	Dry	NA
Slag Pile	1	273,000	186,166	32%	93,207	66%
Tito Park	2	118,526	Removed	NA	Removed	NA
Ore Storage	2	88,920	Removed	NA	Removed	NA
APSD Slurry Wall	2	439,729	Removed	NA	Removed	NA
Acid Plant	2	1,169,201	448,374	62%	5,244	100%
Speiss Dross	2	5,546	Dry	NA	Dry	NA
Slag Pile	2	126,000	121,314	4%	66,856	47%
Acid Plant	3	595,350	415,820	30%	193,795	67%
Speiss Dross	3	3,253,742	2,616,186	20%	1,782,697	45%
Thornock Lake	3	78,000	70,789	9%	56,074	28%
Slag Pile	3	1,176,000	1,136,071	3%	884,208	25%
North Plant Site	3	6,968,487	5,512,881	21%	3,918,583	44%

Source Area	Model Layer	Realignment Simulation	PRB Simulations[a]	Percent Reduction from Realignment	Slurry Wall 0.1 ft/day Permeability	Percent Reduction from Realignment	Slurry Wall 1 ft/day Permeabilit	Percent Reduction from Realignment	Slurry Wall 0.01 ft/day Permeabilit	Percent Reduction from Realignment
Tito Park	1	Removed	Removed	NA	Removed	NA	Removed	NA	Removed	NA
Ore Storage Area	1	Removed	Removed	NA	Removed	NA	Removed	NA	Removed	NA
APSD Slurry Wall	1	Removed	Removed	NA	Removed	NA	Removed	NA	Removed	NA
Acid Plant	1	Dry	Dry	NA	Dry	NA	Dry	NA	Dry	NA
Slag Pile	1	93,207	93,207	0%	93,207	0%	93,207	0%	93,207	0%
Tito Park	2	Removed	Removed	NA	Removed	NA	Removed	NA	Removed	NA
Ore Storage	2	Removed	Removed	NA	Removed	NA	Removed	NA	Removed	NA
APSD Slurry Wall	2	Removed	Removed	NA	Removed	NA	Removed	NA	Removed	NA
Acid Plant	2	5,244	5,244	0%	5,244	0%	5,244	0%	5,244	0%
Speiss Dross	2	Dry	Dry	NA	Dry	NA	Dry	NA	Dry	NA
Slag Pile	2	66,856	66,856	0%	66,856	0%	66,856	0%	66,856	0%
Acid Plant	3	193,795	193,795	0%	193,795	0%	193,795	0%	193,795	0%
Speiss Dross	3	1,782,697	1,782,697	0%	1,782,697	0%	1,782,697	0%	1,782,697	0%
Thornock Lake	3	56,074	56,074	0%	56,074	0%	56,074	0%	56,074	0%
Slag Pile	3	884,208	884,208	0%	884,208	0%	884,208	0%	884,208	0%
North Plant Site	3	3,918,583	3,918,583	0%	761,997	81%	2,153,590	45%	106,181	97%

[a]Saturated source mass loading rates were not adjusted for the PRB simulations.

Note: mg/day = milligrams per day; NA = not applicable.

Attachment A - Selenium
Simulated Saturated Source Mass Loading Rates (mg/day)
Former ASARCO East Helena Facility, East Helena, Montana

Source Area	Model Layer	2011 Calibrated Model	Bypass Simulation	Percent Reduction from 2011 Model	Realignment Simulation	Percent Reduction from 2011 Model
Acid Plant	1	4,628	Dry	NA	Dry	NA
Acid Plant	2	25,106	9,527	62%	570	98%
Slag Pile	2	135,000	105,745	22%	58,692	57%
Slag Pile	3	286,000	274,848	4%	207,069	28%
West Selenium Area	3	664,999	453,267	32%	277,288	58%

