Final Feasibility Study Report
Hamilton/Labree Roads Groundwater Contamination Superfund Site: Operable Unit 1
Hamilton Road Impacted Area
Chehalis, Washington

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Prepared for:
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Region 10
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Acronyms

AB	auger boring
AES	Architect and Engineering Services
AOC	Administrative Order on Consent
ARARs	applicable or relevant and appropriate requirements
bgs	below ground surface
BLRA	baseline risk assessment
BMP	best management practice
CC	Creek Channel
CDM Smith	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CG	Commercial General
cis-1,2-DCE	cis-1,2-dichloroethylene
cm/s	centimeters per second
COPCs	contaminants of potential concern
CSM	conceptual site model
CTS	comprehensive technology scenario
CVOCs	chlorinated volatile organic compounds
cy	cubic yards
DNAPL	dense non-aqueous phase liquid
DNR	Department of Natural Resources
DOT	Department of Transportation
DPT	direct-push technology
EAB	in-situ enhanced anaerobic bioremediation
Ecology	Washington State Department of Ecology
E&E	Ecology & Environment
EE/CA	engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
ERH	electrical resistance heating
ERT	Emergency Response Team
EVO	emulsified vegetable oil
°F	degrees Fahrenheit
Farallon	Farallon Consulting, L.L.C.
FS	feasibility study
FRTR	Federal Remediation Technologies Roundtable
ft/ft	foot per foot
>	greater than
gm/cc	grams per cubic centimeter
GAC	granular activated carbon
GCL	geosynthetic clay liner

GeoEngineers	GeoEngineers, Inc.
Geo-Recon	Geo-Recon International
GP	Geoprobe
gpm	gallons per minute
GRA	general response action
GWRTAC	Ground-Water Remediation Technologies Analysis Center
H_2O_2	hydrogen peroxide
HC	high concentration groundwater
HDPE	high density polyethylene
HI	hazard index
HQ	hazard quotient
HRIA	Hamilton Road Impacted Area
HSA	hollow stem auger
I-5	Interstate 5
ICs	institutional controls
ISCO	in-situ chemical oxidation
ISTR	in-situ thermal remediation
ITRC	Interstate Technology and Regulatory Council
$KMnO_4$	potassium permanganate
<	less than
LCDPH	Lewis County Department of Public Health
LDRs	Land Disposal Restrictions
L/m^3	liters per cubic meter
MCL	Maximum Contaminant Level
Md	mass discharge
µg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
mg/kg	milligrams per kilogram
MSL	mean sea level
MTCA	Model Toxics Control Act
MVS	Mining Visualization Systems
MW	monitoring well
$Na_2S_2O_8$	sodium persulfate
NAPL	non-aqueous phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NZVI	nanoscale zero-valent iron
O&M	operations and maintenance
ORP	oxidation reduction potential
OU1	Operable Unit 1
OU2	Operable Unit 2

%	percent
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene (also referred to as perchloroethylene)
ppm-v	parts per million by volume
PPE	personal protective equipment
PRG	preliminary remediation goal
PW	private well
RA	remedial action
RAO	remedial action objective
RDD	Residential Rural Development District
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
ROD	record of decision
RSL	EPA Regional Screening Level
SAIC	Science Applications International Corporation
SB	sediment/soil boring
scfm/min	standard cubic feet per minute
SD	creek bed sediment/bank surface soil
SG	soil gas
Site	Hamilton/Labree Roads Groundwater Contamination Superfund Site
START	EPA Superfund Technical Assistance and Response Team
SVE	soil vapor extraction
SW	surface water
TBC	to be considered
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TEG	Transglobal Environmental Geosciences
TMPs	temperature monitoring points
TSCA	Toxic Substances Control Act
U&A	usual and accustomed
UGA	Urban Growth Area
URS	URS Group, Inc.
VC	vinyl chloride
VF	volatilization factor
VOCs	volatile organic compounds
WAC	Washington Administrative Code
WDOH	Washington State Department of Health
ZVI	zero-valent iron

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Section 1

Introduction

1.1 Purpose and Organization

This document presents the feasibility study (FS) for a part of the Hamilton Labree Roads Groundwater Contamination Superfund Site (Site) located in Chehalis, Washington. The FS addresses the portion of the Site known as the Hamilton Road Impacted Area (HRIA) or Operable Unit 1 (OU1). The FS was prepared for the U.S. Environmental Protection Agency (EPA) Region 10 by Parametrix/CDM Federal Programs Corporation (CDM Smith) for Task Order 024 under Region 10 Architect and Engineering Services (AES) (Small Business) Contract No. 68-S7-03-04.

The purpose of this FS is to support the selection of a remedial alternative that addresses the known sources of tetrachloroethlyene (PCE) contamination within the HRIA and that serves as a preliminary component of a comprehensive and dynamic site-wide plume management strategy.

The Site-wide plume management strategy will need to address a small, high-strength source area that likely includes dense nonaqueous phase liquid (DNAPL) contamination in creek sediment/surface soil and subsurface soils; a high-concentration, dissolved contaminant groundwater plume (4,000 to 2,720,000 micrograms/liter [μg/L] PCE (HRIA- OU1); and a large, low-concentration, dissolved contaminant plume (5 to 4,000 μg/L PCE (Operable Unit 2 [OU2]). OU2 includes the Breen Property, the Thurman Berwick Creek Area, and the underlying contaminated groundwater outside of the HRIA (**Figure 1-1**).

EPA intends to address contamination at the Site through a phased approach, beginning with an interim remedial action to address the known sources of PCE contamination to groundwater and prevent risks within the HRIA, and to minimize further migration of contaminated groundwater from the HRIA to downgradient areas. A phased approach to site remediation is the most appropriate when site characterization is not yet complete or when data are not sufficient to develop and evaluate remedial alternatives to address risks posed by the entire site or to determine the long-term objectives (e.g., restoring groundwater to safe drinking water levels). There appears to be other contamination sources at the Site outside (downgradient) of the HRIA; however, additional Site-wide data collection and evaluation is needed to develop, select, and implement other remedial actions for the Site that will achieve long-term protection of human health and the environment.

The work performed during the FS was in accordance with guidance developed by EPA for conducting an FS under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (EPA 1988). In addition, the cost estimates for each alternative were developed in accordance with *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (EPA 2000).

This report presents the results of the development, detailed evaluation, and screening of remedial alternatives to address contaminated media for the HRIA. This report is organized as follows:

- Section 1 discusses the purpose of the FS report, the report organization, and site background information (site location, site description, operational history, previous investigations, and environmental setting).

- Section 2 describes the characteristics of the site in a conceptual site model (CSM) that includes description of the site features and physical characteristics, a summary of the nature and extent of contamination resulting from past activities at the site, and a summary of human health risks posed by site contamination.
- Section 3 describes the rationale for the phased approach to remediation and the process for identifying HRIA remedial action objectives (RAOs) applicable to the HRIA as data continue to be collected for the development of a comprehensive site-wide plume management strategy. This section also identifies potential applicable or relevant and appropriate requirements (ARARs) for the site.
- Section 4 describes the options for general response actions (GRAs) and the screening and evaluation of different remedial technologies and process options.
- Section 5 describes the remedial alternatives.
- Section 6 describes the criteria used to evaluate the alternatives retained, presents a detailed analysis of the remedial alternatives, and summarizes the comparative analysis conducted to compare and contrast the remedial alternatives.
- Section 7 combines the individual remedial technology alternatives into a limited number of comprehensive treatment scenarios (CTS) with respect to best engineering practices with the intent to achieve the interim action RAOs for all impacted media in a cost-effective and sustainable way.
- Section 8 lists the references and documents referred to in this FS.
- **Appendix A** provides a series of figures produced by the Mining Visualization Systems (MVS) modeling of the site.
- **Appendix B** lists the ARARs that affect a remedial action at the site.
- **Appendix C** contains the remedial technologies and process options screening tables.
- **Appendix D** documents the detailed cost information that was used to evaluate the retained alternatives.

1.2 Site Location and Description

The OU-1 Site is about 2 miles south of the City of Chehalis, Washington, near the intersection of North Hamilton Road and Labree Road, west of Interstate 5 (I-5). For a general site map, see **Figure 1-1**. The Site has been divided into two OUs to facilitate the identification and remediation of hazardous substances. OU1, also known as the HRIA, and OU2, which includes all other areas outside of OU1 where hazardous substances have come to be located, including areas referred to as the Breen Property, the Thurman Berwick Creek Area, and the areas west and northwest of Labree Road (**Figure 1-2**). Hazardous substances, primarily PCE and its degradation products, have come to be located in both OUs contaminating sediment, soil, and groundwater.

