Focused Feasibility Study
Schwerin Concaves
Walla Walla, Washington

Prepared for
Washington State
Department of Ecology

June 27, 2008
17330-10

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SCHWERIN CONCAVES
WALLA WALLA, WASHINGTON

1.0 SUMMARY

This report was prepared by Hart Crowser for the Washington State Department of Ecology (Ecology) and presents the Focused Feasibility Study (FFS) and engineering evaluation. In the report Hart Crowser assesses remedial alternatives for contaminated soil and groundwater at the former Schwerin Concaves Site (Site) near Walla Walla, Washington (Figure 1). Based on a review of historical uses, Site data, and *in situ* reductive bioremediation pilot test results, this FFS presents an evaluation of site-specific remedial alternatives.

Results from previous work at the Site have demonstrated that elevated hexavalent chromium (chromium VI) concentrations, associated with the former chromium plating operation business, are present in Site soil and groundwater above applicable risk-based concentrations.

During an interim action, Ecology excavated and disposed of the most contaminated soils in two known source areas at the Site. Groundwater monitoring indicated a general decrease in groundwater contamination, but results showed additional work was needed. Therefore, a reductive bioremediation pilot test was conducted during 2006 and 2007 to evaluate the feasibility of biologically converting chromium VI to trivalent chromium (chromium III) *in situ* through groundwater recirculation. Study results were submitted to Ecology in "Remedial Pilot Study Data Summary Report for Schwerin Concaves" and concluded that the appropriate microbes were present on the Site to biologically transform chromium VI to chromium lll.

Risk-based screening of existing soil and groundwater data was conducted to identify contaminants of concern (COCs) at the Site. Human and ecological exposure pathways were identified. During and following the conclusion of the pilot test, chromium VI, chromium III, arsenic, cadmium, iron, lead, zinc, nitrate, and sulfate were identified in Site groundwater at concentrations that exceed cleanup levels (CULs) in one or more wells. CULs are determined by the Washington Model Toxics Control Act (MTCA) Method B screening levels or federal and state maximum contaminant Level (MCL) values. Chromium VI, chromium III, total arsenic, cadmium, lead, and zinc CULs were determined through site-specific screening under Method B. Total iron, sulfate, and nitrate were screened against federal MCLs. CULs were used to quantify the minimum effectiveness for each alternative and not necessarily represent the final site CUL.

2.0 INTRODUCTION

This section briefly summarizes the project scope, and Site location, description, and history. The Schwerin Concaves Remedial Investigation Report (dated November 2005), prepared by Ecology, contains additional descriptions of the project Site and history, and the results of initial Site investigations. A reductive bioremediation pilot study was conducted at the Site from November 2006 through May 2007. Results from the Interim Remedial Action Measure (IRAM) pilot study are summarized in Hart Crowser's Remedial Pilot Study Data Summary Report, dated September 14, 2007. Based on the pilot study results, Hart Crowser prepared a Work Plan for a FFS (dated November 14, 2007) to provide a framework for evaluating potential remedial actions.

2.1 Purpose and Scope of Work

This FFS was prepared to identify alternatives for addressing soil and groundwater contamination at the former Schwerin Site. The scope of work includes preparing a focused evaluation of remedial technology alternatives and providing a recommendation to accelerate Site-wide plume remediation. Specific tasks associated with this work include:

- Describing each alternative and subparts including equipment, infrastructure, and implementation details;
- Evaluating protectiveness, long-term effectiveness, long-term reliability, implementability, implementation risk, and cost-effectiveness;
- Conducting rough cost comparison analysis for alternative and respective subparts; and
- Ranking alternatives according to evaluation criteria to identify the preferred alternative.

These activities are discussed in further detail within this report. This Focused Feasibility Study was prepared for Ecology under Task 8 of Work Assignment No. HART001, Amendment #2.

2.2 Site Location and Description

The Schwerin Concaves Site (Site) is located about 4 miles north of Highway 12 on Sapolil Road in Walla Walla County, Washington. The property is located in Section 31, Township 8 North, Range 37 East, Willamette Meridian at 46° 04′ 08″ north latitude and 118° 21′ 20″ west longitude, and is situated on a farm within a rural area (Figure 1). Topographic map coverage of the Site and vicinity is provided by the Buroker Quadrangle, U.S. Geological Survey, 7.5 minute series dated 1966. The Site elevation is about 1220 feet above sea level using the National Geodetic Vertical Datum (NGVD) of 1929.

The Site is located along the north bank of Dry Creek, which is a tributary to the Walla Walla River. The immediate vicinity is rural and sparsely populated. Agricultural fields bound the Site on the north and east, Dry Creek to the south, and a residence and garage to the west. The Site is relatively flat with the topographic relief provided by the stream channel to the south, and a downhill slope to the north of the Site. The topographic gradient is 1 percent or less from east to west across the Site and is approximately 1220 feet above mean sea level (Figure 2). The surface slopes gently down from north to south and generally drains toward Dry Creek. The property is unpaved and surface water will pond in some areas.

The main plating operation was housed in one large building and six auxiliary buildings that were used to store products and waste. A storage tank housed inside a subterranean covered shed was located to the north of the plating shop. The auxiliary buildings include an office/maintenance shop, former self-propelled shed, long farm shed, two smaller storage sheds, and barn. A residence and garage are located west of the long farm shed and were not associated with plating operations (Figure 2).

2.3 Previous Investigations

Ecology's Hazardous Waste Toxics Reduction Program conducted several compliance visits. During the visits, several hazardous waste management violations were observed. These violations included improper treatment of sludge and wastewater, chemical and sludge storage, and disposal practices. These practices resulted in contamination of the Site. The Site was placed on the Washington State Hazardous Sites List in August 2000 (Ecology 2005).

November 2000. Ecology conducted an initial remedial investigation in November 2000 (Ecology 2005). The investigation included the installation and sampling of four monitoring wells. The investigation confirmed the presence of chromium VI in soil and groundwater. Additional monitoring wells were installed in 2001 to evaluate the extent of groundwater contamination.

December 2002. In December 2002, an interim remedial action was performed. Approximately 892 tons of dangerous waste soil were removed from along the north side of the Plating Shop area (Ecology 2005). Approximately 750 tons of dangerous waste soil and an additional 1,200 tons of contaminated non-dangerous waste soil were removed from the self-propelled shed area.

2.4 Geology and Hydrogeology

Geology. Based on observations from previous environmental activities and our pilot study activities, soils beneath the study area consist of light brown, dry, stiff, sandy Silt. An ash layer was encountered in one boring at depths from about 11 to 13 feet below ground surface (Figure 3). The sandy Silt overlies sandy gravel with silt or gravelly sand. The contact of the two soil layers varies from a depth of 12 feet in monitoring wells MW-4 and MW-5 (Figure 4) to over 20 feet in monitoring wells MW-7, MW-8, MW-9, MW-10, and MW-11 (Figures 4 and 5). The gravel becomes sandier and less silty as the depth increases. The Site geology appears to correspond with the regional geology since the upper soil profile appears similar to loess of the Palouse Formation and the gravelly zone correlates to the "old gravel."

Bedrock was encountered in five of the nine monitoring well borings. The surface of the basalt bedrock was encountered at depths of 35 to 39 feet and was closer to surface in wells MW-4 and MW-5, which are closest in proximity to Dry Creek. Based on the drilling, the basalt appears to form a relatively flat surface that gently dips down away from Dry Creek.

Three cross sections were previously prepared to characterize the subsurface geology and hydrogeology at the Site. These cross sections were updated as part of the Site characterization activities conducted in October 2006. The cross section locations are shown on Figure 2. Updated cross sections are shown on Figures 3, 4, and 5.

Hydrogeology. Groundwater occurrences in the Walla Walla Basin are developed in basalt bedrock, the "Old Gravels," and the recent alluvium overlying the "old gravels," which includes loess soil and glaciofluvial sands and gravels. The majority of groundwater is used for irrigation with the remainder used for domestic and industrial purposes.

The Site hydrogeology is based on the monitoring wells that have been installed at the Site. Groundwater was encountered at varying depths based on the proximity to Dry Creek and the occurrence of bedrock. Groundwater occurs in brown, gravelly sand or sandy gravel with silt.

2.5 Overview of Chromium VI Reductive Bioremediation

Numerous metals present in the subsurface can act as electron acceptors or electron donors for a variety of microbes. Based on groundwater chemistry and available nutrients, microbes will move electrons to yield energy for growth and reproduction. One measure that determines whether a given process will be energetically favorable for a microbe is called the oxidation reduction potential (ORP). When any atom or molecule receives electrons, it is reduced. When the atom or molecule gives up electrons, it is oxidized. Based on a metal's starting oxidation state, ORP provides a general idea as to whether the metal is likely to be oxidized or reduced by microbes. Metals such as iron and manganese can constantly change oxidation states depending on groundwater conditions and available nutrients.

Chromium VI is a highly oxidized metal. Unlike iron or manganese, once chromium VI has been reduced to chromium III, it is very unlikely that it will be re-oxidized to the hexavalent form under natural conditions. Many anaerobic bacterial species are identified as having the direct ability to reduce chromium VI to chromium III for energetic gain. Additional bacteria, such as sulfate- and iron-reducers, reduce chromium VI to chromium III through abiotic (non-biological) reactions via their metabolic byproducts, including hydrogen sulfide and ferrous iron (Arias and Tebo 2003). Once in the reduced (chromium III) state, chromium will form a variety of compounds including chromium hydroxide [$Cr(OH)_3$] and chromium sulfide (Cr_2S_3). Additional compounds can be formed if chromium associates with minerals in soil [e.g. $KCr(SO_4)_2$ and $FeCr_2O_4$] (Zayed and Terry 2003). Under typical aquifer conditions, these compounds have very low solubility and are very stable.

Each atom of chromium VI requires three electrons to reduce it to chromium III. These electrons can be from non-biological or biological origins. Non-biological (abiotic) reduction can be achieved by applying electron-rich molecules such as hydrogen sulfide or ferrous iron. Because chromium VI is highly oxidized, it can physically strip electrons from these molecules to reduce down to chromium III. The reaction also results in the oxidation of hydrogen sulfide and ferrous iron. Biological reduction occurs when electrons are enzymatically added to chromium VI to yield energy for the microbe. Biological reduction can be stimulated by adding electron-rich organic compounds, such as carbohydrates, organic acids, or other fermentable substrates.

2.6 Previous Bioremediation Pilot Study

As discussed in Remedial Pilot Study Data Summary Report (dated September 14, 2007), remedial pilot study activities were completed from October 2006 through

June 2007. The activities included installing, operating, and monitoring an *in situ* groundwater recirculation pilot system to determine the effectiveness in treating the remaining chromium VI in the soil and groundwater. The groundwater recirculation pilot system began operating in November 2006 and operated through May 2007. Groundwater recovered from downgradient extraction wells (MW-10 and MW-11) was amended with dextrose/nutrient mixture before being re-injected in upgradient wells MW-9 and MW-13. The dextrose/nutrient injection and poor groundwater circulation at the Site resulted in a biomass buildup that clogged the well screen at MW-9. Injections at MW-13 kept up with extractions rates, but the poor groundwater circulation at the Site prevented an anaerobic environment from being achieved in most wells, except the injection wells. The limited anaerobic environment was verified by the lack of reduction in nitrate and sulfate concentrations, and the limited reduction in ORP and dissolved oxygen data collected in the field. Chromium VI concentrations decreased an order of magnitude in injection wells MW-9 and MW-13 from 0.116 to 0.012 mg/L and 0.02 to less than 0.005 mg/L, respectively. Chromium VI concentrations decreased slightly in nearby monitoring wells MW-1 and MW-6. Total and chromium VI concentrations in the remaining Site wells remained unchanged through the reporting period (June 2007).

Following completion of the recirculation pilot study, periodic slug injections of dextrose/nutrient were performed in Site wells to confirm that native microbes could successfully reduce chromium VI to chromium III. The system extraction and injection rates of less than 1 gallon per minute (gpm) limited the amount of water that could be recirculated through the subsurface between the extraction and injection wells required to deliver the dextrose throughout the site. To aid in the distribution of dextrose over a larger area, slug injections were performed during June, July, and December 2007. August 2007 analytical results from slug injected wells MW-2, MW-6, MW-7, MW-9, MW-11, and MW-13 showed substantial reductions in chromium VI concentrations. The wells sampled, except MW-7, were non-detect for chromium VI. In MW-7, concentrations of chromium VI declined from 77.5 mg/L during June 2007 to 19.2 mg/L during August 2007. However, due to several sample quality control issues, the chromium VI analytical results may not be accurate. Declines in nitrate and sulfate concentrations (other electron acceptors) suggest substantial reductions of chromium VI in the vicinity wells MW-2, MW-6, MW-9, and MW-13. The pilot study and slug-injections confirmed that microbes could be stimulated to reduce chromium VI to chromium III.

As a result of stimulating reductive processes at the Site, arsenic was sporadically detected in the pilot study area. Under oxidative aquifer conditions, pentavalent arsenic (arsenic V) readily forms insoluble salts. However, under reductive conditions, arsenic is reduced to trivalent arsenic (arsenic III) and becomes mobile. This arsenic III mobility can be limited by reaction with sulfide to form insoluble arsenic sulfide (Lloyd 2003). The sulfide required for this reaction can be either directly added to the aquifer through injection or generated *in situ* through the biological reduction of natural sulfate.

3.0 CONCEPTUAL SITE MODEL

Based on the data gathered from the previous work at the Site, a Conceptual Site Model (CSM) has been developed. The CSM includes identifying Site sources, exposure pathways, and potential receptors. Figure 6 presents the CSM for this Site. A discussion of each of the CSM elements is presented below, followed by an evaluation of the risks the Site poses to human health and the environment.

3.1 Sources

Releases related to the chromium plating operations conducted from the late 1970s through 2000 resulted in chromium VI concentrations that pose an environmental risk above ground, in soil, and in groundwater. The plating operation was housed mainly in one large building with five auxiliary buildings that were used to store products and waste. A storage tank housed inside a subterranean covered shed was located to the north of the plating shop. The auxiliary buildings included an office/maintenance shop, self-propelled shed, long farm shed, a storage shed, and barn.

The process of chromium plating combine concaves was conducted in three main areas: the cleaning station, plating station, and the wastewater treatment station. Following chromium plating, chromium VI in the wastewater was chemically converted to chromium III using ferrous sulfate and then precipitated with hydroxide. Prior to 1988, wastewater was then transferred to the 10,000-gallon subterranean storage tank north of the plating shop where solids were allowed to settle. This treated wastewater was periodically pumped to an unlined settling pond in the self-propelled shed. After 1998, treated wastewater was periodically transported and disposed of into the Walla Walla wastewater treatment system. The remaining sludge precipitate was stripped of moisture and disposed of as hazardous waste in an Arlington, Oregon, facility.

3.2 Exposure Pathways

Various potential exposure pathways have been identified at the Site. The potential pathways include:

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3.2 Exposure Pathways

Various potential exposure pathways have been identified at the Site. The potential pathways include:

- Residual above-ground contamination inside the building and stored in waste containers that is ingested, inhaled, or directly contacted;

- Soil contamination that is ingested, inhaled, or directly contacted;

- Soil contamination leaching to groundwater, where it is ingested;

- Groundwater contamination that is ingested or leads to an exposure through use;

- Groundwater or soil contamination migrating to surface waters or sediment creating an ecological exposure; and

- Contact with contaminated soil and groundwater by excavation workers.

We evaluated each of these pathways with our results summarized below. A summary of the most probable exposure pathways is shown on Figure 6. Given the current Site conditions, exposures assume that the Site will remain an agricultural property through the duration of the remedy.

Residual Contamination Contact, Inhalation, or Ingestion. Visual inspection of relevant structures on the Site suggests the presence of significant residual chromium VI contamination. As chromium VI has a distinctive yellow discoloration, residual surface contamination is noted on walls, floors, and several different containers in the plating shop and soils at the Site. In addition to surface contamination, discoloration is also noted to have penetrated into cinder block walls in the former plating shop. These pathways present a high risk for direct contact, inhalation, or ingestion. This contamination also poses a risk for on-going impacts to surface soils, and potentially into groundwater and surface water. Extensive decontamination or building demolition could mitigate this ongoing risk.

Direct Contact, Inhalation, or Ingestion. Contaminated surface soils around the former plating shop and near the former mobile shed were removed during previous interim actions and have eliminated this exposure pathway. However, the former plating shop has several open-top containers that contain what appears to be waste chromium from historical activities at the Site, as well as other apparent waste chromium on the floor. Exposure pathways that continue to pose a risk to human and ecological receptors include direct contact, inhalation, and ingestion.

Leaching from Soil to Groundwater. Based on elevated concentrations near known chromium wastewater holding and surface disposal areas, significant residual contamination is evident. Bioremediation pilot testing resulted in significant increases in groundwater concentrations of total dissolved chromium as residual chromium VI was biologically reduced in groundwater. This suggests that significant mass of chromium VI is likely adsorbed to the soil matrix. Subsequent declines in total dissolved chromium suggest that the Site soil can provide a suitable matrix to immobilize residual chromium contamination. Infiltration of precipitation may also provide an on-going source of vadose zone soil contamination leaching to groundwater.

Groundwater Use. This pathway consists of pumping groundwater to the surface where it may be used for domestic purposes. Several uses have been identified within the well-search area, including drinking water, irrigation, and recreation. In addition to one on-site well, eight other domestic wells are actively used within a 1-mile radius. However, due to low productivity of the shallow alluvium aquifer at the Site, there is no apparent domestic use of this shallow aquifer. Sampling of these nearby wells also confirmed that no contamination has migrated from the Site to these domestic wells.

Migration to Surface Water or Sediment. Dry Creek, located south of the Site, is a potential receptor for contaminant migration to surface water. Due to surface contamination and lower elevations toward the creek, heavy precipitation events may result in contaminant runoff to surface water and sediments. However, groundwater migration to surface water is not likely due to generally northwest to northeast gradients (away from the creek) and groundwater depths around 15 to 20 feet below ground surface near the creek.

3.3 Receptors

Potential receptors to chemical contamination include both human and ecological receptors. This section identifies the potential receptors within the study area. Figure 6 shows the identified receptors.

Human Receptors. The current and reasonably likely future beneficial uses in the vicinity of the Site are residential and agricultural. As such, current and future exposure pathways include inhalation, direct contact, and ingestion. Inhalation exposure could result from chromium-laden dust and soil. Direct contact is possible due to the prevalence of residual chromium at ground surface, exposure during soil excavation work, and contact with impacted groundwater. Ingestion exposure could result from drinking of groundwater, irrigation (ingestion of impacted food), or unintentional consumption of impacted soil.

Ecological Receptors. Due to surface chromium contamination within the plating building and surface soils, chromium contamination presents an ongoing risk to area ecological receptors. Subsurface chromium contamination poses little risk as contaminated groundwater has not been shown to discharge to Dry Creek.

3.4 Identification of Chemicals of Potential Concern

Guidance for CUL determination is established under Chapter 173-340 WAC, the MTCA. Under this authority, Ecology may enforce conservative Method A or site-specific Method B CULs when multiple contaminants and media are present. We assessed chemical data from the Site based on these CULs to identify COCs to receptors via potentially complete exposure pathways. The applicable soil and groundwater CULs for the Site are presented in Table 1.