Source Area	Model Layer	Realignment Simulation	50% Source Removal	Reduction from Realignment Simulation	70% Source Removal	Reduction from Realignment Simulation	100% Source Removal	Reduction from Realignment Simulation	PRB Simulations[a]	Reduction from Realignment Simulation
Acid Plant	1	Dry	Dry	NA	Dry	NA	Dry	NA	Dry	NA
Acid Plant	2	570	570	0%	570	0%	570	0%	570	0%
Slag Pile	2	58,692	58,692	0%	58,692	0%	58,692	0%	58,692	0%
Slag Pile	3	207,069	207,069	0%	207,069	0%	207,069	0%	207,069	0%
West Selenium Area	3	277,288	138,644	50%	83,186	70%	Removed	NA	277,288	0%

Source Area	Model Layer	Realignment Simulation	Slurry Wall 0.1 ft/day Permeability	Percent Reduction from Realignment	Slurry Wall 1 ft/day Permeability	Percent Reduction from Realignment	Slurry Wall 0.01 ft/day Permeability	Percent Reduction from Realignment	Pump and Treat Simulations[a]	Percent Reduction from Realignment
Acid Plant	1	Dry	Dry	NA	Dry	NA	Dry	NA	Dry	NA
Acid Plant	2	570	570	0%	570	0%	570	0%	570	0%
Slag Pile	2	58,692	58,692	0%	58,692	0%	58,692	0%	58,692	0%
Slag Pile	3	207,069	207,069	0%	207,069	0%	207,069	0%	207,069	0%
West Selenium Area	3	277,288	34,186	88%	136,291	51%	4,164	98%	277,288	0%

[a]Saturated source mass loading rates were not adjusted for the PRB and Pump and Treat simulations.

Note: mg/day = milligrams per day; NA = not applicable.

Appendix C
Cost Details

Appendix C. Summary of Costs for Tier II Source Control Evaluation

Tier II Source Control Evaluation

Area	Alternative	2015 Dollars[a]			Net Present Worth of Long-Term O&M [b]	Combined Total Capital Costs and NPW of Long-term O&M [c]
		Capital Costs	**Long-Term O&M**	**Combined Capital and Long-Term O&M Cost**		
West Selenium	1 - Source Removal	$2,782,125	Not Applicable	$2,782,125	Not Applicable	$2,782,125
	2 - PRB for Selenium	$1,466,175	$2,622,969	$4,089,144	$1,299,422	$2,765,597
	3 - Slurry Wall Enclosure	$1,628,265	Not Applicable	$1,628,265	Not Applicable	$1,628,265
	4 - Pump and Treat	$2,294,341	$3,262,485	$5,556,827	$1,733,921	$4,028,263
North Plant	5 - PRB Arsenic	$9,943,458	$20,777,922	$30,721,381	$10,348,478	$20,291,936
	6 - Slurry Wall Enclosure	$2,031,968	Not Applicable	$2,031,968	Not Applicable	$2,031,968
	7 - Slurry Wall w/Injections	$2,168,011	$329,719	$2,497,730	$314,018	$2,482,029

General Notes:

- **CONFIDENTIAL BUSINESS INFORMATION:** Class 4 Rough Order of Magnitude (ROM) Budget Estimate with expected accuracy price range -30%/+50% (AACE, 2005).
- Estimate is intended for feasibility-level screening only and is NOT approved for construction.
- Estimate includes a 10% adder for G&A and overhead costs and a 15% contingency.

Column Header Footnotes:

[a] Indicates the current 2015 dollars.

[b] Net Present Worth (NPW) of long-term operations and maintenance (O&M) assuming 30-year period at 5% rate of return; see details in worksheets.

[c] Combined 2015 capital costs and the long-term O&M with NPW calculation.