The boundary between the City of Chehalis and unincorporated Lewis County bisects the site roughly north to south along Labree Road. The HRIA, the Breen Property, and the Thurman Berwick Creek Area are east of Labree Road and within the city limits of Chehalis. The portion of the Site within the

City of Chehalis is zoned for commercial use. The portion of the Site located in Lewis County west of Labree Road is zoned as a rural development district (RDD) and agricultural resource lands. Land uses include agricultural (predominately dairy) and residential uses (CDM Smith 2011a, Appendix C).

The site is located within the Newaukum River Valley and has relatively flat landscape (topography). Berwick Creek flows across the site from southeast to northwest and merges with Dillenbaugh Creek northwest of the Breen Property. Overall, the site slopes downward toward the northwest. Groundwater and surface water flow are generally northwest along the Newaukum River Valley towards the Chehalis River (URS 2004).

1.2.1 OU1 - HRIA

The HRIA is located at the most upgradient portion of the Site. It is about 10 acres in size (**Figure 1-2)**. It is crossed from northwest to southeast by North Hamilton Road and Berwick Creek. North Hamilton Road was built in 1974.

The portion of the HRIA located between North Hamilton Road and I-5 consists of grassy open land that includes Berwick Creek (which flows northwest), overhead power lines, and a wire field fence that prevents access to I-5. Two ditches, referred to as Unnamed Ditch #1 and Unnamed Ditch #2, pass underneath I-5 and intermittently discharge to Berwick Creek. The Washington State Department of Transportation and Lewis County currently own this portion of the HRIA.

The portion of the HRIA west of North Hamilton Road includes property formerly owned by United Rentals Northwest, Inc., which continues to be identified on Site maps as the United Rentals Property. The property is level, with mixed gravel, asphalt, and concrete surfaces, and contains two buildings: the main building and the paint shop. An easement containing buried utilities and a stormwater conveyance system is located between the United Rentals Property and North Hamilton Road.

The United Rentals Property has changed occupants and ownership numerous times since the late 1980s. In 1988, Carl Watson purchased this property, which at the time was a swampy hayfield containing a few old car bodies and empty barrels. The property was graded flat, and a layer of fly ash and about 90 truckloads of rocks were imported to build up the footprint for the subsequent buildings. The main building was built during the winter of 1989/1990.

Beginning in June 1990, a transmission rebuilding company operated at the property under the name Westside Trucking Company. In 1991, Westside Trucking Company changed its name to Gear Box, Inc. and operated under that name until October 1992 when the business closed. The property was sold on May 20, 1993, to E.G.W. Machinery, Inc.; the owner of High Reach, Inc. High Reach, Inc. rented and serviced specialized aerial construction equipment. A second building, known as the paint shop, was built on this property in 1993.

In 1998, High Reach, Inc. was purchased by United Rentals Northwest, Inc. At this location, United Rentals ran a rental and repair service for a variety of construction equipment. United Rentals also operated a small business that painted heavy equipment until 2009 after which the property was vacated. In April 2012, the property was sold to Visitrade, Inc., and in June 2012, Visitrade leased the property to a building materials store named Builder’s Surplus Northwest.

The portion of the HRIA west of North Hamilton Road and south of the United Rentals Property includes a gravel access road and an open, steep-sided drainage ditch originally owned by Warren Willard. In 2007, Mr. Willard sold this property to the McGill Investment Company.

The property south of the McGill property includes a level area covered with gravel and a commercial warehouse next to and south of the gravel area. Up to 4 feet of material, mainly boulders, was used to fill in and level the property before development. The developed property was originally owned by Reginald and Kimberly Hamilton who ran a company named Hamilton Rocking and Contracting Company from the early 1990s to 1997. They shared the property with the Smith Tractor Company until 1997 when Smith Tractor Company became the sole tenant. The Smith Tractor Company rented and sold trucks and construction equipment along with parts for this type of equipment. The company added a wash rack that had a concrete slab floor behind the building in about 1996 and used the gravel area to park tractor-trailers. The property has been sold twice since it was developed and has had a number of tenants. The current owner is Hamilton Road Adventures, which leases the property to Emerald Recreational Vehicles (Emerald RV). Emerald RV buys, sells, and rents RVs and related equipment to the public.

1.2.2 OU2

OU2 includes all other areas outside of the HRIA where hazardous substances have come to be located, including areas referred to in this FS as the Breen Property, the Thurman Berwick Creek Area, and the area west and northwest of Labree Road.

The Breen Property (part of OU2) is located northwest of the HRIA and covers about 11 acres (**Figure 1-2**). The Breen Property was purchased by Sterling (Bud) Breen, Sr., president of the S.C. Breen Construction Company (the Breen Company), in the early 1950s. The property was used for agricultural purposes before it was developed by the Breen Company. By the early 1970s, most of the Breen Property had been cleared of vegetation.

The Breen Property, originally one tax parcel, was subdivided in 1992. It now consists of two separate tax parcels.[1] The western portion of the Breen Property is still owned by the Breen Company and is made up of about 5.75 acres, which includes several wood-framed, steel-clad buildings with concrete floors and open areas between the buildings used for storing trucks and other heavy equipment and construction materials.

One of these buildings, referred to as Building C in this FS, was built in about 1960 on the southwest part of the parcel. This building, referred to then as the "Old Shop," served as the Breen Company's main office and truck maintenance shop until the early 1990s. Since then, Building C has been leased to a number of other companies, including the Roy F. Weston Company (now Weston Solutions, Inc.).

North of Building C was the Breen Surplus store, which began operating in the mid-1960s. Breen Surplus bought and sold a variety of equipment, tools, paints, thinners, and solvents. This store and building no longer exist.

Southeast of Building C is a 24 ft x 28 ft cement slab that was used as a heavy equipment wash-down pad. Based on a review of aerial photographs, this wash-down pad appears to have been constructed between 1966 and 1969. Runoff and sediment from the cleaning operation was collected in a pit, about 5 feet deep, which had been excavated next to the concrete pad. This collection pit has never been located; the wash-down pad is no longer being used.

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[1] For purposes of the FS, the term "Breen Property" refers to both tax parcels.

In 1972, another steel-clad building with a concrete floor, referred to as Building A on Site maps, was built on the north end of the Breen Property. In about 1983, a similar building, referred to as Building B, was constructed on the Breen Property southeast of Building A. In 1995, Bulldog Trailers began, and continues today, to operate out of both buildings making and selling general-purpose utility trailers.

The Breen Company sold the eastern portion of its property to the Chehalis Livestock Market in 1992 (Farallon Consulting, L.L.C. [Farallon] 2003). The parcel is about 4.92 acres in size and is primarily used as a cattle auction facility. It contains a large building, referred to as the Livestock Auction Building, which houses an arena, a café, and offices. Adjacent to this building are livestock pens.

The livestock market opened around 1960. A smaller wood-framed building with a dirt floor is located along the southern boundary (Livestock Shed). This building is mostly used to hold calves and other small livestock before auction. The remainder of this parcel is an unpaved parking area. Berwick Creek runs west along the southern property boundary of this parcel and then runs under North Hamilton Road where it daylights within the Thurman Berwick Creek Area.

1.2.2.1 Thurman Berwick Creek Area

The Thurman Berwick Creek Area (part of OU2) is located in the southeast corner of the intersection of North Hamilton Road and Labree Road, west and downgradient of the HRIA and south of the Breen Property. The Thurman Berwick Creek Area is divided by Berwick Creek into two portions: the northwest portion, which currently contains a residential structure built in 1930, and the southeast portion, which is undeveloped land. Both portions are currently owned by the Balmelli Family Limited Partnership.

1.2.2.2 Downgradient Areas West of Labree Road

This portion of the Site (part of OU2) includes the remaining area within the PCE groundwater plume footprint that is downgradient of the HRIA, the Breen Property, and the Thurman Berwick Creek Area west of Labree Road (**Figure 1-2**). Most of the current land use in this area is farmland, but residential and light commercial uses also occur.

1.3 History of Site-Wide Investigations

In 1993, a business along North Hamilton Road submitted a public water system application for a commercial well. As part of the approval process, the business was required to perform water quality testing, including a test for volatile organic compounds (VOCs). Test results indicated PCE at 122 μg/L in the water sample (the federal and state drinking water Maximum Contaminant Level [MCL] for PCE is 5 μg/L). The discovery of PCE in groundwater led the Lewis County Department of Public Health (LCDPH) to request the Washington State Department of Health (WDOH) investigate groundwater in private and public water-supply wells in the area (WDOH 1999).

In late 1993/early 1994, WDOH sampled 18 private water-supply wells in the area. PCE was detected in six of the 18 water-supply wells, ranging from 3.3 μg/L to 2,165 μg/L (Washington State Department of Ecology [Ecology] 1999a). In response to the findings, LCDPH informed affected well owners of the sampling results and advised them to obtain alternative sources of drinking water (WDOH 1999). Ecology began supplying bottled water to affected well owners for drinking and cooking. In 1996, WDOH re-sampled five of the six PCE-contaminated water supply wells[2] and found that concentrations had increased slightly from those measured in 1993 and 1994 (PCE ranged from 5.75 µg/L to 3,009 µg/L).