COCs Identified in Soil. During remedial investigations conducted from 2000 through 2002, chromium VI and chromium III in site soil were identified at concentrations exceeding Method B unrestricted soil cleanup levels. Following the interim actions (soil removal), verification samples of excavated areas indicated that contamination was removed to below the CULs.

COCs Identified in Groundwater. Remedial investigation groundwater data exceeded CULs for chromium VI, total chromium, arsenic, and lead. With the completion of additional groundwater monitoring wells, sampling was expanded during 2006 and 2007. As presented in Table 2, groundwater samples collected during 2006 and 2007 contained concentrations above applicable CULs for chromium VI, chromium III, arsenic, cadmium, iron, lead, zinc, nitrate, and sulfate on at least one occasion. Of these COCs, only chromium VI and nitrate have exceeded CULs in more than one well and during more than one sample event from November 2006 through August 2007. Field parameters collected during the sampling events are presented in Table 3.

4.0 FEASIBILITY STUDY OBJECTIVES AND EVALUATION CRITERIA

4.1 Feasibility Study Objectives

The FFS objective is to evaluate cleanup alternatives that protect human health and the environment by reducing human and ecological exposure to Site contamination. For the purpose of this assessment, these levels shall be presumed to be the CULs indicated in Table 1.

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4.2 Evaluation Criteria

To select the most appropriate cleanup action for the Schwerin site, we evaluated the feasibility of each alternative by balancing remedy selection factors, in accordance with WAC 173-340-360. These factors are as follows:

- **Protectiveness.** Overall protectiveness of human health and the environment, and improvement of the overall environmental quality;
- **Permanence.** Reliability of cleanup action to permanently reduce the toxicity, mobility, or volume of hazardous substances;
- **Cost.** Including implementation costs, all operation and maintenance costs, and net present value of the cleanup action;
- **Effectiveness Over the Long Term.** Ability and reliability of the alternative to limit risk during the period of time hazardous substances are expected to remain on site at concentrations that exceed cleanup levels;
- **Management of Short-Term Risk.** Potential impacts to workers, the community, and the environment during implementation;
- **Technical and Administrative Implementability.** Ease or difficulty of implementing the cleanup action, considering technical, mechanical, and regulatory requirements; and
- **Consideration of Public Concerns**. Whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns.

5.0 EXTENT OF CONTAMINATION

Several heavy metals have been detected at concentrations above their respective CULs in both soil and groundwater at the Site. Table 1 summarizes the CULs for soil and groundwater, and Table 2 compares the groundwater analytical results with the CULs. Due to changes resulting from the November 2006 through May 2007 bioremediation pilot study and the age of available soil data, only recent groundwater data were used in this assessment.

Chromium VI, chromium III, arsenic, cadmium, iron, lead, zinc, nitrate, and sulfate have been detected in groundwater at concentrations that exceed CULs. Chromium VI has been repeatedly detected above its MTCA CUL in nearly

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Chromium VI, chromium III, arsenic, cadmium, iron, lead, zinc, nitrate, and sulfate have been detected in groundwater at concentrations that exceed CULs. Chromium VI has been repeatedly detected above its MTCA CUL in nearly every well on the Site. Arsenic, cadmium, and lead have only periodically been detected above their respective MTCA CULs. Iron and nitrate are detected above CULs in the majority of samples collected, and zinc and sulfate have only been detected once above their respective CULs.

Hexavalent Chromium. The highest concentrations of chromium VI were detected on the north side of the plating building and in the vicinity of the former self-propelled shed. Concentrations decline downgradient from these two locations. During 2006 and 2007, MW-7 and MW-4 contained up to 77.5 and 12.6 mg/L of chromium VI, respectively. Downgradient of MW-7, monitoring wells MW-11 and MW-12 contained up to 11.2 and 15.6 mg/L of chromium VI, respectively. Only MW-5, located between Dry Creek and the former self-propelled shed, remained below CULs during 2006 and 2007.

Figure 7 shows a rough approximation of the chromium VI plume. By using MW-3 to define the western extent of the plume and MW-1 as an approximate eastern extent of the plume, the likely impacted area between MW-8 (south) and the property line to the north constitutes approximately 140,000 square feet (3.2 acres).

Arsenic and Cadmium. In Site shallow groundwater, arsenic and cadmium have been detected at concentrations as high as 0.115 and 0.770 mg/L, respectively. These two maximums both occurred in MW-11 while it was operating as an extraction well during the bioremediation pilot test. Given the historical pattern of detections, a north-south aligned plume of contamination is estimated to contain arsenic and cadmium at concentrations above their respective CULs (Figure 7). This plume extends from approximately 50 feet south of MW-9, under the former plating shop, and up to MW-11. Based on this approximation, this plume is estimated to be 20,800 square feet.

Lead. The estimated extent of lead contamination above the Method A CUL is fairly small and based on exceedances in the vicinity of the former self-propelled shed (MW-4) and groundwater detections extending roughly northeast toward MW-7. This plume is estimated to be 3,200 square feet.

Other COCs. Due to sporadic detections of other COCs or the absence of defined source areas, we were not able to estimate the areas impacted by iron, zinc, nitrate, and sulfate. Iron and sulfate were both used in the hexavalent wastewater treatment process. The zinc is likely related to plating process along with the chromium VI. Although no known source was identified, it is likely the nitrates are related to the agricultural activities in the area.

6.0 REMEDIATION TECHNOLOGIES AND PRELIMINARY SCREENING

To focus the feasibility study, preliminary screening was based primarily on most likely exposure pathways, receptors, and the *in situ* pilot study results. The pilot study confirmed the biological reduction of chromium VI to chromium III can be effective at the Site, but the Site conditions limited the effectiveness of the groundwater recirculation system, and this approach was removed from further consideration. Based on this information and discussions with Ecology, the following alternatives were selected for evaluation:

- Alternative 1 – Aggressive *In Situ* Soil and Groundwater Treatment and Monitoring;
- Alternative 2 – Limited *In Situ* Soil and Groundwater Treatment and Monitoring;
- Alternative 3 – Limited Source Area Soil Removal and *In Situ* Source Area Treatment and Monitoring;
- Alternative 4 – Source Area Soil Removal and Monitoring; and
- Alternative 5– Building Decontamination, Demolition, and Monitoring.

7.0 DETAILED ANALYSIS OF REMEDY ALTERNATIVES

We completed a detailed evaluation against the remedy selection using the evaluation criteria discussed in Section 4.2 and balancing the factors for each of the interim removal alternatives retained for detailed evaluation. This was followed by a comparative evaluation of alternatives (Section 8.0) of each remedy, relative to each other. Each of the seven evaluation criteria are broken down further into subcategories and ranked accordingly. The alternative ranking evaluation results are presented in Table 8. This detailed analysis serves as the basis for the recommending Alternative 2 - Limited *In Situ* Soil and Groundwater Treatment and Monitoring as the preferred alternative.

The following five remedy alternatives were evaluated for the Site and are presented in descending order with respect to relative degree of long-term effectiveness:

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To focus the feasibility study, preliminary screening was based primarily on most likely exposure pathways, receptors, and the *in situ* pilot study results. The pilot study confirmed the biological reduction of chromium VI to chromium III can be effective at the Site, but the Site conditions limited the effectiveness of the groundwater recirculation system, and this approach was removed from further consideration. Based on this information and discussions with Ecology, the following alternatives were selected for evaluation:

- Alternative 1 – Aggressive *In Situ* Soil and Groundwater Treatment and Monitoring;
- Alternative 2 – Limited *In Situ* Soil and Groundwater Treatment and Monitoring;
- Alternative 3 – Limited Source Area Soil Removal and *In Situ* Source Area Treatment and Monitoring;
- Alternative 4 – Source Area Soil Removal and Monitoring; and
- Alternative 5– Building Decontamination, Demolition, and Monitoring.

7.0 DETAILED ANALYSIS OF REMEDY ALTERNATIVES

We completed a detailed evaluation against the remedy selection using the evaluation criteria discussed in Section 4.2 and balancing the factors for each of the interim removal alternatives retained for detailed evaluation. This was followed by a comparative evaluation of alternatives (Section 8.0) of each remedy, relative to each other. Each of the seven evaluation criteria are broken down further into subcategories and ranked accordingly. The alternative ranking evaluation results are presented in Table 8. This detailed analysis serves as the basis for the recommending Alternative 2 - Limited *In Situ* Soil and Groundwater Treatment and Monitoring as the preferred alternative.

The following five remedy alternatives were evaluated for the Site and are presented in descending order with respect to relative degree of long-term effectiveness:

- Alternative 1 – Aggressive *In Situ* Soil and Groundwater Treatment and Monitoring
  - Decontamination and/or demolition of former plating building;
  - *In situ* slug injections of EHC® at selected locations;
  - Groundwater monitoring; and
  - Institutional controls.

- Alternative 2 – Limited *In Situ* Soil and Groundwater Treatment and Monitoring
  - Decontamination and/or demolition of the former plating building;
  - *In situ* slug injections of emulsified oil at selected locations;
  - Groundwater monitoring; and
  - Institutional controls.

- Alternative 3 – Limited Source Area Soil Removal and *In Situ* Source Area Treatment and Monitoring

  - Decontamination and demolition of the former plating building;
  - Removal of a limited amount of source area soils;
  - *In situ* groundwater recirculation treatment of remaining source area;
  - Groundwater monitoring; and
  - Institutional controls.

- Alternative 4 – Source Area Soil Removal and Monitoring
  - Decontamination and/or demolition of the former plating building;
  - Removal of source area soils;
  - Groundwater monitoring; and
  - Institutional controls.

- Alternative 5 – Building Decontamination, Demolition, and Monitoring
  - Decontamination and/or demolition of the former plating building;
  - Groundwater monitoring; and
  - Institutional controls.

Each of the above alternatives should also include characterization and disposal of waste currently on the Site. This will eliminate the direct human and ecological exposure, and reduce the potential for additional soil, groundwater, and surface water contamination.

We completed a detailed evaluation against the remedy selection protectiveness criteria and the balancing factors for each of the removal alternatives. Balancing factors for bioremediation approaches include calculations of hydrogen equivalents required to reduce COCs and the unit cost of using each donor to address these demands (Tables 4 and 5). This evaluation is summarized in the following paragraphs.

7.1 Aggressive In Situ Soil and Groundwater Treatment and Monitoring

A groundwater recirculation system was originally proposed as part of this alternative. However, the pilot study results identified the limited conductivity at the Site would make this approach unreliable. Based on the limited effectiveness of the groundwater recirculation system during the pilot study and travel distance across the Site, this approach will not be considered further.

Description. This alternative would employ a combination of Plating Shop decontamination and/or demolition, and aggressive electron donor amendment slug injections to biologically remediate contaminated groundwater across much of the Site. This aggressive remedial approach would also target contamination present from Dry Creek to the northern extent along MW-10/MW-12.

Following decontamination and/or demolition, the second phase of this alternative would be slug injections of low-mobility EHC® placed around the former Plating Shop and the former self-propelled shed source areas, as shown on Figure 10. Additional slug injections would be used to install a permeable reactive barrier approximately 50 feet south of the MW-10/MW-12 alignment as an additional treatment contingency. Amendment calculations are presented in Table 7.

Institutional controls would also likely be necessary to restrict access and use of contaminated soils and groundwater at the Site. This approach assumes that a risk assessment will be performed after the 15 years of monitoring, and that additional monitoring may or may not be required. Costs for annual groundwater monitoring are included for 15 years.

Protectiveness. This alternative would provide a high degree of protection to potential receptors. The combination of reducing surface contamination, slug injections throughout a majority of chromium plume, focused treatment of source area groundwater and soil, and installation of a permeable reactive barrier for water quality polishing would largely address COCs and elements of concern at the Site. On-going monitoring would help ensure that groundwater concentrations remain protective of potential receptors. Institutional controls would help reduce potential on-site worker and residential exposure to impacted vadose zone soils.

Permanence. It is anticipated that this alternative would reliably address the primary risks associated with the surface, soil, and groundwater contamination.

Due to subsurface variability, the potential exists for pockets of residual contamination to remain after 3 to 5 years of aggressive treatment. By enhancing treatment of high-mass areas, any remaining mass within the saturated interval is not anticipated to result in adverse risk to potential receptors. This alternative does not fully address residual surface and soil contamination outside of target treatment zones, so development restrictions would need to remain in place.

Cost. The costs for this alternative include costs for the decontamination and demolition, EHC® product, push probes, and engineering oversight. This alternative is the most costly, due to the higher cost of the electron donor (EHC®), and the number of probes required to deliver the product. This approach is the most effective in removing a bulk of the contamination in source area soils, groundwater, and to a lesser extent the vadose zone. Due to the number of locations, a more complete contact with the contaminants throughout the plume and along the perimeter would be expected with this alternative. Site monitoring will consist of quarterly groundwater sampling and analysis for the first 5 years, and annual groundwater monitoring for Years 6 through 10. With the treatment of 128,000 tons of contaminated soil by this alternative ($680,400), the total cost per ton of treatment for this approach is approximately $5.32 per ton. These costs include only the contaminated soil volumes treated and do not include the building demolition or ongoing monitoring costs.

Effectiveness Over the Long Term. This aggressive alternative would largely address the primary risks to human health and the environment at the Site soon after implementation. Removing surface contamination and saturating a majority of the groundwater plume would quickly control the risk to potential receptors. Over time, site-wide compliance with CULs is possible while reducing the chance for rebound. Compliance with groundwater CULs may be met within 3 to 5 years of implementation. This is the only alternative that could potentially be effective for addressing mass north of the MW-10/MW-12 well alignment.

Management of Short-Term Risk. Risks that may be realized during implementation of this alternative include the Plating Shop decontamination risks, construction hazards associated with push probes, and the risk of temporarily mobilizing arsenic, cadmium, and lead by stimulating reductive processes that increase solubility of these metals. In addition to mobilizing heavy metals, biological methylation of arsenic, cadmium, and lead metal in highly reductive environments could potentially present significant toxicity risks due to increased volatility and toxicity of these compounds (Turpenen 2002). By shifting the on-site reductive conditions, there is a small risk of mobilizing downgradient, off-site portions of the plume by decreasing affinity of chromium VI for clay particles and other oxidized minerals.

A risk to surface receptors is also posed by storing and injecting large volumes of EHC®. Injection equipment failure or excessive injection rates may also result in contaminated groundwater surfacing to Dry Creek. There is also the risk of increased contaminant migration toward the operating on-site extraction well proposed for use during injection due to heavy use and alteration of natural gradients. These risks could be controlled by reducing injection rates or spacing injection sequences over time.

Technical and Administrative Implementability. In addition to the three factors that could affect push probe implementation (refusal, surface obstacles, and water supply), subsurface lithologic variability may impact installation and performance. This alternative assumes the building demolition would be completed and access under the existing slab is no longer an issue.

Consideration of Public Concerns. The public concerns for construction activities will be limited to the immediately adjacent properties. Drilling activities required for the injection points will create a local noise on the Site for several weeks. The other public risk related to the EHC injections is the potential for over-injection that would result in a release into the surface water of Dry Creek. Safety measures will be taken during the injections to prevent this from occurring.

Approximately 15 to 25 truck loads of demolition debris would also be removed from the Site for off-site disposal. The volume of construction debris (less than 15 truck loads) for disposal of non-hazardous materials in a local landfill should be a small enough volume that would not pose a public concern. We are not aware of any other public concerns with this alternative at this time.

7.2 Limited In Situ Soil and Groundwater Treatment and Monitoring

Description. This alternative includes the Plating Shop decontamination and demolition. This alternative would also introduce electron donor through slug injections to convert the bulk of carcinogenic chromium VI to non-carcinogenic chromium III, and groundwater monitoring for 10 years. This approach assumes that a risk assessment will be performed after the 10 years of monitoring, and that additional monitoring may or may not be required. Slug injections would be performed in several stages and custom-tailored to address the approximate contaminant mass in each area of the Site. The goal of the injections would be to reduce the COC concentrations to achieve CULs for most areas south of the MW-10/MW-12 well alignment.

For this alternative, we evaluated two long-lasting (i.e., up to 5 years) amendments. These include the Remediation and Natural Attenuation product Newman Zone®, which is comprised of emulsified soybean oil and sodium lactate, and Adventus' EHC® product, which is comprised of processed cellulose and zero-valent iron. We understand Ecology has adopted new laws regulating the release of bio oils and special considerations will be required to use the emulsified soybean oil. For the purposes of the FFS, we are assuming that Ecology would provide a waiver for this product's use at a site containing contaminants that potentially threaten human health or the environment. The proposed treatment regiments are presented on Figures 8 and 9, and volume calculations and estimated costs are presented in Tables 6 and 7.

Based on this evaluation, the amount of electron donor, and number of injection locations, the emulsified oil was evaluated further for this alternative, and the information gathered from the EHC® evaluation was used in a subsequent alternative. Institutional controls would also likely be necessary to restrict use of contaminated soils and groundwater at the Site. Costs for annual groundwater monitoring are included for 10 years.

Protectiveness. In addition to the protectiveness provided by building decontamination and demolition, the slug-injection of a long-lasting (i.e., up to 5 years) electron donor source would significantly reduce both groundwater and soil chromium VI concentrations. Once chromium VI is converted to chromium III, it forms various precipitates with iron and hydroxide and settles out of groundwater, significantly reducing the risk to potential receptors. By applying enough electron donor to stimulate sulfate reduction, other COC metals (i.e., arsenic, cadmium, iron, lead, and zinc) would precipitate out of groundwater and attach to the soil matrix as sulfide complexes. Groundwater concentrations of inorganic nitrate and sulfate would also be reduced. This alternative is not anticipated to address any contamination north of the MW-10/MW-12 well alignment. On-going monitoring would help ensure that groundwater concentrations remain protective of potential receptors. Institutional controls would help reduce potential worker and residential exposure on the Site.

Permanence. This alternative is one of the most reliable approaches for treating the core plume area. Based on the proposed injection pattern, the risk of large sections of the aquifer not receiving treatment is significantly reduced. By alternating injection sequences, displacement of the plume outside of the treatment area can be minimized. By introducing this long-term amendment, diffusion of both electron donor and chromium VI over time will provide additional treatment of areas not immediately contacted by the injection. Once reduced, chromium III is not likely to re-oxidize to chromium VI under normal environmental conditions. Slug injections into the aquifer will also raise the water table, contacting the vadose soil contamination, and minimizing the long-term potential for rebound due to water table fluctuations. This alternative does not fully address residual surface soils and vadose zone soil contamination outside of target treatment zones and development restrictions (institutional controls) would need to remain in place.

Cost. The costs for this alternative include costs for the Newman Zone® product, drilling, manifold piping, installation, and engineering oversight. Based on the amount of electron donors needed, costs for five products were compared and the Newman Zone® (emulsified soybean oil and lactate) is the lowest cost per mole, and preferred for the slug injection approach. This alternative is probably the most effective in removing the bulk of the contamination in source area soils, vadose zone, and groundwater. Some perimeter areas containing lower concentrations of chromium VI will likely receive minimal treatment, but also have limited potential for significant exposure to potential receptors. Site monitoring will consist of quarterly groundwater sampling for the first 5 years, and annual groundwater monitoring for Years 6 through 10.

With the treatment of 108,900 tons of contaminated soil by this alternative ($264,845), the total cost per ton of treatment for this approach is approximately $2.43 per ton. These costs include only the contaminated soil volumes treated and do not include the building demolition or ongoing monitoring costs.