Alternate 1 - West Selenium - Source Removal

Tier II Source Control Evaluation

Capital Costs for Alternative 1

BidItem	Description	Quantity	Units	Unit Price	Total
10	BONDS & INSURANCE	1	LS	$ 75,774	$ 75,774
20	SUBMITTALS	1	LS	$ 44,395	$ 44,395
30	MOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 89,765	$ 89,765
40	INSTALL SWPP ELEMENTS	1	LS	$ 9,308	$ 9,308
50	INITIAL SURVEY & LAYOUT	1	LS	$ 6,160	$ 6,160
60	UTILITY LOCATE	1	LS	$ 2,800	$ 2,800
70	UTILITY REMOVE OR RELOCATE	1	LS	$ 2,800	$ 2,800
80	SET UP DECON STATION	1	LS	$ 11,713	$ 11,713
90	INSTALL SAFETY FENCE	840	LF	$ 17	$ 14,112
95	AIR MONITORING	100	DY	$ 1,120	$ 112,000
100	IMPROVE ACCESS ROAD FOR EXCAVATION	1	LS	$ 8,648	$ 8,648
105	DUST CONTROL	1	LS	$ 9,721	$ 9,721
110	REMOVE SUB SURFACE DEBRIS	1	LS	$ 6,903	$ 6,903
120	EXCAVATE THROUGH IM COVER(3' THICK) & SP	2426	CY	$ 7	$ 15,915
137	INSTALL SOLDIER PILE & LAGGING	29400	SF	$ 41	$ 1,211,868
138	REMOVE SOLDIER PILE & LAGGING	29400	SF	$ 7	$ 200,802
140	INSTALL & REMOVE RAMPS	6644	CY	$ 15	$ 98,265
150	EXCAVATE UNSATURATED SOIL TO ONSITE SP	22245	CY	$ 11	$ 250,924
160	EXCV SOIL BELOW GW-HAUL TO ICS2 FILL	7407	CY	$ 14	$ 102,143
170	DEWATER EXCAVATION	1	LS	$ 63,145	$ 63,145
180	BACKFILL FROM ONSITE SP	16745	CY	$ 11	$ 184,195
185	BACKFILL FINAL LIFT	5500	CY	$ 9	$ 49,610
190	BF BELOW GROUNDWATER CLEAN MTRL	7407	CY	$ 14	$ 102,068
200	BACKFILL CAP MATERIAL FROM ONSITE SP	2426	CY	$ 11	$ 26,807
210	RESTORE IM COVER	21836	SF	$ 1	$ 23,801
220	REGRADE SITE	1	LS	$ 4,209	$ 4,209
350	DEMOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 41,307	$ 41,307
400	CLOSURE REPORT	1	LS	$ 12,967	$ 12,967
				Grand Total:	**$ 2,782,125**

Notes:

1 Class 4 ROM Budget Estimate with expected accuracy price range -30%/+50% (AACE, 2005).

2 Estimate is intended for feasibility-level screening only and is NOT approved for construction.

3 Estimate includes a 10% adder for G&A and Overhead costs and a 15% Contingency.

4 This alternative does not require long-term operations & maintenance.

Alternate 2 - West Selenium - Permeable Reactive Barrier (PRB)
Tier II Source Control Evaluation

Capital Costs for Alternative 2

BidItem	Description	Quantity	Units	Unit Price	Total
10	BONDS & INSURANCE	1	LS	$ 36,214	$ 36,213.66
20	SUBMITTALS	1	LS	$ 21,617	$ 21,617.49
30	MOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 304,443	$ 304,442.50
40	INSTALL SWPPP ELEMENTS	1	LS	$ 5,259	$ 5,258.51
50	SURVEY & LAYOUT(THIRD PARTY SERVEYOR)	1	LS	$ 5,963	$ 5,962.66
60	UTILITY LOCATE	1	LS	$ 2,033	$ 2,032.72
70	UTILITY REMOVE OR RELOCATE (ALLOWANCE)	1	LS	$ 2,033	$ 2,032.72
80	SET UP DECON STATION	1	LS	$ 17,436	$ 17,435.84
105	DUST CONTROL	1	LS	$ 4,705	$ 4,704.86
110	REMV SUB SURFACE DEBRIS & PREP WORK PLATFORM	100	CY	$ 48	$ 4,845.00
115	REHANDLE BOULDERS (ALLOWANCE)	4	HR	$ 2,805	$ 11,220.64
125	INSTALL FUNNEL WALLS	2400	VSF	$ 70	$ 169,128.00
130	INSTALL PRB	2133	CY	$ 278	$ 593,165.97
135	PROVIDE PRB MEDIA	445	CY	$ 61	$ 27,136.10
140	INSTALL MONITORING WELL 2"	6	EA	$ 12,698	$ 76,186.50
210	RESTORE IM COVER	4000	SF	$ 2	$ 7,440.00
220	REGRADE SITE	1	LS	$ 4,074	$ 4,074.17
350	DEMOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 163,930	$ 163,929.75
400	CLOSURE REPORT	1	LS	$ 9,348	$ 9,347.51
				Capital Costs - Grand Total:	**$ 1,466,175**