In 1996, LCDPH learned from a confidential source that drums containing solvents were buried on the Breen Property. Ecology began an investigation that included a geophysical survey by Geo-Recon International ([Geo-Recon] 1996) and a subsurface investigation by Science Applications International Corporation ([SAIC] 1997). Between October 1997 and July 1998, Ecology sampled monitoring wells quarterly. Some of the monitoring wells were installed by SAIC as part of the subsurface investigation, and some were private water-supply wells installed by various local well drillers for individual property owners. In spring 1998, Ecology contracted Transglobal Environmental Geosciences (TEG) Northwest, Inc. to conduct an additional subsurface investigation (Ecology 1999a). Based on results of these investigations (mainly from groundwater sampling results), the drums were suspected to be buried under Building B on the Breen Property.

Also in spring 1998, another source of contamination was found during the subsurface investigation by TEG. This second source area was located between North Hamilton Road and I-5 along Berwick Creek, which is now included within the HRIA. TEG advanced direct push (i.e., Strataprobe™) borings across the HRIA and collected groundwater samples. The highest concentration of PCE (60,000 µg/L) was detected in a boring advanced between Berwick Creek and North Hamilton Road about 40 feet east of the United Rentals Property. PCE concentrations in groundwater from adjacent borings ranged from 22,000 µg/L to 57,000 µg/L. PCE concentrations of 20,000 µg/L or higher in groundwater are potentially indicative of nearby DNAPL.

In August 1999, the Breen Company entered into an Agreed Order with Ecology to conduct an additional investigation on the Breen Property. This investigation included a geophysical survey by Northwest Geophysical Associates in August 1999 (GeoEngineers, Inc. [GeoEngineers] 2001, Appendix D) and additional subsurface investigation by GeoEngineers in August 1999 (GeoEngineers 2001). Before conducting the geophysical survey in Building B, a part of the concrete floor was broken up and removed to eliminate the wire mesh reinforcing material within the floor that could have interfered with the geophysical instruments. The concrete floor and offices at the north end of Building B and the paint booth at the southern end of Building B were not removed. The geophysical survey identified an anomaly in the south central portion of Building B where the concrete floor had been removed. This anomaly turned out to be a buried drum cache.

All of the drums appeared to contain water, as groundwater had seeped into the leaking drums, as well as a black sludge-like material. The contents of two of the excavated drums were sampled and analyzed. Based on laboratory results, the two drums contained a mixture of lubrication oil, grease, and solvents typically associated with painting and equipment-degreasing activities. PCE, trichloroethylene (TCE), and cis-1,2-dichloroethylene (cis-1,2-DCE) were detected above MCLs in both drums; vinyl chloride was detected above MCLs in one of the drums. The other drums were assumed to contain similar compounds. A total of sixty-six, 55-gallon drums, four 30-gallon drums, and several 1- to 5-gallon containers, as well as 600 tons of PCE and petroleum-contaminated soil, were removed from under Building B and taken to nearby treatment and disposal facilities. Groundwater recovered from the excavation was treated using a granular activated carbon (GAC) filter and then taken to the City of Longview's sewage treatment plant for disposal (GeoEngineers 2001).

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[2] One of the six wells was no longer in service.

On July 27, 2000, the Site was added to the EPA National Priorities List (NPL), and EPA took over supplying bottled water to affected well owners from Ecology (EPA 2001a, EPA 2002a). Also in 2000, the EPA Superfund Technical Assistance and Response Team (START) contractor, Ecology and Environment, Inc. (E&E), began a four-phased removal assessment in the HRIA. Soil borings and new groundwater monitoring wells were installed, and subsurface soil and groundwater samples were taken in and near the HRIA to evaluate the extent of impacts to private water-supply systems (E&E 2000, E&E 2001, E&E 2002). The removal assessments resulted in a Time Critical Removal Action to expand the City of Chehalis municipal water-supply system to 18 properties across the Site (15 residential and 3 commercial) (EPA 2002b, EPA 2002c, E&E 2003).

On October 31, 2001, an Administrative Order on Consent (AOC) was signed between EPA and the Breen Company (EPA 2001b). The AOC required the Breen Company to conduct a Site-wide Remedial Investigation/Feasibility Study (RI/FS) within the Breen Property, the area downgradient of the HRIA and cross gradient of the Breen Property (east of Labree Road), and the area downgradient of the Breen Property (west of Labree Road). The Breen Company investigations did not include the PCE source area within the HRIA east of North Hamilton Road or the United Rentals Property west of North Hamilton Road, as these areas were being investigated by EPA. EPA submitted data collected during the HRIA investigations to the Breen Company for inclusion into Site-wide RI/FS reports.

In accordance with the AOC, the Breen Company (through its consultant, Farallon) began Phase I investigations in 2002 (Farallon 2002). The overall objective of the Phase I investigation was to review existing Site data and identify data gaps to guide the development of a Site-wide RI/FS work plan. Phase I RI activities based on the Site-wide RI/FS work plan were initiated in the summer of 2003 under EPA oversight (Farallon 2003).

In August 2003, EPA contractor URS Group, Inc. (URS) began additional field investigations in the HRIA to better define the extent of sediment, soil, and groundwater contamination, including defining the extent of PCE DNAPL in support of an Engineering Evaluation/Cost Analysis (EE/CA) report (URS 2004). The purpose of the EE/CA report was to evaluate data collected from previous investigations and alternatives for cleaning up the HRIA and support EPA's identification of a preferred removal action alternative for the HRIA.

In early 2004, the Breen Company requested that work under the AOC be suspended prior to completion in order to negotiate a cash-out settlement with EPA. Negotiations ended in 2007 without reaching an agreement.

Also in 2004, EPA completed the EE/CA field investigations, which revealed that the source of contamination in the HRIA appeared to be the result of a spill or direct release of liquid PCE into Berwick Creek. The person or persons who caused this release is unknown. The exact date of the release is also unknown; estimates range from the 1970s to no later than 1990 based on the results of various plume migration analyses that have been conducted, when North Hamilton Road was constructed, and observed contamination patterns along Berwick Creek.

It appears that most of the spilled or released PCE sank to the creek bottom where it pooled in low areas in the sediment and silt layer. PCE then moved downward into the underlying soil and groundwater below the silt layer where it continued to dissolve and move with the regional groundwater flow to downgradient areas. The preferred removal action alternative presented in the EE/CA report was to use a hydraulic containment technology without removing the silt layer from under Berwick Creek in order to stabilize the contaminated groundwater plume. The EE/CA report also recognized that over the long term, after a Site-wide RI/FS was completed, a more aggressive technology needed to be used to further reduce PCE concentrations within the HRIA (URS 2004).

In December 2004, EPA signed a Time-Critical Removal Action Memorandum to build and operate a pump and treat system that would stabilize the contaminated groundwater plume and prevent further migration of PCE from the HRIA (EPA 2004). However, due to design and funding issues, the pump and treat system was not implemented.

In 2005 and 2006, with the Breen Phase I RI activities still suspended, EPA assembled all of the available investigation data that had been collected across the Site and released draft Site-wide RI and FS reports (Parametrix 2006a and b). Analyses of these reports concluded that aggressive source control at the HRIA, establishment of institutional controls, and long-term monitoring of the PCE plume was the appropriate course of action for the Site as a whole. However, upon further review of Site-wide data, EPA reconsidered this approach and pursued a more comprehensive strategy that would also consider response actions for other areas of the Site in what is now known as OU2. This decision was made in part because EPA identified another potential source of groundwater contamination at or upgradient of the Thurman Berwick Creek Area which is within OU2.

As part of the more comprehensive Site-wide strategy, Parametrix, on behalf of EPA, performed supplemental groundwater and surface water sampling across the Site in July 2007 (Parametrix 2009). Seventeen existing wells were sampled (eight private wells and nine monitoring wells) in the HRIA, the Breen Property, the Thurman Berwick Creek Area, and downgradient areas west and northwest of Labree Road. The purpose of the sampling was to evaluate whether significant changes in concentrations had occurred since the previous Site-wide sampling events in 2003/2004. The private wells sampled included five locations on Rice Road beyond the end of the public water-supply line installed in 2002. Results of well sampling showed that PCE concentrations had not changed significantly between 2003/2004 and 2007 and that the contaminated groundwater plume had not reached homes beyond the end of the public water-supply line. In addition to well sampling, two surface water samples were collected from Dillenbaugh Creek, which showed PCE slightly below the PCE MCL. The data from this event were used to further define Site-wide groundwater contamination and to assess contaminant migration and potential groundwater-surface water interaction associated with Dillenbaugh Creek.