Effectiveness Over the Long Term. The pilot study has shown *in situ* bioremediation as an effective method for reducing chromium VI to the non-carcinogenic chromium III. The Newman Zone® emulsified oil has demonstrated success in promoting the long-term reduction of chromium VI, nitrate, and sulfate. This amendment releases low molecular weight fatty acids, which have been identified as optimal electron donors for chromium VI reduction (Lloyd 2003). By applying varying amounts of amendment in core plume areas, this approach will be effective in addressing a significant amount of contaminant mass present on the Site. The effectiveness of metal-sulfide precipitation (i.e., arsenic, cadmium, iron, lead, and zinc) depends on the proximity of the reduced metal and available sulfide. For areas where metal reduction is occurring but conditions are not favorable for sulfate reduction, localized increases in COC metals may be observed. This alternative will not address the downgradient area or any off-site mass.

Management of Short-Term Risk. Risks that may be realized during implementation of this alternative include the Plating Shop decontamination and demolition risks, construction hazards associated with push probes, and the risk of temporarily mobilizing arsenic, cadmium, and lead by stimulating reductive processes that increase solubility of these metals. Based on groundwater chemistry, arsenic, cadmium, and lead are anticipated to be in their oxidized form. Biological reduction of these metals creates a more soluble and mobile form of contaminant. If the reductive zone created by on-site injections is too large, risks for off-site migration of these metals increases. In addition to mobilizing these heavy metals, over-application of amendment can also result in biological methylation of arsenic, cadmium, and lead metal. Heavy metal methylation could potentially present a significant toxicity risk due to increased volatility and toxicity of these compounds (Turpenen 2002). If strong, on-site reductive conditions move off-site, there is also a small risk of mobilizing downgradient, off-site portions of the plume by decreasing the natural affinity of chromium VI for clay particles and other oxidized minerals. These implementation risks could potentially be mitigated by tailoring amendment application based on area-specific hydrogen demands, by using long-lasting (i.e., slow hydrogen release) compounds, or increasing groundwater concentrations of sulfide. Sulfide can be injected directly through push probes or biologically created through the reduction of sulfate.

A risk to surface receptors is also posed by storing and injecting large volumes of emulsified oil. Injection equipment failure or excessive injection rates may cause inadvertent discharge of emulsified oil to the Dry Creek. Excessive injection rates may also result in contaminated groundwater surfacing to Dry Creek. There is also the risk of increased contaminant migration toward the operating on-site extraction well proposed for use during injection due to heavy use and alteration of natural gradients. These risks could be controlled by reducing injection rates or spacing injection sequences over time.

Technical and Administrative Implementability. Three factors may hinder the implementability of this alternative at the Site. These include the potential for push probe refusal, surface obstacles, and water demand. To keep costs for this alternative reasonable, push probe technologies would need to be used for injection. Due to the injection depths and soil characteristics, push probe refusal is possible. Deviation from the proposed injection pattern could reduce effectiveness and reliability. Large surface obstacles may limit rig access, resulting in uneven probe placement. Significant amounts of water will be required to mix the amendments for push probe injection. The Newman Zone® injection will require 915,000 gallons of water. Injections with Newman Zone® should be completed in two weeks due to emulsion stability and distribution factors, requiring delivery of 14 gpm of water for two weeks during the most demanding injection series.

Consideration of Public Concerns. The public concerns for construction activities will be limited to the immediately adjacent properties. Drilling activities required for the injection points will create a local noise on the Site for several days. The other public risk related to the emulsified-oil injections is the potential for over-injection that would result in a release into the surface water of Dry Creek. Safety measures will be taken during the injections to prevent this from occurring.

Approximately 15 to 25 truck loads of demolition debris would also be removed from the Site for off-site disposal. The volume of construction debris (less than 15 truck loads) for disposal of non-hazardous materials in a local landfill should be a small enough volume that would not pose a public concern. We are not aware of any other public concerns for this alternative at this time.

Other Factors. Although the volume of water and emulsified oil is anticipated to increase the water table well into the vadose zone, any shallow contamination above this level will remain following the injections and subsequent biological treatment. This remaining vadose zone contamination would allow for potential future leaching of chromium into groundwater through surface water infiltration.

7.3 Limited Source Area Soil Removal and In Situ Source Area Treatment and Monitoring

Description. For this alternative, the Plating Shop would be decontaminated and demolished. A reduced volume of source area soils would be removed (compared to Section 7.4) and disposed of off Site. The remaining source area soils and groundwater will be addressed with *in situ* bioremediation.

To further enhance remediation of contaminant mass, the former chromium plating vaults and adjacent source area soils under the Plating Shop would be removed and a horizontal, vadose zone infiltration gallery would be installed (Figure 11). To enhance contaminant control, MW-13 would be converted to an extraction well to create a vertical recirculation cell. Infiltrating and recirculating electron donor in the highest concentration source area would mitigate residual contamination above and below the water table.

The installation of a vadose zone infiltration gallery is highly recommended due to its relatively low installation cost following demolition. Institutional controls would also likely be necessary to restrict access and use of contaminated soils and groundwater at the Site. This approach assumes that a risk assessment will be performed after the 10 years of monitoring, and that additional monitoring may or may not be required. Costs for annual groundwater monitoring are included for 10 years.

Protectiveness. This is judged to be the most protective short-term alternative, eliminating the primary ongoing source of groundwater contamination. By removing the bulk of above ground and source area soil contamination, conditions will be most protective of surface receptors. *In situ* groundwater treatment would dramatically reduce contaminant mass in the saturated zone and the infiltration gallery would address source area contaminant mass in the vadose zone below the excavation limit. However, this approach would have limited benefits for any groundwater contamination that has already migrated beyond the source area and would not be protective of potential future exposure to domestic wells or Dry Creek. On-going monitoring would help ensure that groundwater concentrations remain protective of potential receptors. Institutional controls would help reduce potential on-site worker and residential exposure.

Permanence. Of all the remediation alternatives considered, this alternative provides the best long-term reliability. By both physically removing source area mass and stimulating *in situ* bioremediation across much of the plume, the COC risk to potential receptors would be significantly mitigated. However, this alternative does nothing to remove, treat, or control the contaminated groundwater beyond the source area.

Cost. This remediation alternative would be effective for physically removing chromium VI mass in the subsurface vadose zone and the recirculation system would reasonably treat the remaining source in the saturated zone. This approach would be more cost-effective if sampling data collected in the vault area indicate that a larger volume of contaminated soil requires additional treatment. Costs for annual groundwater monitoring are included for 10 years.

With the treatment of 600 tons of soil for removal, disposal, and backfill; and 5,720 tons treated *in situ* by this alternative ($346,800), the total cost per ton of treatment for this approach is approximately $54.90 per ton. These costs include only the contaminated soil volumes treated and do not include the building demolition or ongoing monitoring costs.

Effectiveness Over the Long Term. Removal of high contamination material is very effective for reducing contaminant mass present at the Site. The recirculation pilot study has shown *in situ* bioremediation as an effective method for reducing chromium VI to the non-carcinogenic chromium III form. This approach will be effective in addressing a significant amount of contaminant mass in the source area. Injection of electron donor into the vadose zone will be effective is reducing contaminant mass beneath the former source area. This alternative does not address the groundwater contamination beyond the source area.

Management of Short-Term Risk. Surface risks that may be encountered during implementation of this alternative include exposure of the decontamination and demolition workers to the contaminated materials, dust, and soil during excavation; physical hazards associated with demolition, excavation, and push probes; and environmental risks associated with disturbing, transporting, handling, and disposal or treating of contaminated soil *ex situ*. These risks can be managed through engineering controls and worker protections. Risk to surface receptors is also posed by storing and injecting large volumes of emulsified oil. Injection equipment failure or excessive injection rates may cause inadvertent discharge of emulsified oil to the Dry Creak. Additional risks associated with reductive *ex situ* treatment of soils include formation of highly toxic methylated metals (including arsenic and cadmium). Improper blending could also leave portions of the soil untreated, and undesirable biological odors may also be generated during the *ex situ* remediation.

Subsurface risks include construction hazards associated with push probes, and the risk of temporarily mobilizing arsenic, cadmium, and lead by stimulating reductive processes that increase solubility of these metals. In addition to mobilizing heavy metals, biological methylation of arsenic, cadmium, and lead metal in highly reductive environments could potentially present significant toxicity risks due to increased volatility and toxicity of these compounds (Turpenen 2002). These risks could potentially be mitigated by tailoring amendment application and by using long-lasting (i.e., slow hydrogen release) compounds. Excessive injection rates may result in contaminated groundwater surfacing to Dry Creek and an increased risk of contaminant migration to the operating on-site extraction well proposed for use during injection. These risks could be controlled by reducing injection rates or spacing out injection sequences over time.

Technical and Administrative Implementability. Following the removal of the Site building, the underlying source soils around the former chromium plating vaults would be excavated and either directly disposed of or pre-treated *ex situ*. Installation of the infiltration gallery would be relatively simple following slab demolition and source area soil excavation. It is not expected that the shallow groundwater will complicate the vault and soil excavation due to the fine-grained nature of the Site soils and depth to water in the area. The potential for push probe refusal, surface obstacles, and lack of water could hinder implementation of the slug injection portion of this alternative. Standard demolition and excavation equipment would be used to complete the work.

Consideration of Public Concerns. The construction activities at the Site will not be a public concern except for the hauling of contaminated soils to the landfill. The trucks will have to be clean and covered before leaving the Site.

The volume of soil being removed will require approximately 40 to 50 trucks to be added to the local traffic over the few days of implementation. The same amount of trucks will be required for the backfill materials.

Approximately 15 to 25 truck loads of demolition debris would also be removed from the site for off-site disposal. The volume of construction debris (less than 15 truck loads) for disposal of non-hazardous materials in a local landfill should be a small enough volume that would not pose a public concern. We are not aware of any other public concerns with this alternative at this time.

7.4 Source Area Soil Removal and Monitoring

Description. For this alternative, the Plating Shop would be decontaminated, demolished, and disposed of at an appropriate waste facility. Contaminated soil underneath the former plating vaults would be removed for disposal, as shown on Figure 11. Long-term groundwater sampling and analysis would be performed to determine risk to potential receptors and institutional controls would be put in place to protect against future exposure. This approach assumes that a risk assessment will be performed after the 20 years of monitoring, and that additional monitoring may or may not be required. Costs for annual groundwater monitoring are included for 20 years.

Protectiveness. The combination of Plating Shop and source area soil removal provides a high degree of surface receptor protection. These actions would also remove most of the contaminant mass in the vadose zone that may provide an on-going source of groundwater contamination. Despite inappropriate waste management practices at the Site for many years, the most recent sampling of domestic supply wells and surface water suggests that the plume is fairly immobile. Chromium VI has a strong affinity for minerals containing hydroxyl groups and oxides, such as iron oxide, and clay particles under oxidized, acidic to neutral conditions (Zayed and Terry 2003). Thus, area soil conditions may provide insight into the apparent low-mobility nature of this historical plume. By keeping the aquifer oxidized, the risk of mobilizing arsenic, cadmium, lead, and zinc is significantly reduced. However, this does not provide any level of protectiveness to exposure of residual chromium VI or guarantee that the plume will not eventually reach off-site receptors. This alternative would not address nitrate or sulfate COC concentrations, or any other COCs in the groundwater beyond the source area. On-going monitoring would help ensure that groundwater remains protective of potential receptors. Institutional controls would help reduce potential worker and residential exposure on the Site.

Permanence. Physical removal of surface and soil contaminant mass is the most reliable way to remediate a Site. Alternatively, the excavated soil could be treated on-site using reductive *ex situ* treatment. This approach is certainly not as reliable as removing the soil from the Site, but properly implemented and tested would be very reliable in reducing the contaminant concentrations. However, this alternative does not reliably ensure that other potential receptors (such as those impacted by migrating groundwater) are protected.

Cost. Decontamination, demolition and disposal costs are high. Disposal costs may be reduced by on-site *ex situ* remediation of chromium VI with fatty acid producers, such as EHC®, and humic compounds, such as X-19®. Final cost of *ex situ* treatment is unknown due to absence of data under the vaults. Costs for annual groundwater monitoring are also included for 20 years.

With the treatment of 1,250 tons of contaminated soil by this alternative ($340,750), the total cost per ton of treatment for this approach is approximately $273 per ton. These costs include only the contaminated soil volumes treated and do not include the building demolition or ongoing monitoring costs.

Effectiveness Over the Long Term. Physical removal of high contamination material is very effective for reducing contaminant mass present in the source area at the Site. These measures would do little to address the potential contaminant mass present within the saturated interval or the groundwater contamination beyond the source area.

Management of Short-Term Risk. Risks that may be realized during implementation of this alternative include exposure of the decontamination and demolition workers to the contaminated materials and soil, hazards associated with demolition and excavation, and the potential for exposure to contaminated dust released into the atmosphere during demolition and excavation (though this would be a short-term risk). This risk can be managed through engineering controls and worker protection. There is also some small risk associated with spilling the excavated soil during transport.

Additional risks would be associated with on-site reductive *ex situ* treatment of soils contaminated with arsenic or cadmium. Excessive *ex situ* amendment application could result in methanogenic activity, potentially resulting in methylation of metals and increased receptor risk. Low concentrations of soil sulfate could reduce the amount of sulfide generated by EHC® to bind these metals in an insoluble matrix. X-19 Bio-Met already contains sulfur compounds and would be custom-blended to address soil conditions. Improper blending could also leave portions of the soil untreated, and undesirable biological odors may also be generated during the *ex situ* remediation.

Technical and Administrative Implementability. Following the removal of the Site building, the area of source soils will be accessible. It is not expected that the shallow groundwater will complicate the excavation due to the fine-grained nature of the Site soils and depth to water in the area. Excavated soil would be transported to a disposal facility. Alternatively, the excavated soil could be treated on-site using reductive *ex situ* treatment. Space is available on the Site for holding this soil. Standard demolition and excavation equipment would be used to complete the work.

Consideration of Public Concerns. The construction activities at the Site will not be a public concern except for the hauling of contaminated soils to the landfill. The trucks will have to be clean and covered before leaving the Site. The volume of soil being removed will require approximately 80 to 90 trucks to be added to the local traffic over the few days of implementation. The same amount of trucks will be required for the backfill materials.

Approximately 15 to 25 truck loads of demolition debris would also be removed from the Site for off-site disposal. The volume of construction debris (less than 15 truck loads) for disposal of non-hazardous materials in a local landfill should be a small enough volume that would not pose a public concern. We are not aware of any other public concerns with this alternative at this time.

7.5 Building Decontamination, Demolition, and Monitoring

Description. This alternative includes the Plating Shop decontamination and demolition and would be conducted to reduce human health and ecological risks at the Site. This alternative would also include continuing groundwater monitoring to ensure dissolved constituents do not pose unacceptable risk to potential receptors for a period of 20 years. This approach assumes that a risk assessment will be performed after the 20 years of monitoring, and that additional monitoring may or may not be required. Institutional controls would also likely be necessary to restrict access and use of contaminated soils and groundwater at the Site. Costs for annual groundwater monitoring are included for 20 years.

Protectiveness. Decontamination and demolition of the building would help reduce the mass of contamination above ground. This alternative would significantly reduce the potential for direct contact by human and ecological receptors, and would also reduce the potential for contaminant migration into soil, groundwater, and surface water. On-going groundwater monitoring would help ensure that conditions remain protective of potential receptors. Institutional controls would help reduce potential on-site worker and residential exposure. This measure does not address groundwater contamination above CULs.

Permanence. Due to the pervasive nature of contamination in the subsurface, this alternative is not anticipated to provide acceptable long-term protection to potential receptors.

Cost. The costs associated with this alternative include surface removal of chromium VI, demolition of the Plating Shop, engineering controls, waste disposal, and groundwater monitoring. The cost is the least expensive of the alternatives, but provides the least amount of mass removal and future protection for potential off-site migration.

Effectiveness Over the Long Term. This alternative would be effective in reducing exposure to human and ecological receptors, but have very limited effectiveness on subsurface contamination in the soil and more importantly the more mobile groundwater.

Management of Short-Term Risk. Risks that may be realized during implementation of the decontamination and demolition alternative include exposure of the workers to contamination. As the respiratory tract is a major target organ of chromium VI, the greatest risks are associated with dry decontamination. Exposure to airborne chromium VI could result in respiratory distress and lung cancer. Acute animal tests have shown chromium VI to have extreme inhalation and oral toxicity (EPA 2008). Wet decontamination is likely to be the most protective decontamination method. This risk can be managed through engineering controls and worker protection. There is also some risk associated with the transport of the decontaminated material to the disposal/treatment facility

Technical and Administrative Implementability. This alternative is the easiest to implement and could be completed in a few weeks.

Consideration of Public Concerns. A few dozen truck loads of demolition debris would also be removed from the Site for off-site disposal. The trucks will have to be clean and covered before leaving the Site. The volume of debris being removed will require approximately 15 to 25 trucks to be added to the local traffic over the few days of implementation. The volume of construction debris (less than 15 truck loads) for disposal of non-hazardous materials in a local landfill should be a small enough volume that would not pose a public concern. We are not aware of any other public concerns with this alternative at this time.

8.0 COMPARATIVE EVALUATION OF ALTERNATIVES

This section presents an evaluation of the removal action alternatives in relation to one another. This comparative analysis of the alternatives is summarized in Table 8. In the table, each alternative is compared to the other alternatives within each criterion and assigned a ranking of 1 through 3. A ranking of 1 is considered inferior and a ranking of 3 is considered superior among the alternatives presented. Order of magnitude (±25%) costs are presented in Table 9.

8.1 Comparative Analysis

Protectiveness. Each of the alternatives achieves the CULs to a different degree depending on the pathways and receptors that are most important to the project goals. The decontamination, demolition, and source area removal would address the surface receptors but would do little to address the groundwater contamination that would remain persistent and mobile for decades. Alternatives 1 and 2 combined with the decontamination and demolition addresses the surface impacts as well as the groundwater and vadose zone contaminants much more completely and, therefore, are rated higher. Alternatives 3 and 4 address only the source area soils that are protective of human and ecological receptors for direct contact, but do not address migrating groundwater to nearby domestic wells or Dry Creek.

Permanence. The decontamination, demolition, and source area removal or removal and treatment have an excellent long-term reliability in addressing the surface and source concerns, but do not address the long-term groundwater issues. Alternatives 1 and 2 in conjunction with the decontamination and demolition would have an excellent long-term reliability for both the surface impacts and mobile contamination in the groundwater and, therefore, are rated higher than Alternatives 3 and 4 that do not treat the migrating groundwater beyond the source area.

Cost. Feasibility cost estimates were developed for each of the removal options based on present worth of capital costs and long-term costs. The following list summarizes the cost estimates for the identified alternatives.

- Alternative 1 – Aggressive *In Situ* Soil and Groundwater Treatment and Monitoring, Building Decontamination and Demolition ($1,176,000);

- Alternative 2 – Limited *In Situ* Soil and Groundwater Treatment and Monitoring, Building Decontamination and Demolition ($760,000);

- Alternative 3 – Limited Source Area Soil Removal and *In Situ* Source Area Treatment and Monitoring, Building Decontamination and Demolition, ($898,000);

- Alternative 4 – Source Area Soil Removal and Monitoring, Building Decontamination, and Demolition ($990,000); and

- Alternative 5 – Building Decontamination, Demolition, and Monitoring ($650,000).