Long-Term Operation & Maintenance Costs for Alternative 2

BidItem	Description	Quantity	Units	Unit Price	Total
10	BONDS & INSURANCE	1	LS	$ 36,214	$ 36,213.66
20	SUBMITTALS	1	LS	$ 21,617	$ 21,617.49
30	MOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 304,443	$ 304,442.50
40	INSTALL SWPPP ELEMENTS	1	LS	$ 5,259	$ 5,258.51
80	SET UP DECON STATION	1	LS	$ 17,436	$ 17,435.84
95	AIR MONITORING	40	DY	$ 1,084	$ 43,364.80
105	DUST CONTROL	1	LS	$ 4,705	$ 4,704.86
130	INSTALL PRB	2133	CY	$ 278	$ 593,165.97
135	PROVIDE PRB MEDIA	445	CY	$ 61	$ 27,136.10
210	RESTORE IM and ET COVER	4000	SF	$ 2	$ 7,440.00
220	OFFSITE RAILCAR HAUL AND DISPOSAL	445	CY	$195	$ 86,775.00
350	DEMOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 163,930	$ 163,929.75
				Year 10 Replacement Costs - Total:	**$ 1,311,484**
				Year 20 Replacement Costs - Total:	**$ 1,311,484**
				GRAND TOTAL LONG-TERM O&M:	**$ 2,622,969**

Notes:

1 Class 4 ROM Budget Estimate with expected accuracy price range -30%/+50% (AACE, 2005).
2 Estimate is intended for feasibility-level screening only and is NOT approved for construction.
3 Estimate includes a 10% adder for G&A and Overhead costs and a 15% Contingency.

Alternate 3 - West Selenium - Slurry Wall Enclosure

Tier II Source Control Evaluation

Capital Costs for Alternative 3

BidItem	Description	Quantity	Units	Unit Price	Total
10	BONDS & INSURANCE	1	LS	$ 44,964	$ 44,964
20	SUBMITTALS	1	LS	$ 43,002	$ 43,002
30	MOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 337,101	$ 337,101
40	INSTALL SWPP ELEMENTS	1	LS	$ 18,222	$ 18,222
50	SURVEY & LAYOUT(THIRD PARTY SERVEYOR)	1	LS	$ 11,933	$ 11,933
60	UTILITY LOCATE	1	LS	$ 4,068	$ 4,068
70	UTILITY REMOVE OR RELOCATE (ALLOWANCE)	1	LS	$ 6,780	$ 6,780
80	SET UP DECON STATION	1	LS	$ 18,037	$ 18,037
90	INSTALL SAFETY FENCE	1700	LF	$ 7	$ 11,526
105	DUST CONTROL	80	HR	$ 120	$ 9,633
110	REMV SUB SURFACE DEBRIS & PREP WORK PLATFORM	600	CY	$ 30	$ 17,832
115	REHANDLE BOULDERS (ALLOWANCE)	16	HR	$ 2,807	$ 44,912
125	INSTALL & CONSTRUCT SLURRY WALLS	54720	VSF	$ 16	$ 890,294
210	RESTORE IM COVER	11000	SF	$ 2	$ 21,340
220	REGRADE SITE	6000	SY	$ 3	$ 17,220
350	DEMOBILIZE EQUIPMENT,YARD & OFFICE	1	LS	$ 122,045	$ 122,045
400	CLOSURE REPORT	1	LS	$ 9,354	$ 9,354
				Grand Total:	**$ 1,628,265**