In November 2007, EPA's Environmental Response Team (ERT) took air samples in and around private residences and commercial buildings across the Site to assess possible risks to human health from volatilization of contaminants from groundwater to indoor and outdoor (ambient**)** air. A total of 34 samples were collected over a 24-hour time period. Low levels of PCE and TCE were detected inside most of the residential and commercial buildings and in ambient (outdoor) locations; however, the levels were low enough that they do not pose a current health risk (Lockheed Martin 2008, EPA 2008a, CDM Federal Programs Corporation [CDM Smith] 2011a).

Finally, in May 2010, EPA measured water levels and assessed the condition of most of the monitoring wells across the Site. The results of this assessment, including a water level map (Final Report on the May 2010 Water Level Measurement and Monitoring Well Network Assessment, June 15, 2011), are presented in Appendix C of the Draft Site-wide RI Report (CDM Smith 2011b).

In 2011, after review of the additional data collected in 2007 and 2010 and reviewing previous data that had been collected across the Site, EPA determined that an interim remedial action was warranted for the HRIA. Additional studies are needed to further define the nature and extent of contamination and determine options for cleaning up the rest of the Site.[3]

More detailed information on previous investigations and findings about the Site can be found in the Draft Site-wide RI Report (CDM Smith 2011b).

[3] On April 23 and 24, 2013, EPA and START Contractor E&E sampled 19 domestic wells along Rice and Hamilton Roads. The purpose of this sampling was to determine if contaminated groundwater from the Hamilton/Labree source areas had migrated to down- and cross-gradient properties not connected to the Chehalis municipal water-supply system. No Site chemicals were found at detectable levels in any of the wells sampled.

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Section 2

Site Characteristics

Volatile organic compounds, particularly PCE, have been identified as the primary contaminants that contribute to human health and ecological risks at the Site. This section provides summaries of topics discussed in the RI and Baseline Risk Assessment (BLRA) including site features, physical characteristics, nature and extent of contamination, and a summary of risks. This section also discusses Site-wide MVS modeling results, identifies, the principal threat wastes at the Site, and presents a preliminary conceptual site model (CSM).

For complete details of the Site characteristics and the nature and extent of contamination, please refer to the draft final RI report (CDM Smith 2011a).

2.1 Summary of Physical Characteristics

2.1.1 Climate

Average annual precipitation in the Chehalis area is approximately 47 inches, with December being the wettest month (Western Regional Climate Center 2006). An estimated three quarters of the annual precipitation falls during October through March. The climate of the region includes wet winters and moderately warm, dry summers. The mean average annual temperature for the Chehalis area is about 50 degrees Fahrenheit (°F).

2.1.2 Topography and Drainage

The Site lies within the Newaukum Prairie, a relatively flat area formed by the Newaukum River. Hills bound the Prairie to the west and east, rising to elevations of 400 to 700 feet above mean sea level (MSL). Site topography ranges from 195 to 210 feet above MSL. Surface water drainage varies from location to location within the area depending on the proximity of surface water features, such as Berwick Creek, Dillenbaugh Creek, and the Newaukum River. The valley generally slopes down to the northwest towards the Chehalis River. The regional topography and drainages are shown in **Figure 2-1**.

2.1.3 Geology

Surficial deposits mapped for the Site area consist of alluvium and Newaukum terrace unit glaciofluvial deposits (Weigle and Foxworthy 1962). The alluvial deposits are referred to as the "silt cap" although some investigators have identified it as a silt and clay cap. Nevertheless, this "cap" appears to be continuous across the Site and ranges between 1 and 15 feet thick. It creates locally confined groundwater conditions in the underlying Newaukum terrace unit.

The Newaukum terrace unit is a glaciofluvial deposit consisting of sand in a silt and clay matrix that contains the shallow aquifer. The maximum depth of the shallow aquifer is approximately 50 feet below ground surface (bgs).

The shallow aquifer is underlain by a non-marine sedimentary unit described as thin-bedded "blue" clays (with occasional sand and silt lenses). This bluish-gray clayey silt layer is approximately 100 feet thick and hardens with depth (Dames and Moore 1994). This layer is believed to be Miocene-

Pliocene (Weigle and Foxworthy 1962) and has a fluvial or lacustrine origin. This unit is the aquitard that divides the shallow and deep aquifers at the Site. It appears to be continuous beneath the Site, which is consistent with regional geologic information (Ecology 2005).

Below the silt and clay aquitard is a confined aquifer comprised of older Miocene alluvial sediments deposited by a meandering or braided river system. The groundwater in the deep aquifer occurs in sand lenses and channel deposits more than 150 feet deep and ranging from 5 to 70 feet thick in the area of the HRIA (Dames and Moore 1994). Wells installed in this aquifer in the Newaukum River valley are typically artesian.

In summary, the current understanding of the Site stratigraphy is as follows:

- Alluvially deposited silt “cap” from 1 to 15 feet bgs.
- Glaciofluvially deposited sand and gravel in a silt and clay matrix from 5 to 50 feet bgs (shallow aquifer).
- Non-marine sedimentary silt to clay deposit 100 feet thick (aquitard) (from approximately 50 to 150 feet bgs).
- Miocene alluvial sediments below the aquitard (greater than 150 feet bgs), thickness unknown (deep aquifer).

2.1.4 Groundwater

The groundwater flow direction beneath the HRIA is to the west/northwest but becomes northwesterly downgradient of the Breen Property. Historic water levels have ranged between approximately 1.5 and 10 feet bgs. Water levels can vary several feet seasonally; in any individual well, as much as a 6.47 foot difference has been observed. Regional investigations have categorized the shallow aquifer in the HRIA as an unconfined or water table aquifer (Dames and Moore 1994; Ecology 2005). In the HRIA, however, the shallow aquifer exhibits the characteristics of a confined or semi-confined aquifer primarily due to the silt cap immediately above the shallow aquifer, and water levels measured 4 to 6 feet above the base of this silt cap in December 2003 (URS 2004).

The overall groundwater slope (gradient) beneath the HRIA is 0.0063 foot per foot (ft/ft) (URS 2004). A localized steeper gradient (approximately 0.016 ft/ft) is apparent immediately downgradient of North Hamilton Road. The average groundwater gradient calculated for the entire Site is 0.0032 ft/ft (E&E 2001).

Site-wide vertical gradients within the shallow aquifer are not well understood. There are only five locations with paired monitoring wells screened in the shallow aquifer, and only four of those locations have surveyed elevation data for both wells to enable calculation of vertical gradients. Of these well clusters, two are in the southwestern area of the Breen Property, one is in the northwestern area of the Breen Property, and one is just south of North Hamilton Road between the HRIA and the Thurman Berwick Creek Area. The three locations within 200 feet of Berwick Creek (MW-20/21, MW-22/23, and MW-29/30) have upward gradients while the cluster located further away (MW-17/18) has a downward gradient.

2.1.5 Surface Water

The Newaukum River is east of the Site and flows northwesterly where it joins with the Chehalis River about five miles northwest of the Site. There are also two creeks that run through the Site; Berwick Creek and Dillenbaugh Creek (**Figure 1-2**). In addition, there are two ditches with intermittent flows that discharge into Berwick Creek at the HRIA. Both ditches pass under I-5 and flow from east to west. Berwick Creek flows through the HRIA from southeast to northwest, turns west at the Breen Property and extends approximately 1,500 feet where it turns towards the north-northwest, meeting Dillenbaugh Creek about 2,100 feet further. Dillenbaugh Creek flows roughly southeast to northwest through the downgradient area of the Site and discharges into the Chehalis River.

2.1.6 Site Surface Water and Groundwater Interaction

Surface water monitoring on Berwick Creek was conducted as part of the Breen Phase I RI (Farallon 2003). A comparison of surface water and groundwater elevations for corresponding monitoring points measured in September and November 2002 indicated that surface water elevations were at or above the potentiometric surface of the shallow aquifer during both events (Farallon 2003). These data indicate that there is a potential for surface water to seasonally discharge to groundwater in areas where the silt cap below the Berwick Creek bed is thin or permeable. Data for surface water monitoring stations #5 through #10 are shown in **Table 2-1**. Station locations #1 through #4 apparently were not monitored.

Groundwater elevations in monitoring wells adjacent to Berwick Creek within the HRIA were above the approximate surface water elevation (URS 2004), indicating a potential for groundwater to seasonally discharge to surface water in this reach of Berwick Creek. However, at all exploration locations near the creek, the silt cap of the shallow aquifer was found to be present between surface water and groundwater. The low vertical hydraulic conductivity (6.3×10^{-7} centimeters per second [cm/s]) of the silt cap probably minimizes the groundwater and surface water interaction within the HRIA. However, this low conductivity value is based on bulk hydraulic conductivity measurements that do not include conductivity, which may be locally greater due to fracturing, scouring, or pathways formed by predevelopment vegetation roots.