Effectiveness Over the Long Term. The decontamination, demolition, and source area removal would be very effective in addressing the surface contaminants but would do little to address the vadose zone and groundwater contamination. Alternatives 1and 2 combined with the decontamination and demolition would be effective in remediating both the surface impacts as well as the groundwater and vadose zone contaminant much more completely and, therefore, are rated higher than Alternatives 3 and 4 that would again only treat the source area soils, but would do little to treat groundwater beyond the source area.

Management of Short-Term Risk. The implementation risk for the decontamination and demolition of the building is limited to the worker risk of contact with contaminated media during the implementation. Off-site disposal has additional risk to the community associated with overland travel to the disposal site. The combination of excavation and recirculation in the source area has less implementation risk due to the lesser excavation volume. Alternatives 1 and 2 have the additional risk of releasing amendments over the weeks of injections and storing materials on the Site. Also the high pressure injections could potentially injure workers and potentially push contaminants toward Dry Creek. Additional implementation risks for the injections include mobilizing additional metals. Alternative 3 and 4 rank slightly higher as they incorporate standard construction techniques and although not treating the groundwater, the source removal has limited chance of mobilizing metals in the groundwater.

Technical and Administrative Implementability. The decontamination and demolition of the building only would be the easiest alternative to implement and is rated the highest. If the building was demolished, the source area excavation alternatives become much easier to implement. If the decontamination option was selected without the building demolition, protecting the existing structure would make the implementation of any source removal more difficult. On-site treatment of excavated soil from the source area is harder to implement than off-site disposal as it requires additional soil handling and a longer time period. If the existing structure is left in place, the combination of excavation, off-site soil disposal along with *in situ* treatment for the remaining source area would require less soil removal and make it easier to protect the existing structure. Alternatives 1 and 2 would require significant more effort and more uncertainties with the number of probes and volumes of amendment that would be handled of a period of several weeks and, therefore, are rated the lowest. Alternative 3 and 4 would require more effort if the building was left in place, but could be completed in only a few weeks with significantly less effort than implementing Alternatives 1 and 2.

Consideration of Public Concerns. The decontamination, demolition, and off-site disposal generates the lowest truck traffic and produces the least amount of transported contaminated media. Alternative 3 includes the building decontamination and is the next best choice with limited off-site disposal of contamination. Alternatives 1 and 2 include the building demolition but add little to the truck traffic with no additional offsite disposal issues. Alternative 4 is rated the lowest due to the amount of off-site disposal and the import of backfill material.

8.2 Recommended Interim Removal Action

Decontamination of the building and removal of wastes accumulated at the Site would be a good first step if a phased approach is necessary due to funding restraints. The groundwater could be monitored on a regular basis until such time that the limited *in situ* treatment (Alternative 2) could be implemented. This alternative provides treatment of the primary contaminant (chromium VI) as well as other metals, if properly implemented. This alternative will also limit future off-site migration. This combination of alternatives is significantly less expensive than off-site disposal as a hazardous waste, and would address a significantly larger area than either of the source area removals. Therefore, we are recommending that the IRAM include decontamination (preferably with demolition) and the limited *in situ* soil and groundwater treatment alternative (Alternative 2).

9.0 REFERENCES

AFCEE 2004. Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents. Prepared by Air Force Center for Engineering.

AFCEE 2007. Final Protocol for In Situ Bioremediation of Chlorinated Solvents Using Edible Gel. October 2007.

Arias and Tebo, 2003. Cr(VI) Reduction by Sulfidogenic and Nonsulfidogenic Microbial Consortia. Applied Environmental Microbiology, Volume 69, pp 1847-1853. March 2003.

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Table 1 - Summary of MTCA Cleanup Levels (CULs)
Schwerin Concaves
Walla Walla, Washington

Chemical Group	Contaminant of Concern	Carcinogenic	MTCA Method	Soil CUL in mg/kg	Groundwater CUL in mg/L
Metal	Hexavalent Chromium	Yes	B	19(b)	0.048
Metal	Trivalent Chromium	No	B	2,000(b)	24
Metal	Total Arsenic	Yes	A	20	0.005
Metal	Total Cadmium	Yes	A	2	0.005
Metal	Total Lead	No	A	250	0.015
Metal	Total Iron	No	B	NA	0.30(a)
Metal	Total Zinc	No	B	NA	4.8
Inorganic	Sulfate	No	B	NA	250(a)
Inorganic	Nitrate (as nitrogen)	No	B	NA	10

Notes:
MTCA Method B Soil and Groundwater Cleanup Levels are based on a review of Ecology's CLARC on-line database as of April 2008.
MTCA Method A CULs based on WAC 173-340-900, Tables 720-1 and 740-1.
MTCA Method B Groundwater CULs based on drinking water exposures.
(a) Based on secondary MCL.
(b) Based on groundwater protection.
NA = not applicable.
mg/kg = milligram per kilogram.
mg/L = milligrams per liter.

Table 2 - Summary of Groundwater Analytical Results
Schwerin Concaves
Walla Walla, Washington

Well	Sample Date	Hexavalent Chromium	Calculated Trivalent Chromium	Total Chromium	Total Arsenic	Total Cadmium	Total Iron	Total Lead	Total Zinc	Total Organic Carbon	Nitrate	Sulfate
		Concentration in mg/L										
MW-1	7-Nov-06	**0.568**	0.072	0.640	< 0.0200	< 0.00200	--	< 0.0300	0.0132	--	--	--
	5-Jun-07	**0.428**	ND	0.426	< 0.0200	< 0.00200	--	< 0.0300	0.0637	< 2.00	8.93	12.8
MW-2	7-Nov-06	< 0.00625	15.0	15.0	< 0.0200	< 0.00200	--	< 0.0300	0.0113	--	--	--
	5-Jun-07	**11.4**	ND	11.2	< 0.0200	< 0.00200	--	< 0.0300	--	2.24	**10.4**	18.6
	23-Aug-07	<0.0500 H,UJ1	0.144	0.144	0.00305	0.00205		< 0.00100	0.0348	244	< 0.100	1.61
MW-3	7-Nov-06	**0.0675**	0.0070	0.0745	< 0.0200	< 0.00200	--	< 0.0300	0.0222	--	--	--
	4-Jun-07	**0.0630**	ND	0.0530	< 0.0200	< 0.00200	--	< 0.0300	0.0312	< 2.00	8.60	19.6
MW-4	7-Nov-06	< 0.00625	16.7	16.7	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	--	--	--
	4-Jun-07	**12.6**	0.7	13.3	< 0.0200	< 0.00200	--	**0.175**	0.143	5.75	3.36	126
MW-5	7-Nov-06	< 0.00625	0.0152	0.0152	< 0.0200	< 0.00200	--	< 0.0300	0.0251	--	--	--
	5-Jun-07	< 0.00500	0.0107	0.0107	< 0.0200	< 0.00200	--	< 0.0300	0.0360	2.91	< 0.500	3.84
MW-6	7-Nov-06	**0.520**	0.379	0.899	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	--	--	--
	5-Jun-07	< 0.00500	0.0374	0.0374	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	< 2.00	0.860	20.4
	23-Aug-07	< 0.0500 H,UJ1	0.00827	0.00827	0.00294	< 0.00100	--	0.00139	0.0168	328	< 1.00	< 10.0
MW-7	7-Nov-06	< 0.00625	**75.4**	75.4	< 0.0200	< 0.00200	--	< 0.0300	0.0236	10.6	5.42	26.0
	28-Dec-06	**57.5**	--	--	--	--	--	--	--	119	--	--
	24-Jan-07	**66**	ND	58.5	< 0.0200	< 0.00200	--	< 0.0300	0.0239	59	<1.0	22.4
	27-Feb-07	**47**	15.3	62.3	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	136	0.72	26.4
	21-Mar-07	**58.2**	0.7	58.9	--	--	--	--	--	223	1.44	26
	25-Apr-07	**55.2 (65.0*)**	7.0	62.2 (65.3*)	< 0.0200	< 0.00200	**7.09**	< 0.0300	< 0.0100	295	1.10	30.9
	5-Jun-07	**77.5**	0.8	78.3	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	252	1.05	29.7
	23-Aug-07	**19.2 H,J1**	**207**	226	0.00314	< 0.00100	--	0.00678	0.0594	385	4.90	44.7
MW-8	7-Nov-06	**0.232**	0.091	0.323	< 0.0200	< 0.00200	--	< 0.0300	0.0138	--	--	--
	4-Jun-07	**0.128**	ND	0.126	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	< 2.00	1.45	9.18
MW-9	7-Nov-06	**0.116**	0.021	0.137	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	--	--	--
	4-Jun-07	0.0120	6.71	6.72	**0.0732**	**0.633**	--	< 0.0300	0.0180	7,400	**57.4**	**928**
	23-Aug-07	< 0.100 H,UJ1	8.84	8.84	**0.0256**	**0.119**		0.00403	**7.14**	13,600	< 1.00	< 10.0
MW-10	7-Nov-06	**0.348**	0.114	0.462	< 0.0200	< 0.00200	--	< 0.0300	0.109	--	--	--
	28-Dec-06	--	--	--	--	--	--	--	--	--	--	--
	24-Jan-07	--	--	0.587	--	--	--	--	--	2.79	**21.3**	18.3
	27-Feb-07	**2.05**	ND	0.98	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	3.84	**18.6**	17.4
	21-Mar-07	**0.675**	0.293	0.968	--	--	--	--	--	2.90	**18.4**	17.5
	25-Apr-07	**1.00 (1.06*)**	ND	0.986 (1.42*)	< 0.0200	< 0.00200	**0.986**	< 0.0300	< 0.0100	< 2.00	**16.6**	18.0
	4-Jun-07	**0.880**	0.097	0.977	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	< 2.00	**17.4**	19.1
MW-11	7-Nov-06	**0.885**	5.21	6.09	< 0.0200	< 0.00200	--	< 0.0300	0.0179	4.29	**12.8**	19.9
	28-Dec-06	**11.2**	--	--	--	--	--	--	--	--	--	--
	24-Jan-07	**2.0**	5.1	7.14	**0.115**	**0.77**	--	< 0.0300	1.06	133	6.2	3.9
	27-Feb-07	**3.88**	2.47	6.35	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	3.44	**14.6**	21
	21-Mar-07	**5.98**	0.10	6.08	--	--	--	--	--	3.79	**14.7**	21
	25-Apr-07	**5.20 (6.23*)**	0.75	5.95 (8.25*)	< 0.0200	< 0.00200	0.277	< 0.0300	< 0.0100	< 2.00	**15.6**	22.6
	4-Jun-07	**5.45**	0.25	5.70	< 0.0200	< 0.00200	--	< 0.0300	0.0120	< 2.00	**15.2**	21.4
	23-Aug-07	< 0.0100 H,UJ1	5.43	5.43	< 0.00100	< 0.00100	--	< 0.00100	< 0.0100	1.24	**14.6**	20.0
MW-12	7-Nov-06	**0.344**	9.54	9.88	< 0.0200	< 0.00200	--	< 0.0300	< 0.0100	< 2.00	--	--
	4-Jun-07	**15.6**	1.2	16.8	< 0.0200	< 0.00200	--	< 0.0300	0.0180	8.80	**18.8**	26.8

Table 2 - Summary of Groundwater Analytical Results
Schwerin Concaves
Walla Walla, Washington

Well	Sample Date	Hexavalent Chromium	Calculated Trivalent Chromium	Total Chromium	Total Arsenic	Total Cadmium	Total Iron	Total Lead	Total Zinc	Total Organic Carbon	Nitrate	Sulfate
		Concentration in mg/L										
MW-13	7-Nov-06	0.0200	6.72	6.74	< 0.0200	< 0.00200	--	< 0.0300	0.0281	5.32	2.08	9.80
	28-Dec-06	0.00500	--	--	--	--	--	--	--	2,480	--	--
	24-Jan-07	**1.3**	3.03	4.33	< 0.0200	**0.0481**	--	< 0.0300	0.59	2,050	<1.0	14.1
	5-Jun-07	< 0.00500	8.17	8.17	< 0.0200	0.00400	--	< 0.0300	0.160	350	< 0.500	12.3
	23-Aug-07	< 0.0500 H,UJ1	14.4	14.4	**0.00725**	0.00378	--	0.00431	0.0348	140	< 0.100	1.15
Method A Cleanup Levels		NA	NA	NA	0.005	0.005	NA	0.015	NA	NA	NA	NA
Method B Cleanup Levels		0.048	24.0	NA	NA	NA	0.30	NA	4.8	NA	10	250

Notes:
Hexavalent Chromium per APHA/EPA Method 7196A.
Total Organic Carbon per EPA Method 415.1 or EPA Method 415.2.
Total metals per EPA Method 200.7 or EPA 6020.
Anions per EPA Method 300.0.
Shaded value represents detected concentrations of listed analyte.
Bold value represents detections above potentially applicable cleanup levels.
Method A Cleanup Levels per WAC 173-340-900 Table 720-1.
Method B Cleanup Levels determined using Ecology's CLARC on-line database.
NA = Method Cleanup Level not available or superseded by site-specific values.
ND = hexavalent chromium concentration equal to or exceeds total chromium concentration.
-- = Not analyzed.
H = sample analyzed past recommended hold time.
UJ1 = analyte not detected, detection limit estimated due to laboratory duplicate and matrix spike outliers (low bias).
J1 = analyte positively detected, detection limit estimated due to laboratory duplicate and matrix spike outliers (low bias).
mg/L = milligrams per liter.
* = Duplicate sample.

Table 3 - Summary of Groundwater Field Parameters
Schwerin Concaves
Walla Walla, Washington

Monitoring Well	Sample Date	Temperature in °C	pH	Electrical Conductivity in µMhos	Oxidative-Reductive Potential in mV	Dissolved Oxygen in mg/L
MW-1	5-Jun-07	12.92	6.17	639	-84	2.01
MW-2	5-Jun-07	12.46	7.74	726	51	3.01
MW-3	4-Jun-07	15.86	7.52	591	97	7.98
MW-4	4-Jun-07	12.07	6.29	945	-34	1.66
MW-5	5-Jun-07	12.47	7.80	343	83	5.89
MW-6	5-Jun-07	13.50	7.64	647	56	3.33
MW-7	20-Dec-06	11.21	6.45	755	59	1.03
	24-Jan-07	12.10	7.10	461	48	1.03
	27-Feb-07	11.70	6.10	1550	101	7.50
	21-Mar-07	12.40	8.03	1017	32	6.29
	25-Apr-07	13.20	7.60	942	158	1.20
	5-Jun-07	12.96	6.61	980	111	2.60
MW-8	4-Jun-07	15.54	7.49	397	115	5.98
MW-9	4-Jun-07	12.18	5.20	1,800	-43	0.76
MW-10	24-Jan-07	11.10	7.90	517	188	7.21
	27-Feb-07	9.30	6.40	1234	96	12.40
	21-Mar-07	10.86	9.77	910	1.5	14.30
	25-Apr-07	14.20	7.70	415	78	0.60
	4-Jun-07	19.76	6.69	705	146	7.98
MW-11	20-Dec-06	11.26	7.77	654	70	1.41
	24-Jan-07	6.10	7.10	400	199	7.10
	27-Feb-07	9.80	6.30	1212	92	10.10
	21-Mar-07	11.43	8.71	1066	28	13.38
	25-Apr-07	13.20	7.70	423	140	0.51
	4-Jun-07	18.13	7.20	693	138	6.96
MW-12	4-Jun-07	13.63	7.61	794	-11	3.91
MW-13	20-Dec-06	10.17	7.16	20,210	-123	0.37
	24-Jan-07	9.70	7.50	19,235	-127	0.33
	5-Jun-07	16.65	6.71	11,900	-34	1.01

Notes:

Field parameters measured by hand held meters in the field.
-- = Not analyzed.
µMho = micromho.
mV = millivolts.
mg/L = milligrams per liter.

Table 4 - Groundwater Hydrogen Equivalents
Schwerin Concaves
Walla Walla, Washington