Notes:

1 Class 4 ROM Budget Estimate with expected accuracy price range -30%/+50% (AACE, 2005).

2 Estimate is intended for feasibility-level screening only and is NOT approved for construction.

3 Estimate includes a 10% adder for G&A and Overhead costs and a 15% Contingency.

4 This alternative does not require long-term operations & maintenance.

Alternate 4 - West Selenium - Pump and Treat
Tier II Source Control Evaluation

Capital Costs for Alternative 4

BidItem	Description	Quantity	Units	Unit Price	Total
10	BONDS & INSURANCE	1	LS	$ 65,544	$ 65,544
20	SUBMITTALS	1	LS	$ 30,211	$ 30,211
30	MOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 47,824	$ 47,824
40	INSTALL SWPP ELEMENTS	1	LS	$ 29,914	$ 29,914
50	INITIAL SURVEY & LAYOUT	1	LS	$ 13,860	$ 13,860
60	UTILITY LOCATE ALLOWANCE	1	LS	$ 6,300	$ 6,300
70	UTILITY REMOVE OR RELOCATE ALLOWANCE	1	LS	$ 8,400	$ 8,400
80	SET UP DECON STATION	1	LS	$ 18,622	$ 18,622
90	INSTALL SAFETY FENCE	4800	LF	$ 7	$ 33,600
100	GRADE EXTRACTION WELL SITE	1	LS	$ 4,394	$ 4,394
105	DRILL & INSTALL EXTRACTION WELLS 4"	3	EA	$ 23,827	$ 71,482
110	INSTALL PUMP , LEADER LINES&MANIFOLD	3	EA	$ 10,267	$ 30,801
115	INSTALL POWER TO PUMPING SYSTEM	1	LS	$ 25,200	$ 25,200
120	GRADE HDPE UG PIPELINE	3050	LF	$ 3	$ 10,065
125	EXCAVATE PIPELINE TO PLANT & OUTFALL	2350	CY	$ 13	$ 29,493
130	INSTALL PIPE & BACKFILL (EXCEPT PLANT AREA)	2350	LF	$ 37	$ 87,961
135	TEST PIPELINE	2350	LS	$ 2	$ 4,066
140	EXCAVATE FOR PLANT PIPING	915	CY	$ 34	$ 30,936
142	INSTALL PIPES AND VALVES AND BOXES	685	LF	$ 264	$ 181,066
145	TEST PLANT SYSTEM	1	LS	$ 3,711	$ 3,711
150	GRADE PONDS SITE	1	LS	$ 39,955	$ 39,955
155	CONSTRUCT BCR PONDS #1&#2	1	LS	$ 951,863	$ 951,863
160	CONSTRUCT AERATION CHANNELS	1	LS	$ 3,867	$ 3,867
165	CONSTRUCT OXIDATION PONDS #1&#2	1	LS	$ 15,158	$ 15,158
167	CONSTRUCT 50X50 METAL BUILDING	2	EA	$ 236,040	$ 472,080
170	POWER TO OXIDIZE BUILDINGS	1	LS	$ 21,000	$ 21,000
350	DEMOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 47,824	$ 47,824
400	CLOSURE REPORT	1	LS	$ 9,145	$ 9,145
				Grand Total:	**$ 2,294,341**

Long-Term Operation & Maintenance Costs for Alternative 4 *(broken into annual items and periodic over 30-year period)*