The flow measurements at stations #5 through #10 in September and November 2002 were qualitatively evaluated to determine whether Berwick Creek was losing or gaining water over the reach covered by the surface water monitoring stations. September 2002 measurements (the end of the dry season) recorded little to no flow at the majority of the stations with the exception of surface water (SW) stations SW-8 and SW-9, as shown in **Table 2-1**. Flows of approximately 500 and 870 gallons per minute (gpm), respectively, were measured at these two stations. November 2002 measurements showed flows of 1,400 gpm at station SW-8 and 1,250 gpm at station SW-9. Collectively, these measurements suggest the possibility that this reach of the creek discharges groundwater as base flow (gaining) during the summer. However, the data are not sufficient to make a quantitative assessment of summer base flow contribution.

The two surface water samples collected from Dillenbaugh Creek in 2007 showed PCE concentrations (1.7 μg/L and 3.6 μg/L) slightly below the groundwater MCL (5 μg/L) but above the PCE concentrations detected in a location in Berwick Creek, downgradient of Labree Road. The PCE concentrations at that Berwick Creek location ranged from non-detect to 0.85 μg/L. The higher concentrations at the Dillenbaugh Creek locations indicate that the PCE groundwater plume may be discharging to Dillenbaugh Creek.

2.1.7 Land Use

The Site is located in a rural region used for agricultural activities. An estimated 1,200 people live within 4 miles of the Site and have been identified by EPA as being within the potential area for adverse effects from PCE contamination from groundwater (E&E 2000). The commercial district of the City of Chehalis is located approximately 2 to 2.5 miles northwest of the Site.

The HRIA and the portion of OU2 that is east of Labree Road are located within the City of Chehalis' Urban Growth Area (UGA) and are zoned Commercial General (CG). The Breen Property and the former United Rentals Property are used for commercial purposes. Current land use downgradient (west and north) of Labree Road consists primarily of rural open (Class B Farmlands) and residential (Rural Development District [RDD]-20) use and is not within the Chehalis UGA.

The shallow aquifer is used as a drinking water source for area residences not connected to the City of Chehalis water system and for cooking, bathing, irrigation, and stock watering by residences, commercial businesses, and farms in the area. Approximately 250 private water-supply wells are located within 4 miles of the HRIA and the Breen Property (Farallon 2003).

The Site is designated as within the usual and accustomed (U&A) area for the Confederated Tribes of the Chehalis Reservation, the Cowlitz Indian Tribe, and the Quinault Indian Nation.

Within the Site, Berwick Creek is classified as a Type F stream by the Washington State Department of Natural Resources (DNR) [DNR 2010]. A Type F stream is known to be used by fish or meets the physical criteria to be potentially used by fish. Fish streams may or may not have flowing water all year. There are no use designations specifically for Berwick Creek in Ecology's Water Quality Standards for Surface Waters of the State of Washington (Washington Administrative Code [WAC] 173-201A-602, Table 602) (Ecology 2006). Ecology lists Berwick Creek as a Category 4A and 5 water body in the 2004 Water Quality Assessment 303(d) list (Ecology 2008) due to exceedances of fecal coliform.

Dillenbaugh Creek is classified as a Type F stream by DNR upstream of where it merges with Berwick Creek. Downstream of this area, however, the creek is classified as Type S. A Type S stream is designated "shorelines of the state." There are no use designations specifically for Dillenbaugh Creek in WAC 173-201A-602, Table 602. Ecology lists Dillenbaugh Creek as a Category 4A and 5 water body in the 2004 Water Quality Assessment 303(d) list (Ecology 2008). The Category 4A listing is due to exceedances of fecal coliform. The creek is listed as a Category 5 water body due to an exceedance of dioxin in fish tissue in a section of the creek downstream from the confluence with Berwick Creek.

Future land and resource uses east of Labree Road are anticipated to be similar to current land uses. A freeway interchange was constructed several years ago on Labree Road and additional commercial use is planned for the area between the HRIA and the Labree Road/Thurman Berwick Creek Area.

Future land and resource uses in the area north and west of Labree Road are also anticipated to be similar to current uses, unless it becomes part of the Chehalis UGA. However, there are no plans for this designation at this time.

2.1.8 Ecological Conditions

A variety of animals (e.g., birds, mammals, fish) and plants inhabit or use, or have potential to inhabit or use, the creeks and land across the Site. Birds such as the bald eagle, the American robin, and various ducks, such as the mallard, may visit the Site. A wide range of mammals, including the short-tailed shrew, raccoon, and white-tailed deer, could also frequent the Site.

Searches of wildlife databases and inquiries with regulatory agencies were conducted to determine if any threatened and endangered species and environmentally important animals and plants are likely to be present at the Site, especially in the vicinity of Berwick Creek. Berwick and Dillenbaugh Creeks are designated as essential fish habitat for the Chinook (*Oncorhynchus tschawytscha*) and Coho (*Oncorhynchus kisutch*) salmon under the Magnuson-Stevens Act. Chinook salmon has not been documented in Berwick Creek but has the potential to access it and the Site. Coho salmon is a federal candidate for the Endangered Species Act. Berwick Creek was identified as having Coho salmon spawning and rearing habitat in its lower reaches, which would include areas both downstream and upstream of the HRIA (URS 2004). Bull trout (*Salvelinus confluentus*) is listed as threatened in the Endangered Species Act, and although it has not been documented in Berwick Creek, it has the potential to access it and the Site. The small flowered trillium (*Trillium parviflorum*) is listed as "sensitive" by Washington State and had been documented approximately 0.35 mile upstream of the Site near Berwick Creek.

A bald eagle (*Haliaeetus leucocephalus*) nest has been documented about 1.25 miles southeast of the Site near the Newaukum River. It is possible that bald eagles in the area obtain food from Berwick Creek. Bald eagles were recently delisted under the Federal Endangered Species Act but are still protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act.

For detailed information on the ecology of the Site, see the Draft Site-Wide BLRA report (CDM Smith 2011b).

2.2 Nature and Extent of Contamination

This section first identifies the nature of contamination found across the Hamilton/Labree Site and the affected media (e.g., sediment, soil, groundwater). It then discusses the extent of contamination found within the HRIA.

Historical sampling locations are shown on **Figures 2-2A, 2-2B and 2-2C**.

2.2.1 Contaminants of Potential Concern and Affected Media

The contaminants of potential concern (COPCs) across the Site are PCE and its degradation products TCE, cis-1,2-DCE and vinyl chloride, as well as the chemicals tetrahydrofuran and methylene chloride. Total petroleum hydrocarbons, such as from diesel and gasoline, are also considered to be potential Site-wide COPCs, but additional sampling needs to be conducted in the future to confirm this likelihood. Of these contaminants, only PCE, TCE, cis-1,2-DCE and methylene chloride are COPCs in the HRIA. Since PCE has been detected more frequently and at much higher concentrations than other COPCs, it is used as the representative or indicator COPC in this FS.

These contaminants are found primarily in sediments and adjacent surface soils within the HRIA Berwick Creek channel bed and banks and in subsurface soils and groundwater across the Site. No PCE concentrations above 0.468 milligrams per kilogram (mg/kg), EPA's benchmark for protection of certain organisms living in freshwater sediments, has been found in surface soils outside of the bed and banks of Berwick Creek. In general, surface soils at the Site are defined as 0 to 5 feet bgs. Subsurface soils are at depths greater than 5 feet and typically start below the silt cap of Berwick Creek. Subsurface soil samples from the Site have typically been collected between 5 feet bgs to the top of the aquitard at about 50 feet bgs. In groundwater, contamination occurs in the shallow aquifer located approximately 5 to 50 feet bgs.

PCE concentrations in Berwick Creek bed and banks, subsurface soil, and in groundwater within the HRIA indicate the presence of DNAPL. PCE concentrations indicative of DNAPL have not been detected on top of the aquitard.

The deep aquifer below the aquitard has not been fully characterized as no monitoring wells have been installed within this zone. Minor amounts of PCE have been detected in samples collected from private wells screened in the deep aquifer but not enough to suggest that significant migration of PCE through the aquitard that separates the shallow aquifer from the deeper aquifer has occurred.

2.2.2 Extent of Contamination

This subsection describes the extent of contamination based on the results of investigations conducted within the HRIA. See **Figures 2-2A, 2-2B and 2-2C** for historical sampling locations.

2.2.2.1 Release Areas

The source of contamination within the HRIA appears to be the result of a spill or direct release of liquid PCE into Berwick Creek. The person or persons who caused this release is unknown. The exact date of the release is also unknown. Estimates range from the 1970s to no later than 1990 based on the results of various plume migration and groundwater modeling studies that have been conducted and on other factors, such as construction of North Hamilton Road.

Regarding the latter, it seems unlikely that the release occurred before the 1974 construction of North Hamilton Road, which runs parallel to and west of Berwick Creek in the HRIA. The 2004 EE/CA report estimated the volume of release to be between 100 and 700 gallons (URS 2004). Such large volumes would require easy access to the release area. In addition, contamination patterns observed in the HRIA indicate the release occurred on the west side of Berwick Creek. Soil gas surveys conducted east of Berwick Creek along I-5, and a review of I-5 accident reports in this area, do not support a release along I-5. These factors all seem to suggest that the release did not occur before 1974.