Monitoring Well	Sample Date	Hydrogen Demand for Hexavalent Chromium Reduction												Total H_2 Demand (Chromium/ Sulfate)	
		Hydrogen Demand for Sulfate Reduction													
		Dissolved Oxygen			Nitrate			Hexavalent Chromium			Sulfate				
		mg/L	mM	H_2 mME	mg/L	mM	H_2 mME	mg/L	mM	H_2 mME	mg/L	mM	H_2 mME	mM*	mM
MW-1	7-Nov-06	--	--	--	--	--	--	0.568	**0.0109**	**0.0164**	--	--	--	0.1639	0.1639
	5-Jun-07	2.01	**0.0628**	**0.1256**	8.93	**0.1441**	**0.3601**	0.428	**0.0082**	**0.0123**	12.8	**0.1333**	**0.5331**	0.6092	1.1423
													Maximum =	**0.6092**	**1.1423**
MW-2	7-Nov-06	--	--	--	--	--	--	< 0.00625	--	--	--	--	--	0.0000	0.0000
	5-Jun-07	3.01	**0.0941**	**0.1881**	10.4	**0.1678**	**0.4194**	11.4	**0.2192**	**0.3289**	18.6	**0.1937**	**0.77466**	3.8963	4.6709
	23-Aug-07	--	--	--	< 0.100			<0.0500 H,UJ1	--	--	1.61	**0.0168**	**0.06705**	0.0000	0.0671
													Maximum =	**3.8963**	**4.6709**
MW-3	7-Nov-06	--	--	--	--	--	--	0.0675	**0.0013**	**0.0019**	--	--	--	0.0195	0.0195
	4-Jun-07	7.98	**0.2494**	**0.4988**	8.60	**0.1387**	**0.3468**	0.0630	**0.0012**	**0.0018**	19.6	**0.2041**	**0.81631**	0.8638	1.6801
													Maximum =	**0.8638**	**1.6801**
MW-4	7-Nov-06	--	--	--	--	--	--	< 0.00625	--	--	--	--	--	0.0000	0.0000
	4-Jun-07	1.66	**0.0519**	**0.1038**	3.36	**0.0542**	**0.1355**	12.6	**0.2423**	**0.3635**	126	**1.3119**	**5.2477**	3.8742	9.1219
													Maximum =	**3.8742**	**9.1219**
MW-5	7-Nov-06	--	--	--	--	--	--	< 0.00625	--	--	--	--	--	0.0000	0.0000
	5-Jun-07	5.89	**0.1841**	**0.3681**	< 0.500	--	--	< 0.00500	--	--	3.84	**0.0400**	**0.15993**	0.3681	0.5281
													Maximum =	**0.3681**	**0.5281**
MW-6	7-Nov-06	--	--	--	--	--	--	0.520	**0.0100**	**0.0150**	--	--	--	0.1500	0.1500
	5-Jun-07	3.33	**0.1041**	**0.2081**	0.860	**0.0139**	**0.0347**	< 0.00500	--	--	20.4	**0.2124**	**0.84963**	0.2428	1.0924
	23-Aug-07	--	--	--	< 1.00	--	--	< 0.0500 H,UJ1	--	--	< 10.0	--	--	0.0000	0.0000
													Maximum =	**0.2428**	**1.0924**
MW-7	7-Nov-06	--	--	--	5.42	**0.0874**	**0.2186**	< 0.00625	--	--	26.0	**0.2707**	**1.08286**	0.2186	1.3014
	28-Dec-06	1.03	**0.0322**	**0.0644**	--	--	--	57.5	**1.1059**	**1.6588**	--	--	--	16.6522	16.6522
	24-Jan-07	1.03	**0.0322**	**0.0644**	<1.0	--	--	66	**1.2693**	**1.9040**	22.4	**0.2332**	**0.93293**	19.1043	20.0372
	27-Feb-07	7.50	**0.2344**	**0.4688**	0.72	**0.0116**	**0.0290**	47	**0.9039**	**1.3559**	26.4	**0.2749**	**1.09952**	14.0565	15.1561
	21-Mar-07	6.29	**0.1966**	**0.3931**	1.44	**0.0232**	**0.0581**	58.2	**1.1193**	**1.6790**	26	**0.2707**	**1.08286**	17.2410	18.3238
	25-Apr-07	1.20	**0.0375**	**0.0750**	1.10	**0.0177**	**0.0444**	55.2 (65.0**)	**1.2501**	**1.8751**	30.9	**0.3217**	**1.28694**	18.8708	20.1577
	5-Jun-07	2.60	**0.0813**	**0.1625**	1.05	**0.0169**	**0.0423**	77.5	**1.4905**	**2.2357**	29.7	**0.3092**	**1.23696**	22.5623	23.7993
	23-Aug-07	--	--	--	4.90	**0.0790**	**0.1976**	19.2 H,J1	**0.3693**	**0.5539**	44.7	**0.4654**	**1.86169**	5.7365	7.5982
													Maximum =	**22.5623**	**23.7993**
MW-8	7-Nov-06	--	--	--	--	--	--	0.232	**0.0045**	**0.0067**	--	--	--	0.0669	0.0669
	4-Jun-07	5.98	**0.1869**	**0.3738**	1.45	**0.0234**	**0.0585**	0.128	**0.0025**	**0.0037**	9.18	**0.0956**	**0.38233**	0.4692	0.8515
													Maximum =	**0.4692**	**0.8515**
MW-9	7-Nov-06	--	--	--	--	--	--	0.116	**0.0022**	**0.0033**	--	--	--	0.0335	0.0335
	4-Jun-07	0.76	**0.0238**	**0.0475**	57.4	**0.9260**	**2.3149**	0.0120	**0.0002**	**0.0003**	928	**9.6624**	**38.6498**	2.3659	41.0156
	23-Aug-07	--	--	--	< 1.00	--	--	< 0.100 H,UJ1	--	--	< 10.0	--	--	0.0000	0.0000
													Maximum =	**2.3659**	**41.0156**
MW-10	7-Nov-06	--	--	--	--	--	--	0.348	**0.0067**	**0.0100**	--	--	--	0.1004	0.1004
	28-Dec-06	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	24-Jan-07	7.21	**0.2253**	**0.4506**	21.3	**0.3436**	**0.8590**	--	--	--	18.3	**0.1905**	**0.76217**	1.3097	2.0718
	27-Feb-07	12.40	**0.3875**	**0.7750**	18.6	**0.3001**	**0.7501**	2.05	**0.0394**	**0.0591**	17.4	**0.1812**	**0.72468**	2.1165	2.8412
	21-Mar-07	14.30	**0.4469**	**0.8938**	18.4	**0.2968**	**0.7421**	0.675	**0.0130**	**0.0195**	17.5	**0.1822**	**0.72885**	1.8306	2.5594
	25-Apr-07	0.60	**0.0188**	**0.0375**	16.6	**0.2678**	**0.6695**	1.00 (1.06**)	**0.0204**	**0.0306**	18.0	**0.1874**	**0.74967**	1.0128	1.7624
	4-Jun-07	7.98	**0.2494**	**0.4988**	17.4	**0.2807**	**0.7017**	0.880	**0.0169**	**0.0254**	19.1	**0.1989**	**0.79549**	1.4544	2.2499
													Maximum =	**2.1165**	**2.8412**
MW-11	7-Nov-06	--	--	--	12.8	**0.2065**	**0.5162**	0.885	**0.0170**	**0.0255**	19.9	**0.2072**	**0.8288**	0.7715	1.6003
	28-Dec-06	1.41	**0.0441**	**0.0881**	--	--	--	11.2	**0.2154**	**0.3231**	--	--	--	3.3191	3.3191
	24-Jan-07	7.10	**0.2219**	**0.4438**	6.2	**0.1000**	**0.2500**	2.0	**0.0385**	**0.0577**	3.9	**0.0406**	**0.16243**	1.2708	1.4332
	27-Feb-07	10.10	**0.3156**	**0.6313**	14.6	**0.2355**	**0.5888**	3.88	**0.0746**	**0.1119**	21	**0.2187**	**0.87462**	2.3394	3.2140
	21-Mar-07	13.38	**0.4181**	**0.8363**	14.7	**0.2371**	**0.5928**	5.98	**0.1150**	**0.1725**	21	**0.2187**	**0.87462**	3.1543	4.0289
	25-Apr-07	0.51	**0.0159**	**0.0319**	15.6	**0.2517**	**0.6291**	5.20 (6.23**)	**0.1198**	**0.1797**	22.6	**0.2353**	**0.94125**	2.4583	3.3995
	4-Jun-07	6.96	**0.2175**	**0.4350**	15.2	**0.2452**	**0.6130**	5.45	**0.1048**	**0.1572**	21.4	**0.2228**	**0.89128**	2.6203	3.5115
	23-Aug-07	--	--	--	14.6	**0.2355**	**0.5888**	< 0.0100 H,UJ1	--	--	20.0	**0.2082**	**0.83297**	0.5888	1.4218
													Maximum =	**3.3191**	**4.0289**
MW-12	7-Nov-06	--	--	--	--	--	--	0.344	**0.0066**	**0.0099**	--	--	--	0.0992	0.0992
	4-Jun-07	3.91	**0.1222**	**0.2444**	18.8	**0.3033**	**0.7582**	15.6	**0.3000**	**0.4500**	26.8	**0.2790**	**1.11618**	5.5029	6.6191
													Maximum =	**5.5029**	**6.6191**

Table 4 - Groundwater Hydrogen Equivalents
Schwerin Concaves
Walla Walla, Washington

Monitoring Well	Sample Date	Hydrogen Demand for Hexavalent Chromium Reduction												Total H_2 Demand (Chromium/ Sulfate)	
		Hydrogen Demand for Sulfate Reduction													
		Dissolved Oxygen			Nitrate			Hexavalent Chromium			Sulfate				
		mg/L	mM	H_2 mME	mg/L	mM	H_2 mME	mg/L	mM	H_2 mME	mg/L	mM	H_2 mME	mM*	mM
MW-13	7-Nov-06	--	--	--	2.08	**0.0336**	**0.0839**	0.0200	**0.0004**	**0.0006**	9.80	**0.1020**	**0.40815**	0.0897	0.4978
	28-Dec-06	0.37	**0.0116**	**0.0231**	--	--	--	0.00500	--	--	--			0.0231	0.0231
	24-Jan-07	0.33	**0.0103**	**0.0206**	<1.0	--	--	1.3	**0.0250**	**0.0375**	14.1	**0.1468**	**0.58724**	0.3957	0.9829
	5-Jun-07	1.01	**0.0316**	**0.0631**	< 0.500	--	--	< 0.00500	--	--	12.3	**0.1281**	**0.51228**	0.0631	0.5754
	23-Aug-07	--	--	--	< 0.100	--	--	< 0.0500 H,UJ1	--	--	1.15	**0.0120**	**0.0479**	0.0000	0.0479
													Maximum =	**0.0631**	**0.5754**

Notes:

* = Hexavalent chromium hydrogen demand assumes K_d value of 10 (only 10% of the total mass is dissolved in groundwater).

** = Duplicate sample.

Shaded value represents detected concentrations of listed analyte.

Bolded value represents detections above potentially applicable cleanup levels.

-- = Not analyzed.

H = samples analyzed past recommended hold time.

UJ1 = analyte not detected, detection limit estimated due to laboratory duplicate and matrix spike outliers (low bias).

J1 = analyte positively detected, detection limit estimated due to laboratory duplicate and matrix spike outliers (low bias).

mg/L = milligrams per liter.

mM = millimolar; H_2 mME = hydrogen millimolar equivalent concentration.

Molecular weights: Cr = 51.996; Oxygen = 31.999; Nitrate = 61.989; Sulfate = 96.042

Hydrogen molar equivalent conversions: Cr = 1.5; Oxygen = 2; Nitrate = 2.5; Sulfate = 4.

Dissolved oxygen, nitrate, and sulfate are assumed to be 100% in solution.

Table 5 - Electron Donor H_2 Generation and Comparative Cost Estimates
Schwerin Concaves
Walla Walla, WA

Substrate	Avgerage Weight in g/mol	H_2 Released per Mole Substrate	Mole H_2 per Gram Substrate	Substrate % in Amendment	Cost per Pound Amendment	Cost per Gram Amendment	Cost per Mole H_2	Amendment As Injected (by Volume)	mM H_2 as Injected	mM H_2 at 10 Percent Efficiency
Lactate	90.1	6	0.0666	48%	$ 1.30	$ 0.00287	$ 0.0900	3.3%	1,390	139
								1.0%	421	42
								0.10%	42	4.2
Ethyl Lactate	118.1	12	0.1016	99%	$ 2.25	$ 0.00496	$ 0.0493	3.3%	3,419	342
								1%	1,036	104
								0.10%	104	10
CarBstrate ®										
Dextrose/Glucose	180.2	12	0.0666	70.5%	$ 1.50	$ 0.00331	$ 0.0704	3.3%	1,549	155
								1.0%	469	47
								0.10%	47	4.7
Newman Zone ®										
Soybean Oil	873.1	156.5	0.1792	46%	$ 1.20	$ 0.00265	$ 0.0313	4%	3,315	332
Lactate	90.1	6	0.0666	3.2%				3%	2,487	249
								2%	1,658	166
								1%	829	83
EHC ®										
Cellulose/Glucose	180.2	12	0.0666	80%	$ 2.20	$ 0.00485	$ 0.0853	0.50%	284	28
Zero Valent Iron	55.8	1	0.0179	20%				0.20%	114	11
								0.10%	57	5.7

Notes:

Each mole of H_2 can offer two electrons for reductive proccesses

Lactate is provided as sodium lactate, containing 79.7% lactate and 20.3% sodium diluted to 60%.

Newman Zone emulsified oil includes 46% soybean oil and 4% lactate by weight, with emulsifiers and stabilizers.

CarBstrate also includes macro- and micro-nutrients for microbial growth.

Source for hydrogen equivalents: *Final Protocol for In Situ Bioremediation of Chlorinated Solvents Using Edible Oil*, Air Force Center for Engineering and the Environment (AFCEE) October 2007 and *Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents*; AFCEE 2004.

Amendment prices (per pound) based on cost delivered.

Specific density (g/ml) of liquid amendments: sodium lactate = 1.323; ethyl lactate = 1.03; Newman Zone = 0.98.

Table 6 - Emulsified Oil Injection Application Calculations and Estimated Costs
Schwerin Concaves
Walla Walla, Washington

# of Probes	Calculations per Probe									Total Calculations for Probe Grouping			
	Probe Depth in Feet	Saturated Inverval in Feet	Injection Interval in Feet	Injection Radius in Feet	Treatment Volume in cf	Treatment Volume in Gallons	Effective Pore Volume in Gallons	Amendment Concentration in %	Oil Volume in Gallons	Total Oil Volume in Gallons	Total Totes	Total Injection in Gallons	Injected Pounds
12	50	25	20	15	14,137	105,746	21,149	3%	634	7,614	29.3	253,790	61,495
3	45	20	15	15	10,603	79,309	15,862	3%	476	1,428	5.5	47,586	11,530
12	45	20	15	15	10,603	79,309	15,862	2%	317	3,807	14.6	190,343	30,748
19	45	20	15	15	10,603	79,309	15,862	1%	159	3,014	11.6	301,376	24,342
1	45	20	15	20	18,850	140,995	28,199	1%	282	282	1.1	28,199	2,278
7	40	20	15	15	10,603	79,309	15,862	2%	317	2,221	8.5	111,033	17,936
									Totals	**18,365**	**71**	**932,327**	**148,329**
										TOTAL AMENDMENT COST		**$177,995**	

Notes:
Effective Pore Volume = 0.20 x Total Treatment Volume.
cf = cubic feet.
1 cf = 7.48 gallons.
Amendment Cost assumes $1.20 per pound for emulsified oil.

Table 7 - EHC Injection Application Calculations and Estimated Costs
Schwerin Concaves
Walla Walla, Washington

		Calculations per Probe										Totals for Probe Grouping			
Zone	**# of Probes**	**Probe Depth**	**Saturated Inverval**	**Injection Interval**	**Injection Radius**	**Treatment Volume**		**Total Pore Volume**		**Final EHC Mass in Soil**	**EHC Mass**	**EHC in Slurry**	**Total EHC Mass**	**Total Water Injected**	**Total Slurry Injection**
		in Feet	**in Feet**	**in Feet**	**in Feet**	**in cf**	**in Gallons**	**in cf**	**in Gallons**	**in %**	**in Pounds**	**in %**	**in Pounds**	**in Gallons**	**in Gallons**
A	33	50	25	25	7.5	4,418	33,046	1,193	8,922	0.10%	909	23%	30,000	12,008	13,986
B	49	45	20	25	7.5	4,418	33,046	1,193	8,922	0.20%	1,224	23%	60,000	24,016	27,971
C	70	40	20	20	7.5	3,534	26,436	954	7,138	0.10%	514	23%	36,000	14,410	16,783
D	260	45	20	25	7.5	4,418	33,046	1,193	8,922	0.50%	346	23%	90,000	36,024	41,957
											Totals		**216,000**	**86,458**	**100,697**
											TOTAL AMENDMENT COST			**$475,200**	

Notes:
Total Pore Volume = 0.27 x Total Treatment Volume.
cf = cubic feet.
1 cf = 7.48 gallons.
Amendment Cost assumes $2.20 per pound for emulsified oil.

Table 8 - Alternative Ranking Evaluation
Schwerin Concaves
Walla Walla, Washington

Factor	Alternative 1 Aggressive *In Situ* Treatment and Monitoring	Alternative 2 Limited *In Situ* Treatment and Monitoring	Alternative 3 Limited Source Removal, *In Situ* Treatment, and Mntg.	Alternative 4 Source Area Soil Removal and Monitoring	Alternative 5 Building Decon., Demolition, and Monitoring
Protectiveness					
Surface Receptors	1	1	3	3	3
Dry Creek	2	2	1	1	1
Groundwater Use	2	2	0	0	1
Soil	2	2	2	2	1
Subtotal:	**7**	**7**	**6**	**6**	**6**
Permanence					
Conversion of site contaminants	2	2	3	1	0
Longevity of treatment	2	2	3	3	2
Precipitation of heavy metals	3	2	0	1	0
Addresses site-wide contaminants	3	2	0	0	0
Addresses off-site contaminants	1	1	0	0	0
Subtotal:	**11**	**9**	**6**	**5**	**2**
Cost					
Initial Costs	0	2	1	1	3
Future Costs	1	1	1	0	0
Actual Cost	$1,176,381	$760,826	$897,501	$990,661	$649,911
Subtotal:	**1**	**3**	**2**	**1**	**3**
Effectiveness Over the Long Term					
Reducing surface mass risks	2	2	3	3	2
Reducing vadose mass risks	2	2	2	2	1
Reducing saturated mass risks	3	3	1	1	1
Subtotal:	**7**	**7**	**6**	**6**	**4**
Management of Short-Term Risks					
Minimize surface receptor impacts	1	1	3	3	2
Minimize Dry Creek impacts	2	2	1	1	2
Minimize future worker	2	2	3	3	2
Minimize implementation worker	1	2	1	1	2
Minimize adverse groundwater impacts	2	2	2	1	1
Minimize methyl-metal creation	3	2	2	3	3
Subtotal:	**11**	**11**	**12**	**12**	**12**

Table 8 - Alternative Ranking Evaluation
Schwerin Concaves
Walla Walla, Washington

Factor	Alternative 1 Aggressive *In Situ* Treatment and Monitoring	Alternative 2 Limited *In Situ* Treatment and Monitoring	Alternative 3 Limited Source Removal, *In Situ* Treatment, and Mntg.	Alternative 4 Source Area Soil Removal and Monitoring	Alternative 5 Building Decon., Demolition, and Monitoring
Technical and Administrative Implementability					
Access	1	2	2	2	3
Logistical ease	1	1	3	3	3
Subtotal:	**2**	**3**	**5**	**5**	**6**
Consideration of Public Concerns					
Truck traffic	2	2	3	0	3
Contaminated media transport	2	2	3	0	2
Noise	0	1	1	1	2
Surface water risks	2	1	1	2	2
Subtotal:	**6**	**6**	**8**	**3**	**9**
Total Evaluation Score:	**45**	**46**	**45**	**38**	**42**

NOTES:
3 = best alternative with regards to other alternatives.
0 = worst alternative with regards to other alternatives.
Mntg. = monitoring.