BidItem	Description	Quantity	Units	Unit Price	Total
	ANNUAL ELEMENTS				
10	ANNUAL ROUTINE LABOR (OPERATION&MAINTENANCE)	1	YR	$ 12,917	$ 12,917
20	ANNUAL MISCL EQUIPMENT & SUPPLIES	1	YR	$ 8,280	$ 8,280
30	ANNUAL PERMIT REQUIRED SAMPLING & DATA MANAGEMENT	1	YR	$ 15,235	$ 15,235
40	ANNUAL PERMIT REQUIRED LAB TESTING FEES	1	YR	$ 9,936	$ 9,936
45	ANNUAL ELECTRIC FEES TO OPERATE SYSTEM	1	YR	$ 11,320	$ 11,320
				ANNUAL SUBTOTAL:	**$ 57,688**
				30-YEAR PERIOD SUBTOTAL OF ANNUAL ITEMS:	**$ 1,730,644**
	PERIODIC ELEMENTS				
55	REPLACEMENT EXTRACTION WELL PMPS (YEARS 5, 10, 15, 20, and 25)	15	EA	$ 1,642	$ 24,633
56	SYSTEM MASTER PUMP-REPLACEMENT (YEAR 15)	3	EA	$ 3,505	$ 10,516
57	SERVICE EXTRACTION WELLS (YEAR 10 and 20)	6	EA	$ 524	$ 3,146
58	ASSUME REPLACE 1 EXTRACTION WELL (YEAR 15)	1	EA	$ 11,233	$ 11,233
60	REPLACE EACH OF BCR CELLS IN THE 30 YEAR SPAN (YEAR 15)	2	EA	$ 371,951	$ 743,902
65	DISPOSE OF SPENT MEDIA (YEAR 15)	1	LS	$ 720,064	$ 720,064
70	CLEANOUT SOLIDS IN OXIDATION PONDS (YEAR 15)	2	EA	$ 9,174	$ 18,347
				SUBTOTAL OF PERIODIC ELEMENTS OVER 30-YEAR PERIOD:	**$ 1,531,841**

Notes:

1 Class 4 ROM Budget Estimate with expected accuracy price range -30%/+50% (AACE, 2005).
2 Estimate is intended for feasibility-level screening only and is NOT approved for construction.
3 Estimate includes a 10% adder for G&A and Overhead costs and a 15% Contingency.

Alternate 5 - North Plant Area - Permeable Reactive Barrier (PRB)
Tier II Source Control Evaluation

Capital Costs for Alternative 5

BidItem	Description	Quantity	Units	Unit Price	Total
10	BONDS AND INSURANCE	1	LS	$ 269,720	$ 269,720
20	SUBMITTALS	1	LS	$ 22,620	$ 22,620
30	MOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 200,293	$ 200,293
40	INSTALLSWPPP ELEMENTS	1	LS	$ 5,613	$ 5,613
50	SURVEY & LAYOUT(THIRD PARTY SERVEYOR)	1	LS	$ 8,547	$ 8,547
60	UTILITY LOCATE(ALLOWANCE)	1	LS	$ 3,469	$ 3,469
70	UTILITY REMOVE OR RELOCATE (ALLOWANCE)	1	LS	$ 3,469	$ 3,469
80	SET UP DECON STATION	1	LS	$ 17,853	$ 17,853
90	INSTALL SAFETY FENCE	1600	LF	$ 7	$ 11,104
105	DUST CONTROL	1	LS	$ 9,635	$ 9,635
110	REMV SUB SURFACE DEBRIS & PREP WORK PLATFORM	1	LS	$ 9,122	$ 9,122
115	REHANDLE BOULDERS (ALLOWANCE)	12	HR	$ 2,872	$ 34,467
125	INSTALL FUNNEL WALLS	12500	VSF	$ 31	$ 381,625
130	EXCAVATE, INSTALL PRB MEDIA AND BACKFILL	5926	CY	$ 271	$ 1,603,398
135	PURCHASE ZVI (GRANULAR IRON)	5040	TN	$ 1,415	$ 7,133,162
140	INSTALL MONITORING WELL 2"	6	EA	$ 13,001	$ 78,009
210	RESTORE IM COVER	6700	SF	$ 2	$ 12,730
220	REGRADE SITE	1	LS	$ 4,172	$ 4,172
350	DEMOBILIZE EQUIPMENT,YARD&OFFICE	1	LS	$ 124,880	$ 124,880
400	CLOSURE REPORT	1	LS	$ 9,571	$ 9,571
				Grand Total:	**$ 9,943,458**