The "no later than 1990" date is based on PCE contamination levels observed in private well (PW)-3 located approximately 400 feet from the HRIA's Southeastern Hotspot in 1993 and on the groundwater seepage velocity provided in URS's 2004 EE/CA report of 0.36 feet/day.

The most likely location of the release is just upstream of where the Unnamed Ditch #1 enters Berwick Creek near Monitoring Well (MW) 602 and MW-602, an area referred to as the "Southeastern Hot Spot" (**Figure 2-3**). High PCE concentrations strongly point to a single release at this location, but multiple releases may have occurred along a 400-foot reach of Berwick Creek. Data supporting this latter assumption include high PCE concentrations identified in an area referred to as the "Northwestern Hot Spot," which begins approximately 80 feet downstream of Unnamed Ditch #1 (**Figure 2-3)** (CDM Smith 2011a). PCE contamination within these Hot Spots is discussed further in the below subsections.

2.2.2.2 Creek Bed Sediment/Bank Surface Soil

Currently, the only identified sediment and surface soil in the HRIA with PCE concentrations indicative of DNAPL are in the bed and banks of the Berwick Creek channel within the Southeastern Hot Spot. During the August 2003 EE/CA investigations, URS collected 39 samples from creek bed sediments and bank soils along Berwick Creek and both unnamed ditches in the HRIA. The maximum PCE concentration detected was 5,220 mg/kg in creek bed sediment/soil boring (SB) sample SB-409, located at the upper boundary of the Southeastern Hot Spot (**Figure 2-4**), at a depth between 0.5 and 1 feet bgs. Concentrations indicative of DNAPL in sediment and soil are those that exceed the soil saturation limit of PCE which in the HRIA is 38 mg/kg of PCE. Other creek bed sediment and bank soil sample locations indicating PCE DNAPL were at SB-410 (1,650 mg/kg between 0.5 and 1 feet bgs) and at SB-411 (685 mg/kg between 0.2 and 1 feet bgs) (URS 2004). These two soil borings are also located in the Southeastern Hot Spot.

PCE concentrations in creek bed and bank samples within and north of the Northwestern Hot Spot ranged from non-detect to 0.0887 mg/kg at SB-403 between 0.33 and 1 feet bgs (URS 2004). No creek bed sediment and bank soil samples have been collected in the far northern portion of the HRIA, particularly in the segment between MW-R4 in the Northwestern Hot Spot and MW-5/MW-33 (**Figure 2-4**). Farallon, on behalf of the Breen Company, collected one creek channel (CC) sample in the very north of the HRIA just south of the Chehalis Livestock Auction building, but no PCE was detected.

2.2.2.3 Subsurface Soil

PCE concentrations high enough to indicate the presence of DNAPL have been observed in subsurface soils beneath the apparent PCE release area in the Southeastern Hot Spot of Berwick Creek. The highest PCE concentration, 3,220 mg/kg, was detected at Geoprobe (GP) boring location GP-502 at a depth of 28 feet bgs. As described earlier, sediment and soil concentrations greater than 38 mg/kg of PCE indicate the presence of DNAPL in the HRIA (URS 2004). Other elevated subsurface soil PCE concentrations were found at GP-501 (858 mg/kg at 12 feet bgs), auger boring (AB) 650 (136 mg/kg at 21 feet bgs), and GP-503 (151 mg/kg at 28 feet bgs) (**Figure 2-2A**) and at MW-9 (53 mg/kg at 43 feet bgs) and MW-602 (399 mg/kg at 15 feet bgs) (**Figure 2-3**). These subsurface soil samples are also located within or immediately adjacent to the Southeastern Hot Spot. The MW subsurface soil samples were taken when these groundwater monitoring wells were installed.

2.2.2.4. Groundwater

The maximum PCE concentration in groundwater of 2,720,000 µg/L was detected at MW-602 at a depth of 14.5 feet bgs within the Southeastern Hot Spot in November 2003. This concentration exceeds the solubility limit of PCE in groundwater (200,000 µg/L), clearly indicating the presence of DNAPL. Concentrations that exceed 10 percent (%) of a contaminant's solubility limit in groundwater are potentially indicative of nearby DNAPL. Therefore, concentrations of 20,000 µg/L or higher in groundwater define the potential extent of the PCE DNAPL source area.

Maximum PCE concentrations in groundwater within the Northwestern Hot Spot were detected in February and November 2003 at MW-R4 at 5,300 µg/L and 8,800 µg/L, respectively, at a depth of 21 feet bgs. Dissolved PCE in groundwater appears to have migrated northwest of the Northwestern Hot Spot based on data collected by Farallon for the Breen Company (Farallon 2004). A groundwater sample collected at MW-33, located northwest of the Northwestern Hot Spot, detected PCE at 1,100 µg/L in April 2004 at a depth of 19 feet bgs.

Groundwater data within the HRIA suggest stratification of PCE within the shallow aquifer. The upper zone of the shallow aquifer, at or above 25 feet bgs, shows higher PCE concentrations than in the lower zone of the shallow aquifer (25 feet bgs down to the top of the silt and clay aquitard). The 20- to 30-foot zone appears to be a transition or mixing zone often characterized by intermediate concentrations.

Multi-level sampling was conducted to assess the potential stratification of the PCE plume in groundwater at the Southeastern Hot Spot and the area immediately downgradient. Results at MW-R8 showed significantly higher PCE concentrations in the upper zone as compared to the lower zone. PCE concentrations ranged from 4,700 µg/L at 15 feet bgs to 360 µg/L at 48.5 feet bgs. Multi-level sampling in MW-R11 did not indicate a significant variation in PCE concentrations in groundwater samples collected at varying depths; however, PCE concentrations were relatively low at approximately 25 µg/L.

Multi-level samples were also collected from all of the MW-600-series wells when they were installed in October and November 2003. The most dramatic stratification was observed in MW-602, which had 2,720,000 µg/L PCE in the 14.5-foot sample, 203,000 µg/L in the 35-foot sample, and 4,980 µg/L in the 41-foot sample.

Stratification also appears to be evident downgradient of the HRIA. The contour lines in **Figure 2-5** show the maximum concentrations detected in the upper zone of the shallow aquifer from the HRIA to the Thurman Berwick Creek Area and to the southwest corner of the Breen Property. **Figure 2-6** shows the maximum concentrations detected at sampling points in the lower zone of the shallow aquifer from the HRIA to the Thurman Berwick Creek Area and the southwest corner of the Breen Property. A comparison of the two figures suggests that contamination in the upper zone declines significantly by the HRIA western boundary whereas contamination in the lower zone of the shallow aquifer extends well beyond the HRIA boundary. In the Thurman Berwick Creek Area and the southwest corner of the Breen Property, PCE in the upper zone has been observed at concentrations greater than 2,000 µg/L while lesser PCE concentrations have been observed in the lower zone of the shallow aquifer. These observations need to be evaluated during future OU2 investigations.

The maximum extent of PCE in groundwater downgradient and west of Labree Road has not been fully delineated. **Figure 1-2** shows the Site-wide estimated extent of PCE based on limited data. After crossing under Labree Road, the plume turns in a north-northwesterly direction, essentially following Berwick and Dillenbaugh Creeks. As stated earlier, additional studies are required to fully characterize the Site, including understanding the extent of the downgradient groundwater plume.

2.2.2.5 Surface Water

Two of the 10 surface water sampling stations are located downgradient of the Southeastern Hot Spot (SW-3 and SW-7) and at the downstream portion of the Unnamed Ditch #1 west of I-5, (SW-5) as shown on **Figure 2-4**. The SW-5 and SW-7 locations were sampled four times between July 2002 and November 2003 and the SW-3 location once in July 2008. The detections and concentrations of PCE in surface water samples at these locations have varied considerably, and no clear seasonal trend has been identified. The highest concentrations of PCE at SW-5 (40 µg/L) and SW-7 (12 µg/L) occurred in November 2002, typically a high precipitation month. However, the PCE concentration at SW-3 in July 1998 was similarly high at 15 µg/L although this station was only sampled once and the other stations were not sampled on this date.

Two additional stations are located upstream of the HRIA. SW-4, located in the upstream portion of Unnamed Ditch #1 east of I-5, was sampled once by Ecology in December 1998; PCE was not detected. SW-6, located near the upstream limit of known contamination in Berwick Creek soils, was sampled four times between July 2002 and February 2003. PCE was detected at concentrations less than 1 µg/L in July 2002 and November 2003 but was not detected during the other two sampling events.

No surface water sampling has been completed in Berwick Creek in the northern portion of the HRIA between MW-R4 and MW-5/MW-33. High PCE concentrations of 8,800 µg/L and 1,100 µg/L have been detected in groundwater at MW-R4 (Northwestern Hot Spot) and MW-33, respectively. It is unknown if contaminated groundwater near these wells discharges to surface water.