Table 9 - Cost Analysis of Alternatives
Schwerin Concaves
Walla Walla, Washington

Technology	Quantity	Unit	Unit Costs	Extended Cost		Notes
Alternative 1 - Aggressive *In Situ* Soil and Groundwater Treatment and Monitoring						
Deed Restriction					*$5,000*	Estimated attorney and filing fees
Decontamination Costs, Detailed in Alternative 5					*$106,435*	
Demolition Costs, Detailed in Alternative 5					*$57,076*	
EHC Injection Costs						
Design/Work Plan	1	lump sum	$7,500	$7,500		Hart Crowser estimate and includes recirculation system design.
Utility Locates	1	lump sum	$500	$500		Hart Crowser estimate.
Mobilization/Demobilization	1	lump sum	$1,500	$1,500		Push probe rig, trailer, field truck, and personnel.
Push Probe Drilling	52	days	$2,000	$103,000		Based on Board Longyear estimate, completing 8-10 probes per day.
Driller's Reporting	412	probes	$25	$10,300		Based on Board Longyear charges for extended use of 500 feet of push probe.
EHC Product	216,000	pounds	$2.20	$475,200		Required Washington completion reports.
Injection Equipment Rentals	2	monthly	$2,000	$4,000		Assumed injections based on Table 8 at $1.20 per pound for emulsified oil product.
Field Geologist or Biochemist Oversight for Injections	52	days	$1,200	$62,400		Assumed rental of one 10-channel and one 4-channel injection manifolds.
Adventus Oversight	8	days	$1,000	$8,000		Assumes high pressure diaphragm pump and air compressor rental.
Work Completion Reporting	1	lump sum	$8,000	$8,000		Based on 4 days on-site of driller and injection setup, 3 additional site visits, travel time, and per diem.
EHC Injection Costs Subtotal					*$680,400*	Assumes daily visits for monitoring and adjustments - 80 days. 2 hours per day, $60/hour.
Groundwater Monitoring Events - Quarterly from Baseline through 5 years						
Laboratory Costs	260	samples	$200	$52,000		Assumed analyzing 13 samples quarterly for 5 years, costs based on quote from Test America ($200).
Beneficial Use Protection Laboratory Costs	20	samples	$200	$4,000		Assumes analyzing 4 residential wells annually ($200) with 3% cost inflation per year.
Sampling Labor and ODCs	20	events	$6,000	$120,000		Assuming 20 sampling events, collecting the above samples, costs based on most recent sampling event with 3% cost inflation per year.
Reporting and Project Management	5	years	$9,500	$47,500		Assumes 20 years at $8,500 per year initially, 2 data reports per year and project management. Price adjusted annually to include 3% inflation.
Groundwater Monitoring Events - Annual for Years 6 through 10						
Laboratory Costs	65	samples	$232	$15,080		Assumed analyzing 13 samples annually, costs based on quote from Test America ($200) with 3% cost inflation per year.
Beneficial Use Protection Laboratory Costs	20	samples	$232	$4,640		Assumes analyzing 4 residential wells annually ($200) with 3% cost inflation per year.
Sampling Labor and ODCs	5	events	$7,000	$35,000		Assuming 5 sampling events, collecting the above samples, costs based on most recent sampling event with 3% cost inflation per year.
Reporting and Project Management	5	years	$9,850	$49,250		Assumes 5 years at $9,850 initially, includes two data reports per year and project management. Price adjusted annually to include 3% inflation.
Groundwater Monitoring Costs Subtotal					*$327,470*	
Estimated Total Cost - Aggressive *In Situ* Soil and Groundwater Treatment and Monitoring					**$1,176,381**	
Alternative 2 - Limited *In Situ* Soil and Groundwater Treatment and Monitoring						
Deed Restriction					*$5,000*	Estimated attorney and filing fees
Decontamination Costs, Detailed in Alternative 5					*$106,435*	
Demolition Costs, Detailed in Alternative 5					*$57,076*	
Emulsified Oil Injection Costs						
Design/Work Plan	1	lump sum	$7,500	$7,500		Hart Crowser estimate.
Utility Locates	1	lump sum	$500	$500		Hart Crowser estimate.
Mobilization/Demobilization	4	lump sum	$1,500	$6,000		Push probe rig, trailer, field truck, and personnel.
Push Probe Drilling and Materials	8	days	$2,000	$16,000		Based on Board Longyear estimate, completing 8 probes per day and one day for mob/demob.
Extended-Use Probe Rental	1	lump sum	$1,000	$1,000		Based on Board Longyear charges for extended use of 500 feet of push probe.
Driller's Reporting	54	probes	$25	$1,350		Required Washington completion reports.
Emulsified Oil Product	148,329	pounds	$1.20	$177,995		Assumed injections based on Table 6 at $1.20 per pound for emulsified oil product.
Injection Equipment Rentals	3	monthly	$4,500	$13,500		Assumed rental of two 10-channel and one 4-channel injection manifolds.
Air compressor rental	3	monthly	$600	$1,800		Assumes high pressure diaphragm pump and air compressor rental.
Field Geologist or Biochemist Oversight for Injections	18	days	$1,200	$21,600		Based on 8 days on-site of driller and injection setup, 3 additional site visits, travel time, and per diem.
Local Contractor Daily Visits	80	days	$120	$9,600		Assumes daily visits for monitoring and adjustments - 80 days. 2 hours per day, $60/hour.
Work Completion Reporting	1	lump sum	$8,000	$8,000		Hart Crowser estimate.
Emulsified Oil Injection Costs Subtotal					*$264,845*	
Groundwater Monitoring Events - Quarterly from Baseline through 5 years						
Laboratory Costs	260	samples	$200	$52,000		Assumed analyzing 13 samples quarterly for 5 years, costs based on quote from Test America ($200).
Beneficial Use Protection Laboratory Costs	20	samples	$200	$4,000		Assumes analyzing 4 residential wells annually ($200) with 3% cost inflation per year.
Sampling Labor and ODCs	20	events	$6,000	$120,000		Assuming 20 sampling events, collecting the above samples, costs based on most recent sampling event with 3% cost inflation per year.
Reporting and Project Management	5	years	$9,500	$47,500		Assumes 20 years at $8,500 per year initially, 2 data reports per year and project management. Price adjusted annually to include 3% inflation.

Table 9 - Cost Analysis of Alternatives
Schwerin Concaves
Walla Walla, Washington

Technology	Quantity	Unit	Unit Costs	Extended Cost		Notes
Groundwater Monitoring Events - Annual for Years 6 through 10						
Laboratory Costs	65	samples	$232	$15,080		Assumed analyzing 13 samples annually, costs based on quote from Test America ($200) with 3% cost inflation per year.
Beneficial Use Protection Laboratory Costs	20	samples	$232	$4,640		Assumes analyzing 4 residential wells annually ($200) with 3% cost inflation per year.
Sampling Labor and ODCs	5	events	$7,000	$35,000		Assuming 5 sampling events, collecting the above samples, costs based on most recent sampling event with 3% cost inflation per year.
Reporting and Project Management	5	years	$9,850	$49,250		Assumes 5 years at $9,850 initially, includes two data reports per year and project management. Price adjusted annually to include 3% inflation.
Groundwater Monitoring Costs Subtotal					*$327,470*	
Estimated Total Cost - Limited *In Situ* Soil and Groundwater Treatment and Monitoring					**$760,826**	
Alternative 3 - Limited Source Area Soil Removal and *In Situ* Source Area Treatment and Monitoring						
Deed Restriction					*$5,000*	Estimated attorney and filing fees
Decontamination Costs, Detailed in Alternative 5					*$106,435*	
Demolition Costs, Detailed in Alternative 5					*$57,076*	
Limited Removal of Source Area Soils						
Design/Work Plan	1	lump sum	$5,000	$5,000		Hart Crowser estimate.
Mobilization/Demobilization	1	lump sum	$3,500	$3,500		Dump boxes, excavator, dump truck, field truck, and personnel.
Waste Characterization of Soil Removed	1	lump sum	$3,000	$3,000		Hart Crowser estimate.
Excavation of Contaminated Soils	600	tons	$20	$12,000		Based on areas and depths shown on Figure 11 and Hart Crowser estimate.
Transportation and Disposal of Hazardous Waste	600	tons	$200	$120,000		Based on areas and depths shown on Figure 11 and Quote from Clearwater.
Engineering Oversight	3	days	$1,500	$4,500		Hart Crowser daily rate, including per diem, supply/equipment charges, and project manager support.
Reporting	1	lump sum	$6,000	$6,000		Hart Crowser estimate.
Removal of Source Area Soils Costs Subtotal					*$154,000*	
Groundwater Recirculation in Source Area Soils and Groundwater						
Design/Work Plan	1	lump sum	$6,000	$6,000 *		Hart Crowser estimate.
Clean Backfill Delivery and Compaction.	600	tons	$25	$15,000		Based on areas and depths shown on Figure 11 and Hart Crowser estimate.
Installation of Infiltrations Gallery (includes materials)	1	lump sum	$5,000	$5,000		Hart Crowser estimate.
Ethyl Lactate Material	12,000	pounds	$2.20	$26,400		Based on areas and depths shown on Figure 11 and Hart Crowser estimate.
Biochemist Engineer Monthly Injections for 2 years	24	monthly	$2,600	$62,400 *		Hart Crowser estimate.
Groundwater Recirculation Equipment Rental	24	monthly	$3,000	$72,000		Hart Crowser estimate.
Reporting	1	lump sum	$6,000	$6,000 *		Hart Crowser estimate.
Groundwater Monitoring Costs Subtotal					*$192,800*	
Groundwater Monitoring Events - Quarterly from Baseline through 5 years						
Laboratory Costs	260	samples	$200	$52,000		Assumed analyzing 13 samples quarterly for 5 years, costs based on quote from Test America ($200).
Beneficial Use Protection Laboratory Costs	20	samples	$200	$4,000		Assumes analyzing 4 residential wells annually ($200) with 3% cost inflation per year.
Sampling Labor and ODCs	20	events	$6,000	$120,000		Assuming 20 sampling events, collecting the above samples, costs based on most recent sampling event with 3% cost inflation per year.
Reporting and Project Management	5	years	$9,500	$47,500		Assumes 20 years at $8,500 per year initially, includes two data reports per year and project management. Price adjusted annually to include 3% inflation.
Groundwater Monitoring Events - Bi-Annually for Years 6 through 10						
Laboratory Costs	130	samples	$232	$30,160		Assumed analyzing 13 samples annually, costs based on quote from Test America ($200) with 3% cost inflation per year.
Beneficial Use Protection Laboratory Costs	40	samples	$232	$9,280		Assumes analyzing 4 residential wells annually ($200) with 3% cost inflation per year.
Sampling Labor and ODCs	10	events	$7,000	$70,000		Assuming 5 sampling events, collecting the above samples, costs based on most recent sampling event with 3% cost inflation per year.
Reporting and Project Management	5	years	$9,850	$49,250		Assumes 5 years at $9,850 initially, includes two data reports per year and project management. Price adjusted annually to include 3% inflation.
Groundwater Monitoring Costs Subtotal					*$382,190*	
Estimated Total Cost for Limited Source Area Soil Removal and *In Situ* Source Area Treatment and Monitoring					**$897,501**	
Alternative 4 - Source Area Soil Removal and Monitoring						
Deed Restriction					*$5,000*	Estimated attorney and filing fees
Decontamination Costs, Detailed in Alternative 5					*$106,435*	
Demolition Costs, Detailed in Alternative 5					*$57,076*	
Removal of Source Area Soils						
Design/Work Plan	1	lump sum	$5,000	$5,000		Hart Crowser estimate.
Mobilization/Demobilization	1	lump sum	$3,500	$3,500		Dump boxes, excavator, dump truck, field truck, and personnel.
Waste Characterization of Soil Removed	1	lump sum	$3,000	$3,000		Hart Crowser estimate.
Excavation of Contaminated Soils	1,250	tons	$20	$25,000		Based on areas and depths shown on Figure 11 and Hart Crowser estimate.
Transportation and Disposal of Hazardous Waste	1,250	tons	$200	$250,000		Based on areas and depths shown on Figure 11 and Quote from Clear Water.

Table 9 - Cost Analysis of Alternatives
Schwerin Concaves
Walla Walla, Washington

Technology	Quantity	Unit	Unit Costs	Extended Cost		Notes
Clean Backfill Delivery and Compaction.	1,250	tons	$25	$31,250		Based on areas and depths shown on Figure 11 and Hart Crowser estimate.
Engineering Oversight	10	days	$1,500	$15,000		Hart Crowser daily rate, including per diem, supply/equipment charges, and project manager support.
Reporting	1	lump sum	$8,000	$8,000		Hart Crowser estimate.
Removal of Source Area Soils Costs Subtotal					*$340,750*	
Groundwater Monitoring Events - Annually for 20 Years						
Laboratory Costs	260	samples	$200	$70,000 *		Assumed analyzing 13 samples annually, costs based on quote from Test America ($200) with 3% cost inflation per year.
Beneficial Use Protection Laboratory Costs	80	samples	$200	$21,000 *		Assumes analyzing 4 residential wells annually ($200) with 3% cost inflation per year.
Sampling Labor and ODCs	20	events	$6,000	$162,000 *		Assuming 20 sampling events, collecting the above samples, costs based on most recent sampling event with 3% cost inflation per year.
Reporting and Project Management	20	years	$8,500	$228,400 *		Assumes 20 years at $8,500 per year initially, includes two data reports per year and project management. Price adjusted annually to include 3% inflation.
Groundwater Monitoring Costs Subtotal					*$481,400*	
Estimated Total Cost - Source Area Soil Removal and Monitoring					**$990,661**	
Alternative 5 - Building Decontamination, Demolition, and Monitoring						
Deed Restriction					*$5,000*	Estimated attorney and filing fees
Building Decontamination Costs						
Design/Work Plan	1	lump sum	$11,000	$11,000		Hart Crowser estimate.
Utility Locates	1	lump sum	$500	$500		Hart Crowser estimate.
Mobilization/Demobilization	1	lump sum	$3,000	$3,000		Dump boxes, Excavator, dump truck, field truck, and personnel.
Public Notification (warning signs, caution tape)	1	lump sum	$200	$200		Includes perimeter caution tape and hazard signs.
Waste Characterization of Unknown Containers as per Inventory	1	lump sum	$8,000	$8,000		Clearwater quote, includes all labor and laboratory analytical testing.
Consolidating Waste and Transportation for Disposal Per Inventory	1	lump sum	$20,000	$20,000		Clearwater quote, includes consolidation and packaging of waste, transportation of all waste in two roll-off boxes.
Disposal of F006 Waste	17	tons	$185	$3,145		Clearwater quote, includes consolidation and packaging of all waste in two roll-off boxes, transportation included in previous line item.
Disposal of IDW Soil/Water	30	drums	$175	$5,250		Clearwater quote, includes 30 IDW drums currently staged at the facility, RCRA Stabilization/Solidification, transportation included above.
Disposal of containers/debris from consolidation	12	yards	$220	$2,640		Clearwater quote, includes 3all container, tanks, and apparatus containing waste, RCRA Macro Encapsulation, transportation included above.
Demolition of Former Plating Vaults and Contaminated Concrete	1	lump sum	$18,000	$18,000		Clearwater quote, includes segregation and loading of hazardous and non-hazardous wastes and transportation to disposal facility.
Disposal of F006 Hazardous Waste	100	tons	$185	$18,500		Clearwater quote, includes disposal hazardous wastes, transportation is included in the lump sum price on previous line.
Backfill, Compaction and Repair Surface Area Removed.	100	tons	$24	$2,400		Hart Crowser estimate based on backfilling and compaction of the area immediately surrounding the vaults.
Per-diem and misc expenses.	12	man-days	$150	$1,800		Clearwater quote, based on estimated number of days in the field to complete the work.
Engineering Oversight	4	days	$1,500	$6,000		Hart Crowser daily rate, including per diem, supply/equipment charges, and project manager support.
Reporting	1	lump sum	$6,000	$6,000		Hart Crowser estimate.
Building Decontamination Costs Subtotal					*$106,435*	
Building Demolition Costs						
Demolition of Remaining Non-Contaminated Structure	1	lump sum	$25,000	$25,000		Clearwater quote, includes segregation and loading of hazardous and non-hazardous wastes and transportation to disposal facility.
Transportation and Disposal of Non-Contaminated Concrete	368	tons	$32	$11,776		Clearwater quote, includes segregation and loading of hazardous and non-hazardous wastes.
Transportation and Disposal of Roofing Material and Non-Haz Demolition Debris	100	tons	$65	$6,500		Clearwater quote, disposal of roofing material and non-hazardous general demolition debris.
Per-diem and misc expenses.	12	man-days	$150	$1,800		Clearwater quote, based on estimated number of days in the field to complete the work.
Engineering Oversight	4	days	$1,500	$6,000		Hart Crowser daily rate, including per diem, supply/equipment charges, and project manager support.
Reporting	1	lump sum	$6,000	$6,000		Hart Crowser estimate.
Building Demolition Costs Subtotal					*$57,076*	
Groundwater Monitoring Events - Annually for 20 Years						
Laboratory Costs	260	samples	$200	$70,000 *		Assumed analyzing 13 samples annually, costs based on quote from Test America ($200) with 3% cost inflation per year.
Beneficial Use Protection Laboratory Costs	80	samples	$200	$21,000 *		Assumes analyzing 4 residential wells annually ($200) with 3% cost inflation per year.
Sampling Labor and ODCs	20	events	$6,000	$162,000 *		Assuming 20 sampling events, collecting the above samples, costs based on most recent sampling event with 3% cost inflation per year.
Reporting and Project Management	20	years	$8,500	$228,400 *		Assumes 20 years at $8,500 per year initially, 2 data reports per year and project management. Price adjusted annually to include 3% inflation.
Groundwater Monitoring Costs Subtotal					*$481,400*	
Estimated Total Cost - Building Decontamination, Demolition and Monitoring					**$649,911**	

Notes:

*Extended Costs presented in current dollars and includes 3% inflation when item is expected to extend beyond 5 years.

1. cy = cubic yards.
2. O&M = Operations and Maintenance

Vicinity Map
Schwerin Concaves
Walla Walla, Washington

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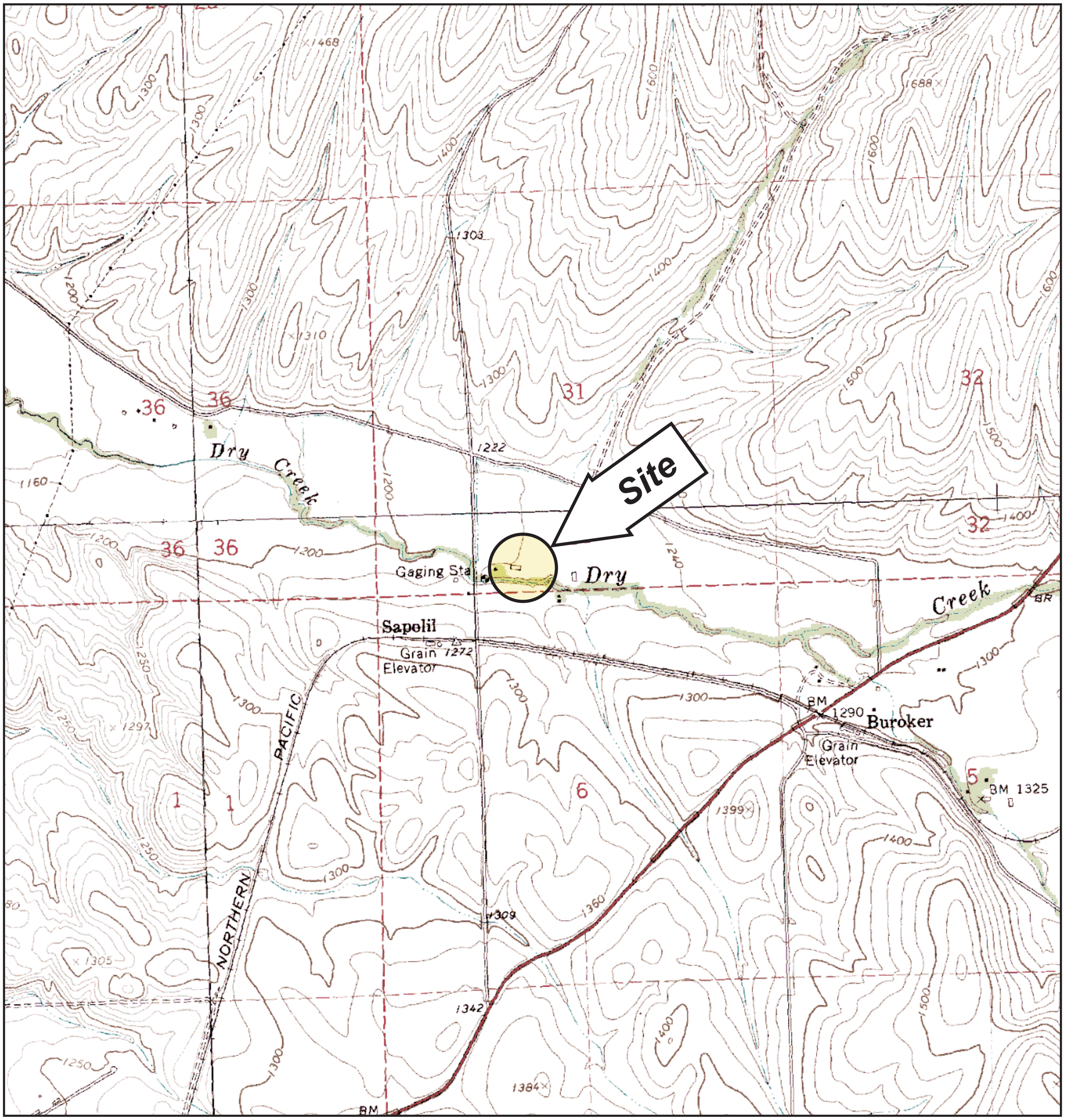

Source: Base map prepared from the USGS 7.5-minute quadrangles of Walla Walla, Buroker, Dixie, and Valley Grove, Washington.