Long-Term Operation & Maintenance Costs for Alternative 5

BidItem	**Description**	**Quantity**	**Units**	**Unit Price**	**Total**
10	BONDS AND INSURANCE	1	LS	$ 256,272	$ 256,272
20	SUBMITTALS	1	LS	$ 22,651	$ 22,651
30	MOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 200,564	$ 200,564
40	INSTALLSWPPP ELEMENTS	1	LS	$ 5,621	$ 5,621
80	SET UP DECON STATION	1	LS	$ 17,877	$ 17,877
90	INSTALL SAFETY FENCE	1600	LF	$ 7	$ 11,120
105	DUST CONTROL	1	LS	$ 9,648	$ 9,648
130	EXCAVATE, INSTALL PRB MEDIA AND BACKFILL	5926	CY	$ 271	$ 1,605,590
135	PURCHASE ZVI (GRANULAR IRON)	5040	TN	$ 1,417	$ 7,142,839
145	OFFSITE RAILCAR HAUL AND DISPOSAL	5040	TON	$195	$ 982,800
210	RESTORE IM and ET COVER	4700	SF	$ 2	$ 8,930
350	DEMOBILIZE EQUIPMENT,YARD&OFFICE	1	LS	$ 125,049	$ 125,049
				Year 10 Replacement Costs - Total:	**$ 10,388,961**
				Year 20 Replacement Costs - Total:	**$ 10,388,961**
				GRAND TOTAL:	**$ 20,777,922**

Notes:

1 Class 4 ROM Budget Estimate with expected accuracy price range -30%/+50% (AACE, 2005).
2 Estimate is intended for feasibility-level screening only and is NOT approved for construction.
3 Estimate includes a 10% adder for G&A and Overhead costs and a 15% Contingency.

Alternate 6 - North Plant Area - Slurry Wall Enclosure

Tier II Source Control Evaluation

Capital Costs for Alternative 6

BidItem	Description	Quantity	Units	Unit Price	Total
10	BONDS & INSURANCE	1	LS	$ 55,588	$ 55,588
20	SUBMITTALS	1	LS	$ 42,988	$ 42,988
30	MOBILIZATION EQUIPMENT,YARD&OFFICE	1	LS	$ 305,817	$ 305,817
40	INSTALL SWPPP ELEMENTS	1	LS	$ 13,256	$ 13,256
50	SURVEY & LAYOUT(THIRD PARTY SERVEYOR)	1	LS	$ 14,763	$ 14,763
60	UTILITY LOCATE	1	LS	$ 4,067	$ 4,067
70	UTILITY REMOVE OR RELOCATE (ALLOWANCE)	1	LS	$ 6,778	$ 6,778
80	SET UP DECON STATION	1	LS	$ 20,195	$ 20,195
90	INSTALL SAFETY FENCE	2000	LF	$ 7	$ 13,560
105	DUST CONTROL	1	LS	$ 14,445	$ 14,445
110	REMV SUB SURFACE DEBRIS & PREP WORK PLATFORM	750	CY	$ 45	$ 33,420
115	REHANDLE BOULDERS (ALLOWANCE)	16	HR	$ 2,806	$ 44,899
125	INSTALL & CONSTRUCT SLURRY WALLS	78000	VSF	$ 16	$ 1,269,060
210	RESTORE IM COVER	4000	SF	$ 4	$ 16,960
220	REGRADE SITE	6800	SY	$ 4	$ 24,480
300	DEMOBILIZE EQUIPMENT,YARD&OFFICE	1	LS	$ 142,341	$ 142,341
400	CLOSURE REPORT	1	LS	$ 9,351	$ 9,351
				Grand Total:	**$ 2,031,968**