2.2.2.6 Soil Gas

A soil gas survey was conducted in the HRIA in August 2003. Analytical results of soil gas surveys can be used to identify source areas, focus soil and groundwater sampling efforts, and potentially qualify risk to indoor air from subsurface contamination. The majority of the soil gas survey was conducted along Berwick Creek to assess whether PCE was present as a result of a spill that may have occurred along I-5. For the Berwick Creek area, the soil gas samples were collected at 4 feet bgs except for two individual samples collected at 5 and 10 feet bgs. Soil gas concentrations of PCE in this area ranged from non-detect to 3.2 parts per million by volume (ppm-v). Three samples contained 1 ppm-v or greater PCE, and one contained 0.19 ppm-v PCE. PCE concentrations in the remaining 29 samples were all less than 0.1 ppm-v. All four samples with greater than 0.1 ppm-v PCE were located within the Southeastern Hot Spot. Overall, the soil gas survey results did not support the scenario of a separate release along I-5.

Two additional soil gas (SG) samples, SG-204 and SG-205, were collected on the opposite side of North Hamilton Road at the southeast corner of the United Rentals Property. These two samples, collected at depths of 10 and 7 feet bgs, contained PCE concentrations of 4 and 18 ppm-v, respectively. Soil data from nearby borings confirmed the presence of PCE. A 10.5 foot soil sample collected from GP-505 near SG-204 contained 1.97 mg/kg PCE. A 16 foot soil sample collected from GP-4 near SG-205 contained 13 mg/kg PCE.

2.2.2.7 Indoor and Ambient Air Quality

In November 2007, EPA's ERT conducted air sampling in and around private residences and commercial buildings to determine whether vapors from volatilization of contaminants in the shallow aquifer were intruding into indoor and ambient air at the Site. Samples were collected from indoor air, ambient air, and sub-slab soil vapors. Sample locations are shown on **Figure 2-7**.

PCE was detected in all four samples collected within the HRIA. The ambient air PCE concentration was 0.14 micrograms per cubic meter (µg/m3). The two indoor air samples taken on the United Rentals Property contained PCE at concentrations of 0.14 µg/m^3 (paint shop) and 0.21 µg/m^3 (main building). As a comparison, the EPA Regional Screening Level (RSL) for PCE in residential air is 9.4 µg/m^3, and the RSL for industrial air is 47 µg/m^3 (EPA 2012a). The sub-slab sample collected at the paint shop building contained 25 µg/m^3 PCE; the EPA target sub-slab soil gas concentration is 94 µg/m^3, which is extrapolated from the RSL for residential indoor air based on a generic attenuation factor of 10 (EPA 2012b).

2.3 MVS Modeling Overview

CTech's MVS Version 9.13 was used to develop a 3D geostatistical model to help better define the lateral and vertical extent of PCE contamination zones in the HRIA, better delineate the HRIA boundary, refine the CSM, identify conditional points of compliance, and develop RAOs for the HRIA. MVS uses kriging as the primary geostatistical interpolation method, which provides statistical confidence to measure the model accuracy. A convex-hull model domain with a resolution of 360 x 360 x 35 (X, Y, Z) was chosen to provide an appropriate fidelity while minimizing computational time.

Site hydrostratigraphy was modeled in a geological-hierarchy format with coordinates in a consistent state plane format horizontally and elevation vertically, both in units of feet. Stratigraphic units modeled, from the ground surface downward, include a surficial silt/clay unit used to define the creek bed sediments, a sand/gravel aquifer, and a silt/clay aquitard. Groundwater and soil analytical data were kriged and bounded within each stratigraphic unit using horizontal/vertical anisotropies of 10 and 5, respectively. Kriging anisotropy allows for geostatistical weighting of data to account for data density differences. For instance, in a soil boring, soil samples may be collected every few feet, but boreholes may be tens of feet apart. Smaller anisotropy values, which weight the vertical data more equally to the lateral data, result in the MVS software estimating "mini-plumes" around each boring/data point because the model sees higher density of data vertically. In order to have the model incorporate data from as many boreholes as possible into the calculation for a given node and thus connect the data to show resultant contaminant extents, the weight value (referred to as kriging anisotropy) was increased. Analytical data were converted to logarithmic values prior to kriging with non-detects represented as one-half their respective detection limit. All models are presented with a horizontal/vertical exaggeration of 35 for visualization purposes, and a 2007 aerial photograph was overlain on the ground surface for spatial reference. Various screen captures from the model were produced to evaluate the extent of PCE contamination at the HRIA and across the Site and are included in **Appendix A**.

When evaluating the modeling output presented in **Appendix A**, the user should consider data limitations and other factors that increase the uncertainty associated with that output. This uncertainty may contribute to under- or overestimation of mass, area, and/or volumes. For example, if data are sparse and/or clustered, the model may expand contamination to areas where there is a lack of bounding data and significantly overestimate mass. In contrast, the model has limited ability to consider groundwater flow paths, which means it will not extrapolate or connect portions of a plume. This can result in an underestimation of mass. Further, the model's limited ability to consider flow gradients means that it may inappropriately assign mass in upgradient and cross gradient directions leading to an overestimation of actual contaminant mass.

In addition, the user should also consider uncertainty associated with the analytical data used in the model due to data quality issues or limits associated with the analytical methods themselves. High detection limits for nondetect results potentially lead to a high bias as the model assigns a value of one half the detection limit to represent nondetect results. Initial runs of the model showed contamination extending under and east of I-5 because of high detection limits associated with samples collected from locations east of I-5. These results were subsequently removed from consideration. In summary, data and information derived from the modeling effort should be considered in conjunction with known site conditions to minimize the impact of uncertainty attributed to model and data limitations.

2.3.1 OU1-HRIA Boundary

As shown on the MVS frame for PCE in groundwater greater than (>) 500 µg/L (**Appendix A**), a distinct northwest-southeast trending "bottleneck" exists between the HRIA and the Breen property. In the >100 µg/L frame, where the HRIA extends further to the northwest and parallel to the Breen plume, the boundary is not as distinct but is still present and can be used to set the proposed western edge boundary for the HRIA just west of the former United Rentals building as shown on **Figure 2-3.**

The HRIA boundary to the east and south is based on the extent of contamination present in those directions. To the north, the HRIA encompasses a portion of Berwick Creek and extends to just south of the livestock auction building on the Breen property.

2.3.2 PCE Mass Estimate

PCE mass estimates are presented in **Table 2-2**. Total mass levels were calculated assuming that PCE concentrations in soil samples represent mass sorbed to soil, mass dissolved in groundwater, and mass as non-aqueous phase liquid (NAPL) while groundwater sample concentrations represent PCE dissolved in groundwater and as NAPL. Mass and volume calculations were completed using the following parameter estimates:

- Soil Density = 1.7 grams per cubic centimeter (gm/cc)
- PCE Density = 1.6 gm/cc
- Total Porosity = 0.36

Due to uncertainties in the creek bed sediment contaminant mass, sediment/bank surface soil mass estimates were not included in the total mass calculations using MVS for subsurface soil and groundwater. Instead, the MVS model was used to estimate the areal extent of contamination less than 5 feet bgs that exceeded 0.468 mg/kg (EPA's fresh water bench mark screening PCE value for sediment). This area is approximately 7,400 square feet and includes locations where maximum PCE concentrations were observed [SB-411 (685 mg/kg), SB-410 (1,610 mg/kg), and SB-409 (5,220 mg/kg). These values are indicative of DNAPL as they exceed the soil saturation limit for PCE (see Section 3.2.2. for more details).

This zone represents the area where PCE was released and is delineated separately (i.e., apart from subsurface soil) because it is at the ground surface, contains a high mass of PCE (163 kg), and represents the largest single concentration of mass that could be directly impacting receptors and could potentially serve as a continuing source of groundwater contamination.

<u>Comparison to Previous PCE Mass Estimate</u>

A PCE mass estimate had also be completed as part of the EE/CA. There are three main differences between the EE/CA analysis and the analysis completed using MVS: (1) the MVS model uses kriged interpolation where the analytical data are log transformed prior to kriging, (2) the MVS model uses a much smaller grid to evaluate data spatially by interpolation through kriging and so all data are "connected" in three dimensions and these spatial relationships are accounted for in the analysis, and (3) MVS evaluates uncertainty for every point to evaluate the spatial uncertainty such that it is possible to identify areas of the predicted plume where there is high confidence in the data set and areas of the predicted plume where there is low confidence can be predicted.