0 2,000 4,000

Scale in Feet

N

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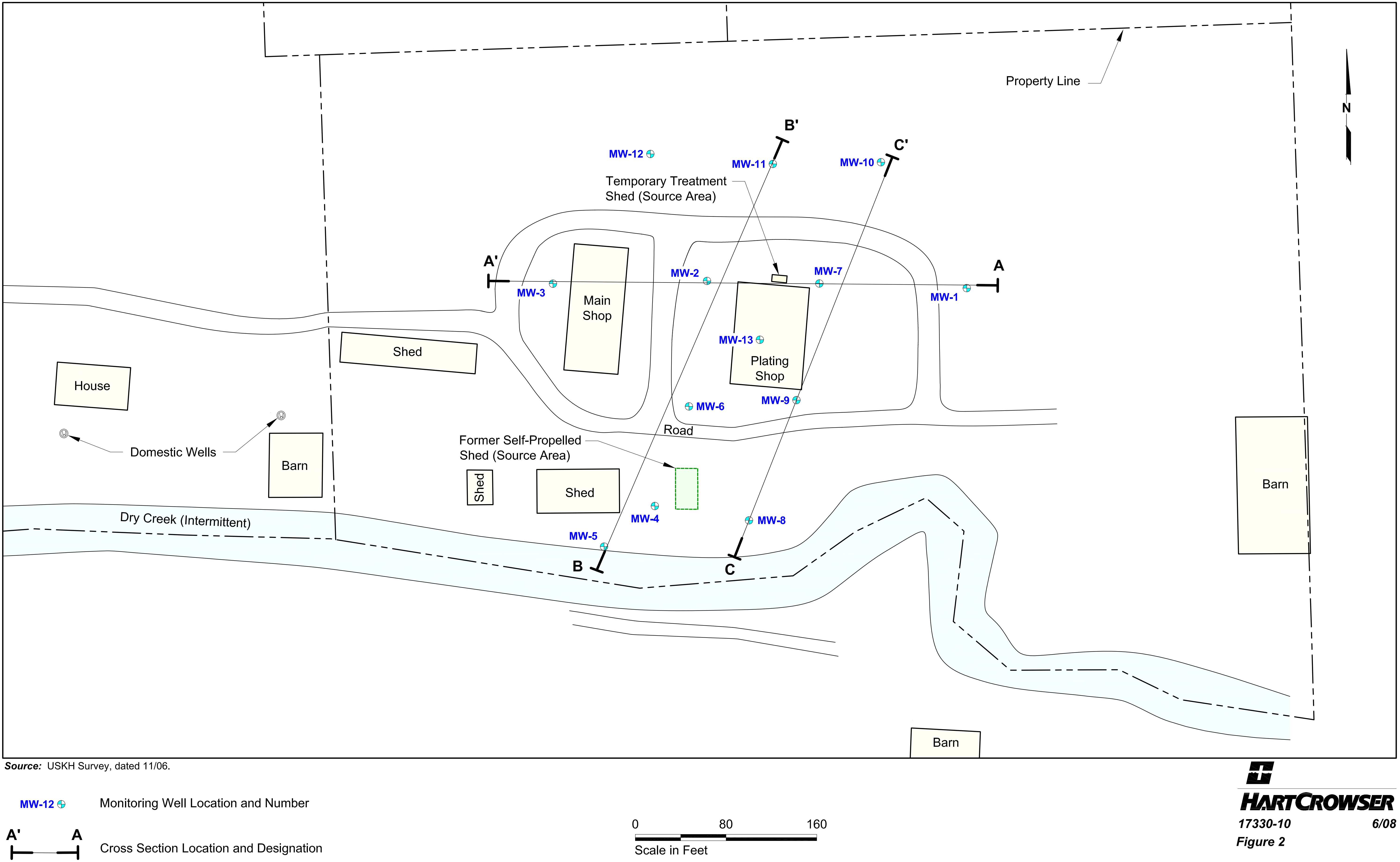
Figure 1

Site and Exploration Plan
Schwerin Concaves
Walla Walla, Washington



Source: USKH Survey, dated 11/06.

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Figure 2

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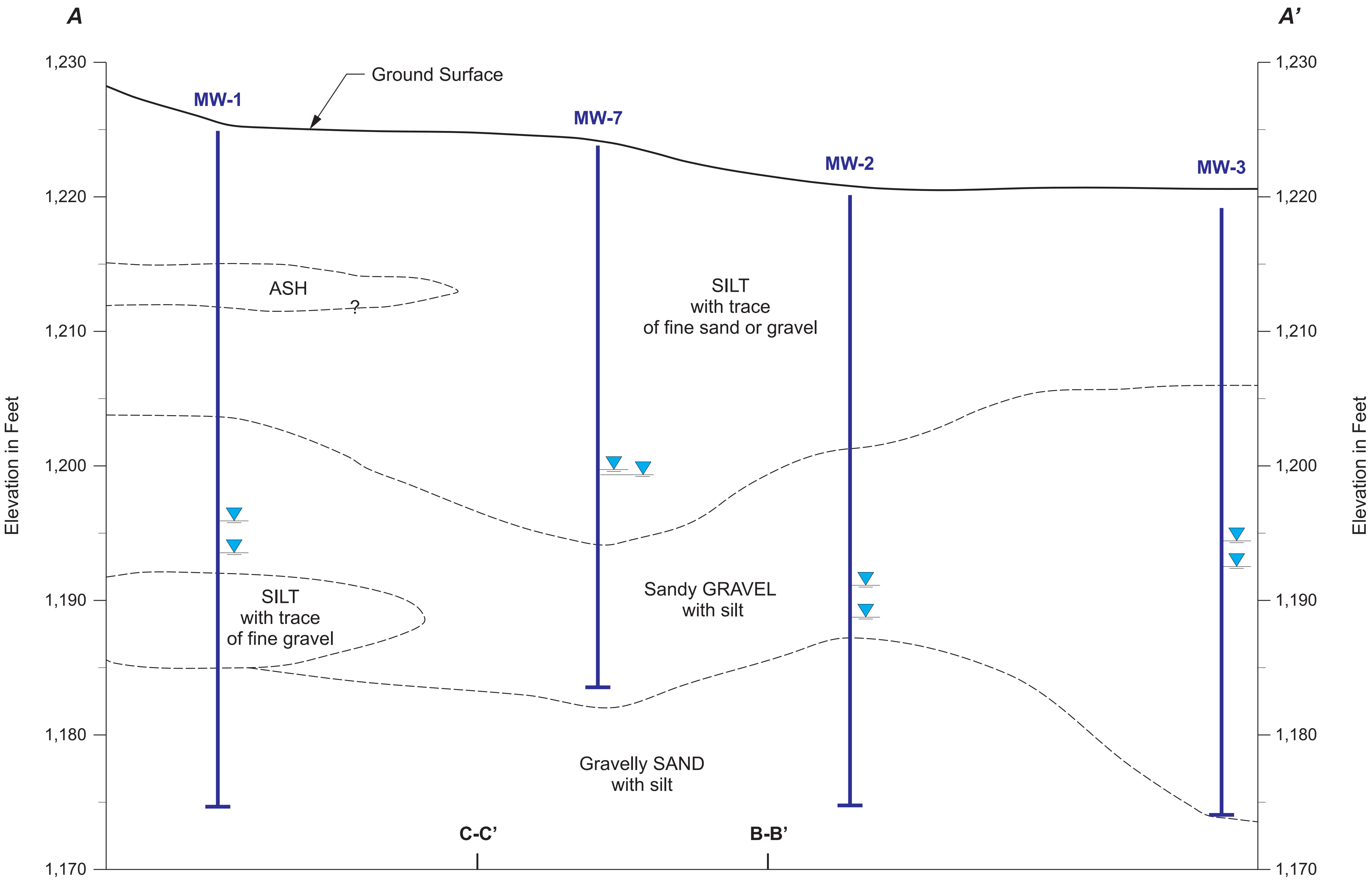
Generalized Subsurface Cross Section A-A’
Schwerin Concaves
Walla Walla, Washington



Note:
Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Source: SAIC Cross Section, dated 6/16/03.

MW-1 Monitoring Well Location and Number

2006-2007 Water Level Maximum

2006-2007 Water Level Minimum

Approximate Horizontal Scale in Feet
0 50 100

0 10 20
Approximate Vertical Scale in Feet
Vertical Exaggeration x 5

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Figure 3

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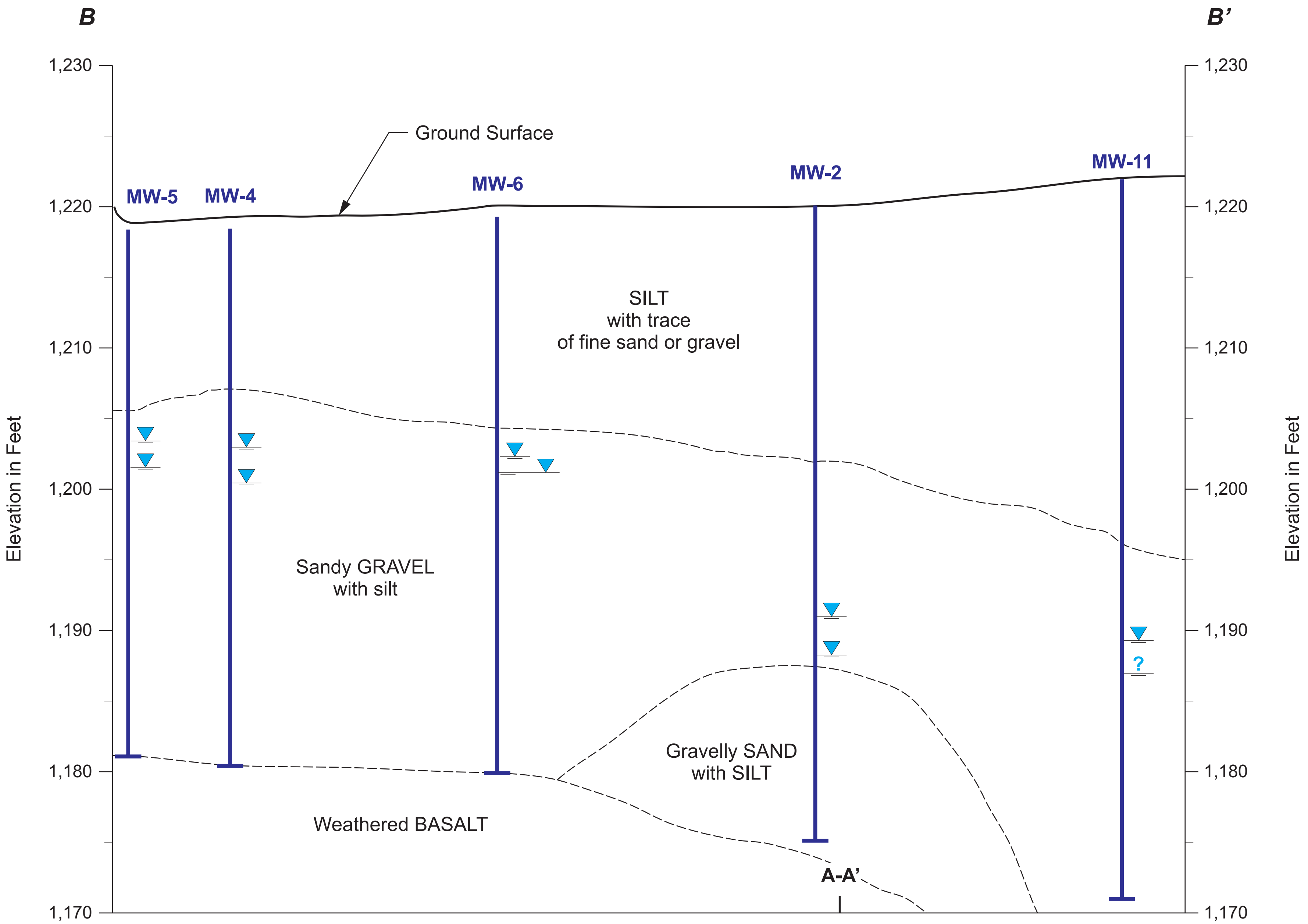
Generalized Subsurface Cross Section B-B’
Schwerin Concaves
Walla Walla, Washington



Note:
Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

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Source: SAIC Cross Section, dated 6/16/03.

MW-4 Monitoring Well Location and Number
▽ 2006-2007 Water Level Maximum
▽ 2006-2007 Water Level Minimum

Approximate Horizontal Scale in Feet
0 50 100

0 10 20
Approximate Vertical Scale in Feet
Vertical Exaggeration x 5

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Figure 4

Generalized Subsurface Cross Section C-C'
Schwerin Concaves
Walla Walla, Washington

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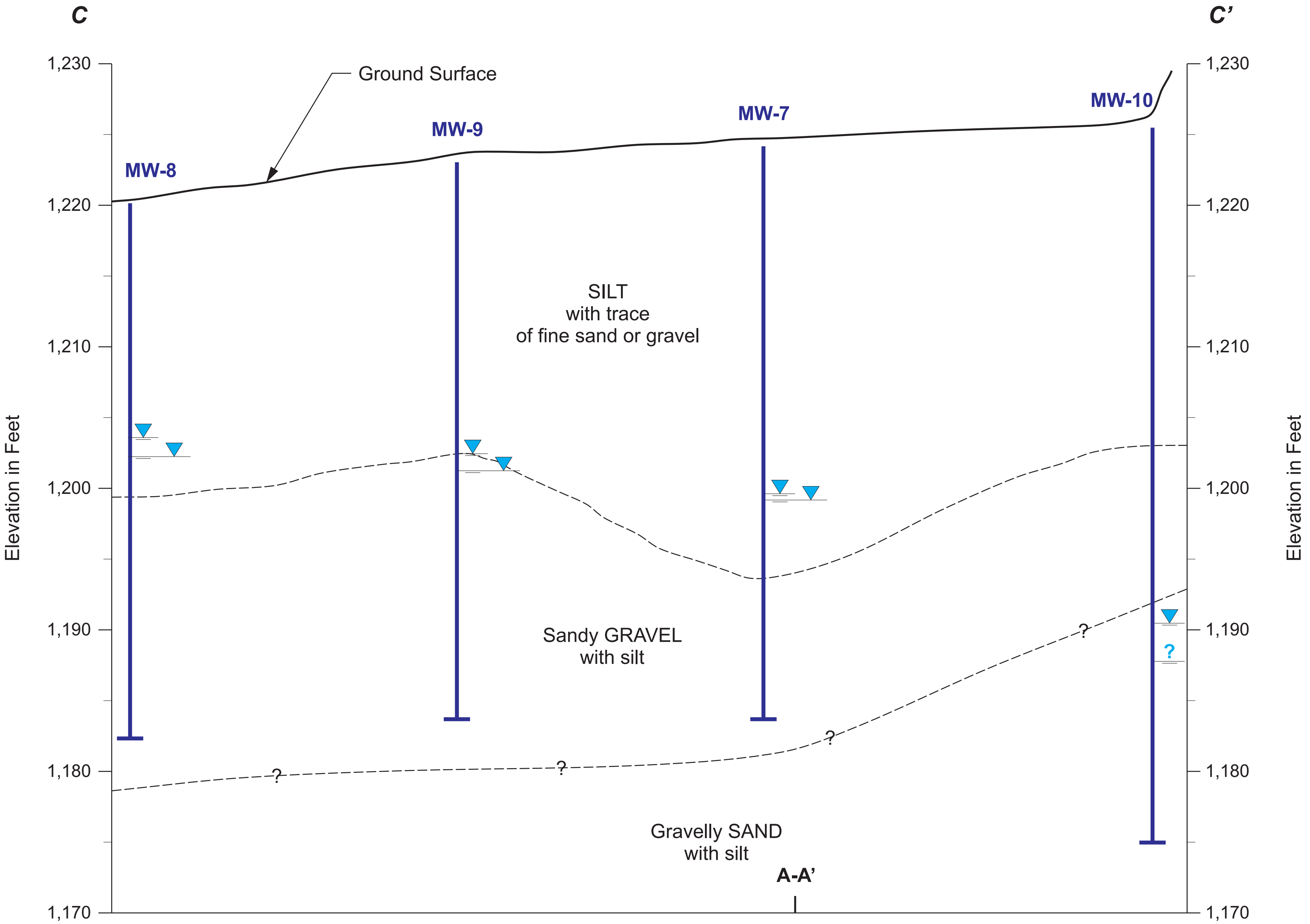

Note:
Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Source: SAIC Cross Section, dated 6/16/03.