Notes:

1 Class 4 ROM Budget Estimate with expected accuracy price range -30%/+50% (AACE, 2005).

2 Estimate is intended for feasibility-level screening only and is NOT approved for construction.

3 Estimate includes a 10% adder for G&A and Overhead costs and a 15% Contingency.

4 This alternative does not require long-term operations and maintenance.

Alternate 7 - North Plant Area - Injection Wells & Injections of ZVI Nanoparticles (slurry)
Tier II Source Control Evaluation

Capital Costs for Alternative 7 *(drilling and installation of 5 injection wells)*

BidItem	Description	Quantity	Units	Unit Price	Total
10	BONDS & INSURANCE	1	LS	$ 2,800	$ 2,800
20	SUBMITTALS	1	LS	$ 5,717	$ 5,717
30	MOBILIZE EQUIPMENT	1	LS	$ 4,323	$ 4,323
40	INSTALL SWPP ELEMENTS	1	LS	$ 2,415	$ 2,415
50	INITIAL SURVEY & LAYOUT	1	LS	$ 1,232	$ 1,232
60	UTILITY LOCATE	1	LS	$ 1,400	$ 1,400
70	UTILITY REMOVE OR RELOCATE (ALLOWANCE)	1	LS	$ 1,400	$ 1,400
80	SET UP DECON STATION	1	LS	$ 1,378	$ 1,378
90	DRILL INJECTION WELLS	250	LF	$ 84	$ 21,000
95	INSTALL WELLS	5	EA	$ 8,896	$ 44,479
100	WELL DEVELOPMENT	5	EA	$ 1,008	$ 5,040
105	WELL PADS & BOLLARDS	5	EA	$ 1,708	$ 8,540
110	INSTALL MONITORING WELLS	4	EA	$ 7,350	$ 29,400
350	DEMOBILIZATION EQUIPMENT	1	LS	$ 2,613	$ 2,613
400	CLOSURE REPORT	1	LS	$ 4,305	$ 4,305
				Grand Total:	**$ 136,042**

Long-term Operations and Maintenance *(injection events)*

BidItem	Description	Quantity	Units	Unit Price	Total
15	BONDS & INSURANCE	1	LS	$ 1,600	$1,600
25	SUBMITTALS	1	LS	$ 4,700	$4,700
35	MOBILIZATION OF EQUIPMENT	1	LS	$ 7,500	$7,500
45	SETUP DECON STATION	1	LS	$ 1,378	$1,378
55	ONE INJECTION EVENT (labor and equipment for 5 wells)	100	HRS	$ 90	$9,000
65	INJECTION MEDIA/SLURRY (ZVI Nanoparticles with water)	1000	LBS	$ 40	$40,000
75	DEMOBILIZATION OF EQUIPMENT	1	LS	$ 3,500	$3,500
85	CLOSURE REPORT	1	LS	$4,000	$4,000
				First Injection Event (Q1 2016):	$82,430
				First Injection Event (Q2 2016):	$82,430
				First Injection Event (Q3 2016):	$82,430
				First Injection Event (Q4 2016):	$82,430
				Total of 4 Injection Events:	**$329,719**

Notes:

1 Total weight of ZVI applied (2 tons over four events) assumed to treat up to 25-50% of water within slurry wall down to maximum contaminant level; additional injections likely needed depending on effectiveness from initial four injections.
2 Class 4 ROM Budget Estimate with expected accuracy price range -30%/+50% (AACE, 2005).
3 Estimate is intended for feasibility-level screening only and is NOT approved for construction.
4 Estimate includes a 10% adder for G&A and Overhead costs and a 15% Contingency.