MW-7 Monitoring Well Location and Number

▼ 2006-2007 Water Level Maximum

▼ 2006-2007 Water Level Minimum

Approximate Horizontal Scale in Feet
0 50 100

0 10 20
Approximate Vertical Scale in Feet
Vertical Exaggeration x 5

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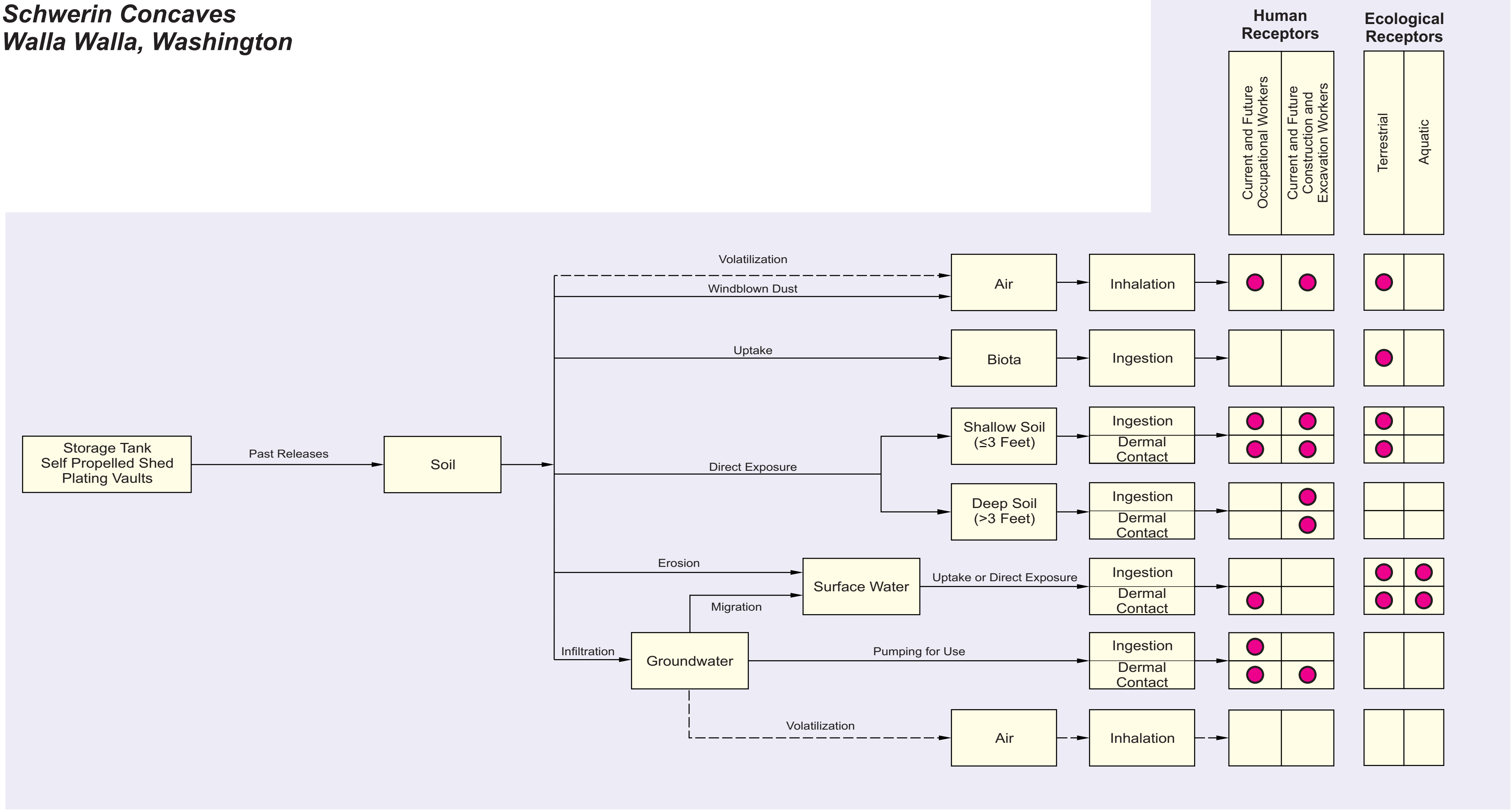
Figure 5

Conceptual Site Model
Schwerin Concaves
Walla Walla, Washington



		Human Receptors		Ecological Receptors	
		Current and Future Occupational Workers	Current and Future Construction and Excavation Workers	Terrestrial	Aquatic
Air	Inhalation	●	●	●	
Biota	Ingestion			●	
Shallow Soil (≤3 Feet)	Ingestion	●	●	●	
	Dermal Contact	●	●	●	
Deep Soil (>3 Feet)	Ingestion		●		
	Dermal Contact		●		
Surface Water	Ingestion			●	●
	Dermal Contact	●		●	●
Groundwater	Ingestion	●			
	Dermal Contact	●	●		
Air	Inhalation				

● Potentially Complete Exposure Pathway

– – – – –► Contaminant Pathway Not Present or Complete

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Figure 6
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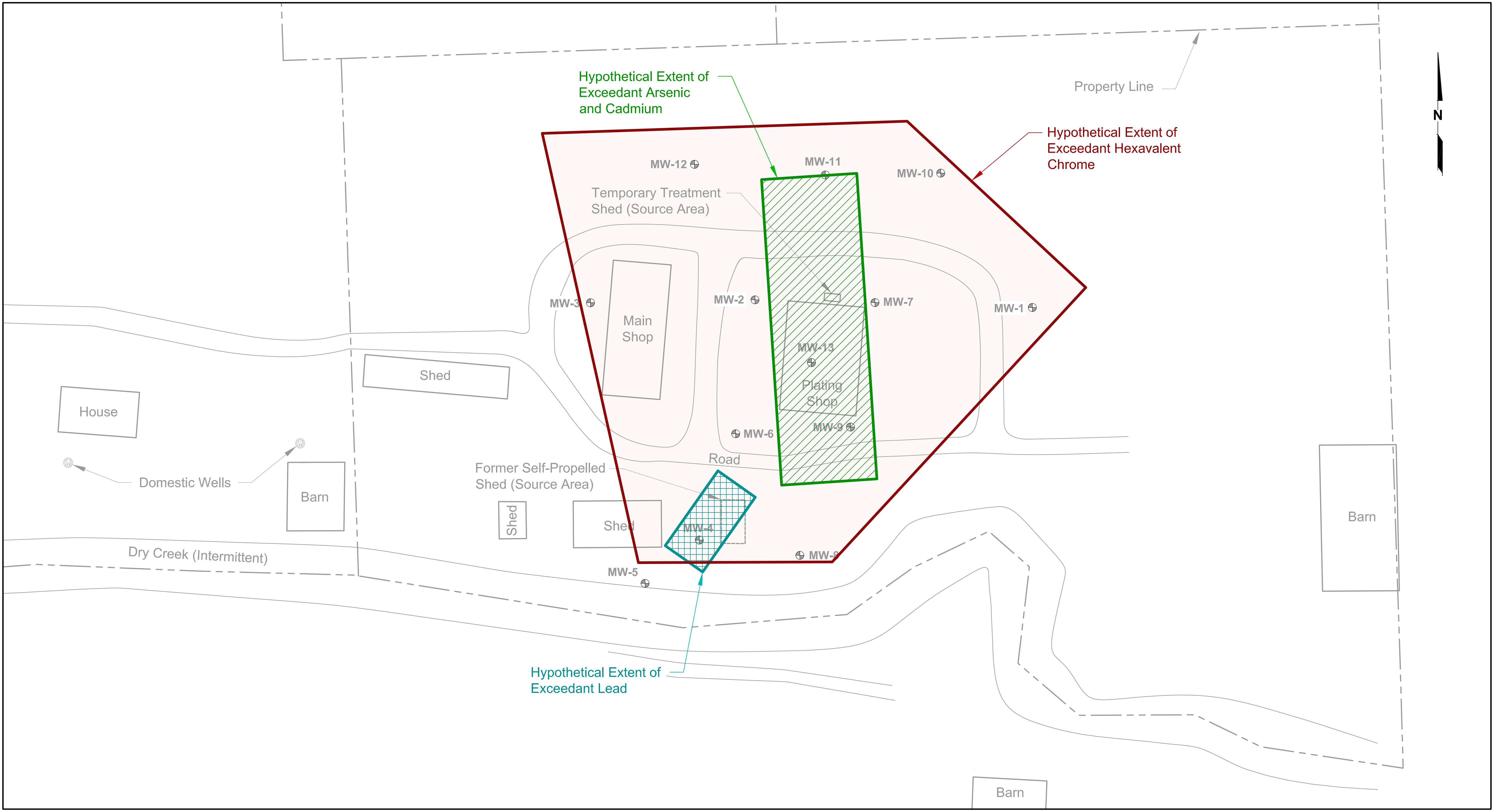
Conceptual Plume Exceeding MTCA Cleanup Levels
Schwerin Concaves
Walla Walla, Washington



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Source: USKH Survey, dated 11/06.

MW-12 ⊕ Monitoring Well Location and Number

0 80 160
Scale in Feet

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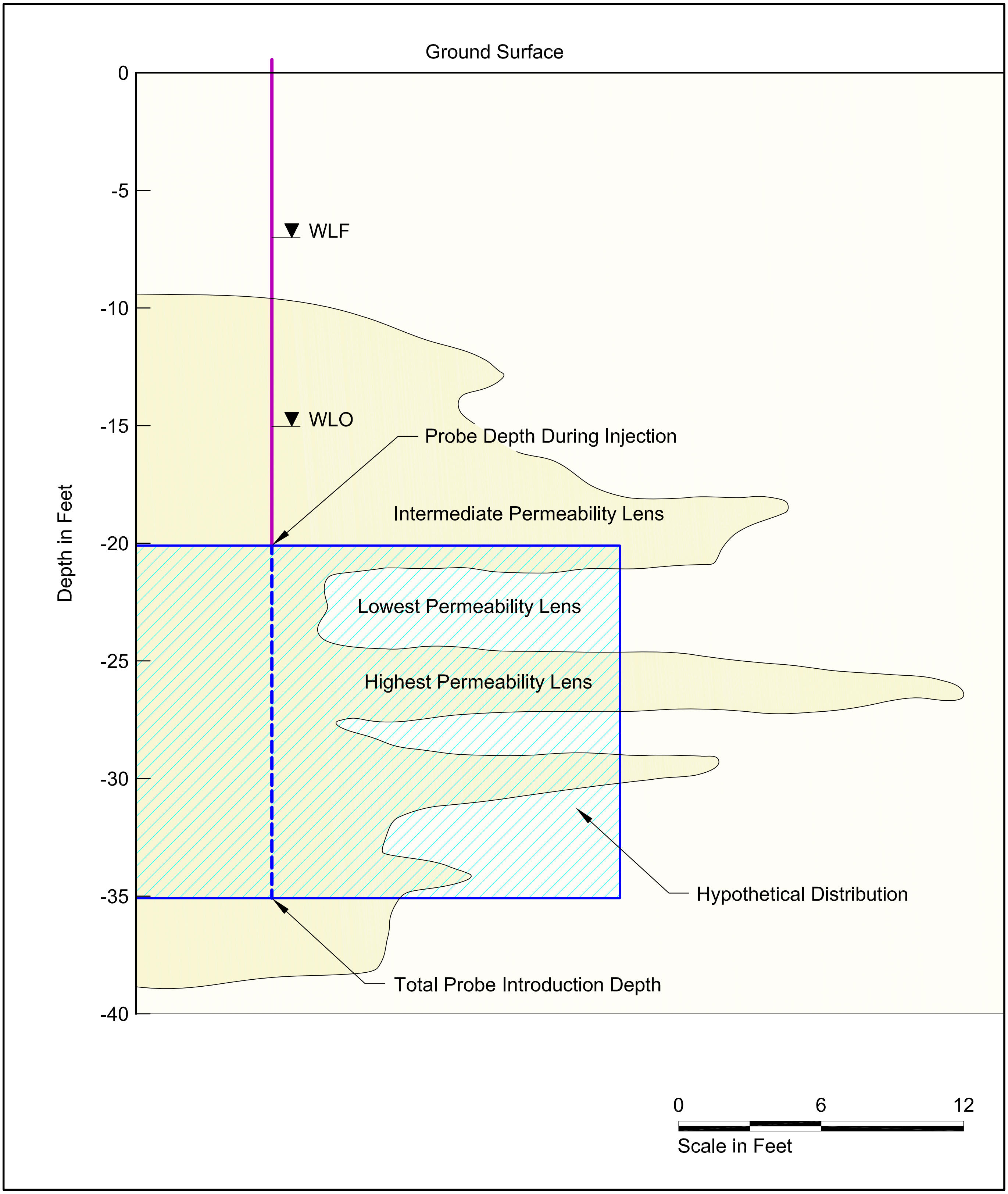
Figure 7

Slug Injection Distribution - Hypothetical Versus Conceptual

Schwerin Concaves
Walla Walla, Washington



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▼ WLO	Pre-Injection Water Level
▼ WLF	Post-Injection Water Level

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Figure 8

Emulsified Oil Injection Layout
Schwerin Concaves
Walla Walla, Washington

Source: USKH Survey, dated 11/06.

MW-12 ⊕ Monitoring Well Location and Number

- - - - - Groundwater Extraction Line

— - — Groundwater Injection Line

Proposed Emulsified Oil Injection Point and Minimum Radius of Distribution

0 50 100

Scale in Feet

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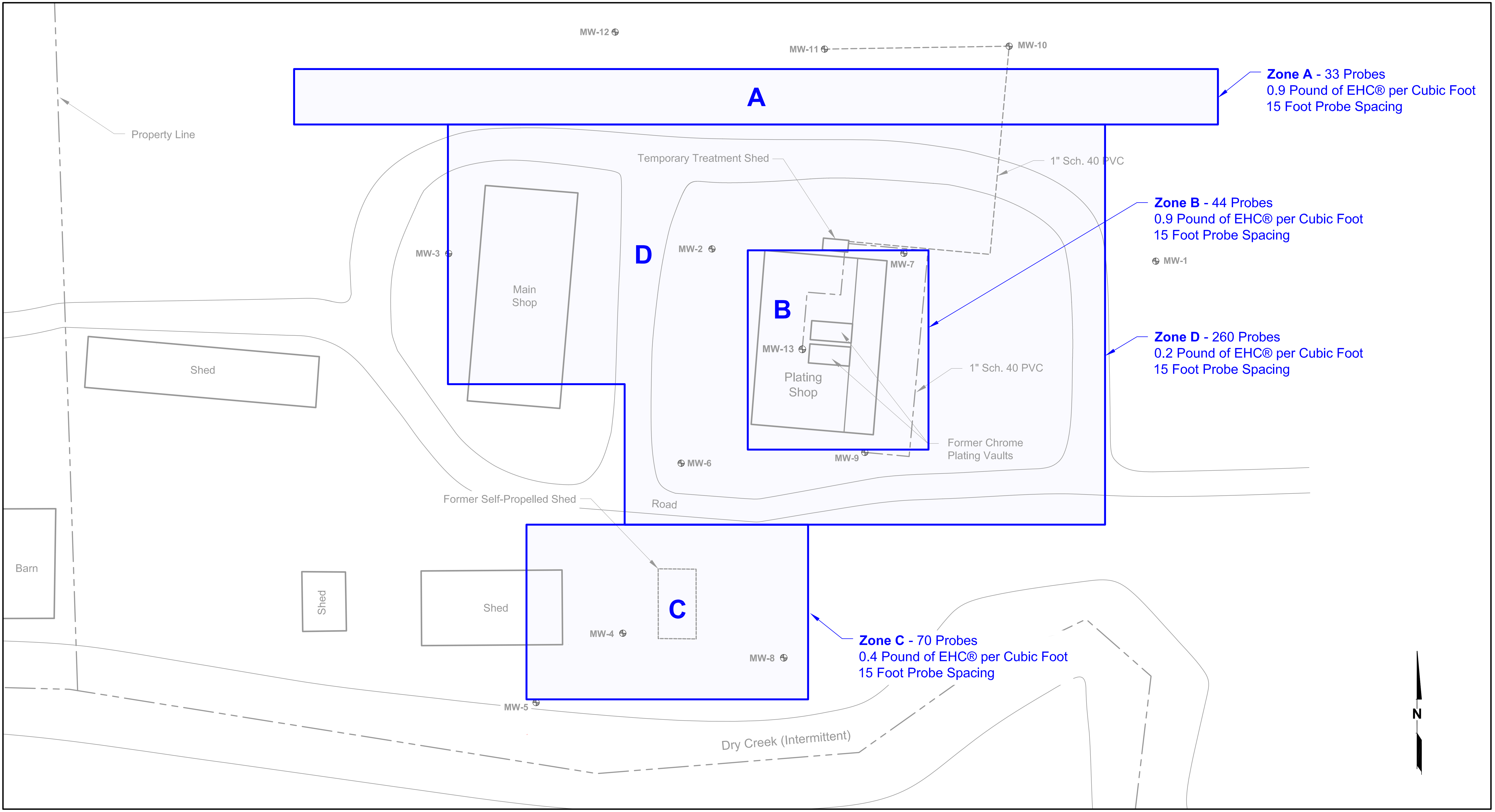
Figure 9

1733010 09 (Em Oil Inject).dwg\1733000 08 (Em Oil Inject).dwg

EHC® Injection Layout
Schwerin Concaves
Walla Walla, Washington



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Source: USKH Survey, dated 11/06.

MW-12 ⊕ Monitoring Well Location and Number

------- Groundwater Extraction Line

— - — Groundwater Injection Line

0 50 100

Scale in Feet

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Figure 10

Soil Excavation Scenarios and Infiltration Gallery
Schwerin Concaves
Walla Walla, Washington

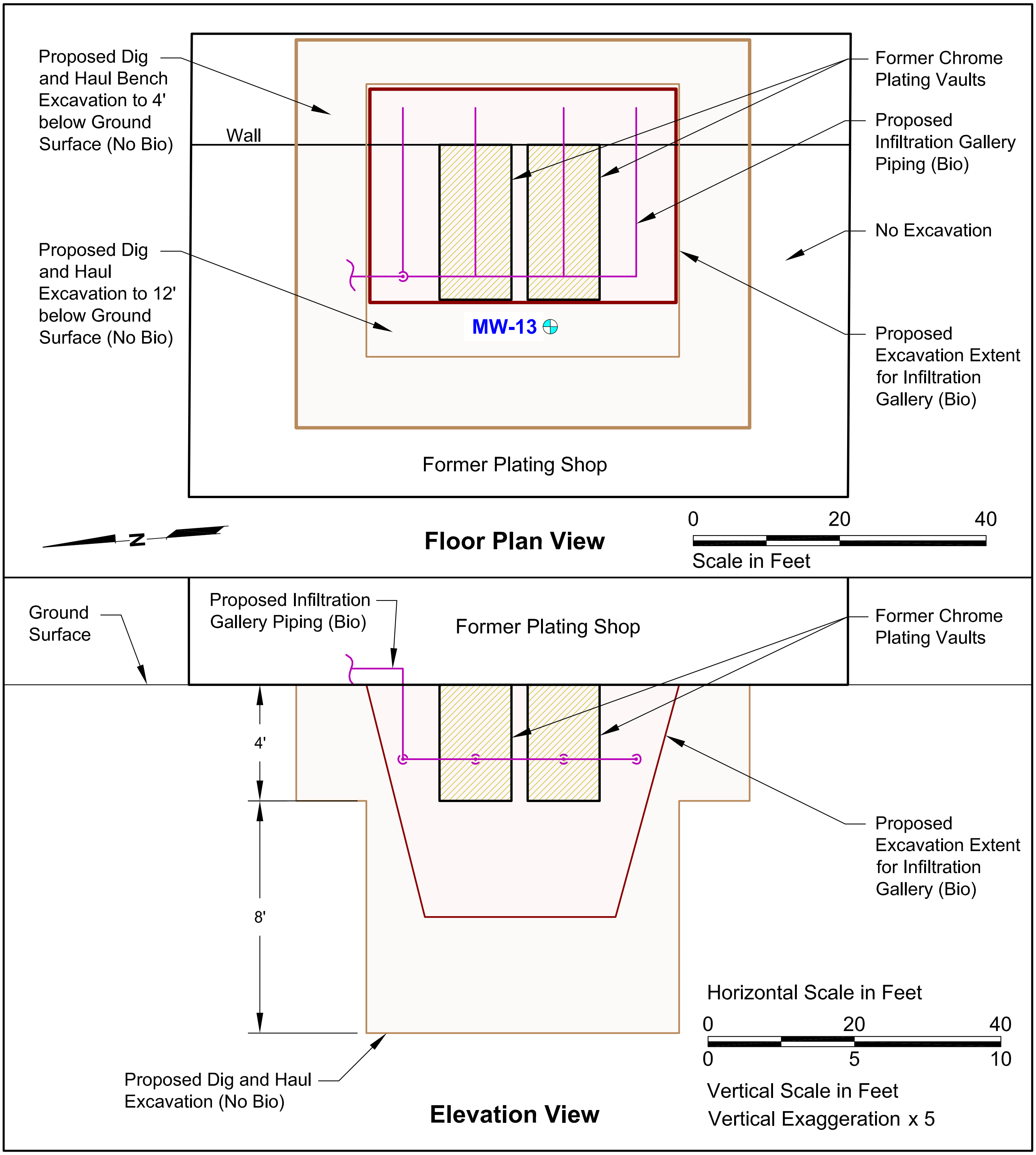

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Figure 11