The EE/CA analysis essentially divided up the data based on areas that contained low concentrations and those that contained high concentrations of contaminants to define boundaries (Silt Cap NAPL Zone, NAPL Zone, Remainder Zone) where data within that boundary were evaluated as independent "bins" of data not accounting for their spatial location within the zone volumes. The three data sets were then evaluated independently by (1) taking mean, standard deviation, and confidence intervals for the data sets independently of one another; (2) evaluating the data distribution above and below a certain threshold (NAPL threshold); and (3) taking a total volume and the average concentration measured within that volume and calculating contaminant mass. In contrast, the MVS model analyzes the data in 3D space by assigning the data to a specific spatial location and then log transforming the data because there are several orders of magnitude difference in soil and groundwater sample contaminant concentrations, thereby evaluating the data in log space. MVS interpolates between those log values and evaluates trends in space. By conducting the statistics (mean, standard deviation etc.) using the straight contaminant concentrations values without log transformation results in higher values because the data set varies over 2 to 3 orders of magnitude. Second, MVS uses interpolation to define contaminant concentrations at nodes within a high resolution grid between data points in 3D space. Therefore, each of these nodes is evaluated as a spatial point within the 3D grid. The smaller cell size of the MVS model combined with the kriged interpolation work together to arguably produce a more accurate estimate of mass, which is almost always lower than using an arithmetic average (non-log transformed) applied over large volumes. This is illustrated in the estimated NAPL in the EE/CA estimate for the NAPL zone (1481 kg over approximately 18,000 square feet around the DNAPL source zone) compared to 506 kg estimated by the MVS model for an area over approximately 33,000 square feet around the DNAPL source area.

Finally, MVS allows an evaluation of confidence for a given node (value) within the grid and at set intervals for the entire 3D plume to evaluate contaminant extent and understand how changing confidence intervals impacts size and extent of the predicted contaminant plume. In the EE analysis, there is no variogram; the analysis evaluated the log distribution curve to evaluate uncertainty for one set of samples (i.e., NAPL Zone) as in one bin of data. In MVS, on the other hand, the entire 3D nodal grid (both measured values and predicted values) are evaluated in 3D space and so every sample affects results around that point. If the confidence is high because the data distribution is highly resolved within one given portion of the visualized contaminant plume, then the 3D plume does not change when confidence values are changed from lower to higher certainty. However, if the spatial data resolution is low, and the model predicts high contaminant concentrations, then MVS will expand the plume dramatically with the assignment of higher confidence values. Evaluating how assigning different confidence values changes the predicted extent of the contaminant plume helps to define where and how much additional data resolution is needed to reduce uncertainty. The EE/CA analysis gave no evaluation of how uncertainty changed within the spatial boundaries (Silt Cap NAPL Zone, NAPL Zone, Remainder Zone) and where areas of high uncertainty within the contaminant plume might exist.

2.4 Principal Threat Wastes

The National Oil and Hazardous Substance Pollution Contingency Plan (NCP) establishes an expectation that EPA will use treatment to address the principal threats posed by a site wherever practicable (40 Code of Federal Regulations [CFR] §300.430(a)(1)(iii)(A)). This expectation is derived from CERCLA §121 (Cleanup Standards). Identifying the principal threats combines concepts of both hazard and risk. In general, principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be contained in a reliable manner or would present a significant risk to human health or the environment should exposure occur. The manner in which principal threats are addressed generally will determine whether the statutory preference for treatment as a principal element is satisfied.

The DNAPL present in the contaminated sediment and soil in OU1 is considered a principal threat waste. Note that contaminated groundwater generally is not considered to be source material; however, DNAPL in groundwater may be considered as source material and therefore as a principal threat waste (EPA 1991). The Selected Interim Remedy addresses the principal threat wastes present in OU1 though in-situ thermal treatment and enhanced in-situ bioremediation.

2.5 Preliminary Conceptual Site Model

A preliminary CSM has been developed for the Hamilton/Labree Site based on the Site's history (e.g., past uses) and physical characteristics (e.g., topography) and from results of various investigations conducted across the Site. The CSM tells the story of when and where the Site was contaminated, what media were affected, where the contamination migrated (called pathways), and who and what is or can be potentially harmed from the contamination (called receptors). Development of the CSM is an evolving process; as more is learned about the Site, the CSM will be modified to reflect that knowledge. This CSM is based on consideration of Site information and previous Site investigations and data summarized in the draft Site-wide RI report (CDM Smith 2011a). The CSM includes the distribution of contamination, location of contaminant mass, and migration pathways to receptors.

As indicated in Section 2.2.1, PCE has been detected more frequently and at much higher concentrations than the other COPCs. Therefore, for the purpose of discussing contamination, PCE is the representative or indicator COPC. Other, essentially secondary COPCs and presumptive COPCs are discussed in Section 2.2.1.

A graphical depiction of the CSM is presented in **Figure 2-8**, showing contaminant release areas, transport pathways, and potential receptors. PCE at the HRIA appears to have been released as a spill or by direct dumping into Berwick Creek between 1974 and 1990. The most likely location of the discharge is between SB-410 and SB-409 (near MW-602 and MW-603 on **Figure 2-4**), which is referred to as the "Southeastern Hot Spot." It is suspected that there was a single release, although it is possible that there were multiple releases in this area of the creek, with a second release in the vicinity of MW-R4, referred to as the "Northwestern Hot Spot." The estimated volume of the release is 100 to 700 gallons (URS 2004).

Berwick Creek is a low-velocity stream for most of the year except when heavy rains or major flooding events occur. Assuming the creek was at a low velocity when the PCE was released, most of it likely sank to the bottom of the creek bed, spread downstream and a little way upstream (due to localized stream topography), and pooled in low areas.

In OU1, the fine-grained material in the Berwick Creek sediments (containing a high fraction of organic carbon), and to a lesser extent, the thin layer of silty/clay immediately beneath it, have sorbed PCE and slowed its migration into the sand and gravel aquifer. However, it appears that the large volume of PCE spilled in the creek overwhelmed the capacity of the creek bed and silty/clay layer to contain the spill, and the PCE in turn migrated into the subsurface soil and shallow aquifer. PCE DNAPL quickly migrated through the creek sediments and the thin layer of silt/clay below the sediments, which are approximately 1 foot thick in the creek bed in the portion of the source area defined by soil borings SB-411, SB-410, and SB-409 (oriented southeast to northwest), and into the sand/gravel aquifer.

The sand and gravel matrix of the shallow aquifer is highly permeable, facilitating the vertical (downward) and lateral (downgradient) migration of the dissolved phase plume. The PCE appears to have continued to move downward and laterally in an irregular pattern within the aquifer matrix, preferentially following lenses of higher permeability soils. The soil and groundwater data suggest that the PCE mass has tended to be absorbed by and pooled on top of the occasional, discontinuous lower permeability silt lenses in the upper zone of the aquifer, thus, impeding the PCE migration. PCE concentrations generally (but not always) decrease with depth.

Table 2-2 lists the estimated amount of contaminant mass at various contaminant levels in HRIA creek bed sediment, soil, and groundwater and is used to help define the remediation target zones discussed in Section 3. It also tabulates the estimated total plume volume and the surface area for each concentration level. Within the HRIA, a total PCE mass of 686 kg in soil is estimated to be distributed across a volume of 639,000 cubic yards (cy), with 339,260 square feet of surface area. Approximately 87% of the mass in groundwater and subsurface soil exists within the volume defined by the 4,000 µg/L isoconcentration line. Additionally, PCE was found in the creek bed sediments at concentrations above 5,000 mg/kg, which may indicate that residual DNAPL still exists in the pores of the sediment. As indicated in Section 2.3.2, the creek sediment locations with elevated PCE concentrations are included in the creek bed sediment/bank surface soil zone with concentrations above 0.468 mg/kg PCE that contains a high mass of PCE (163 kg) and represents the largest single concentration of mass that could be directly impacting receptors and could potentially serve as a continuing source of groundwater contamination.

PCE concentrations in the groundwater are high enough to indicate that the release to the creek was of sufficient quantity to have resulted in migration of DNAPL to the shallow groundwater aquifer based on a few groundwater detections exceeding the solubility limit of PCE (200,000 µg/L) and numerous detections exceeding 10% of the solubility limit (20,000 µg/L). PCE dissolving from pooled DNAPL and that which is desorbing and/or diffusing from the lower permeability layers will act as continuing sources of PCE to the aquifer. The predominant transport direction appears to have been towards the northwest, following the regional groundwater gradient.

Although the HRIA source area continues to generate a high concentration PCE plume, there are apparent constraints on how contamination reaches the areas downgradient of the HRIA source areas because of the bottleneck (see Section 2.3.1), which apparently prevents significant transport of PCE in the upper zone of the shallow aquifer from the HRIA to the Breen Property and the Thurman Berwick Creek Area. There could be multiple reasons that account for this pattern of contaminant migration, but none fully explain it. Lateral and vertical hydraulic gradients may be different in the upper and lower zones of the shallow aquifer. In addition, seasonal changes in gradient may also have some effect. As indicated previously, much of the dissolved PCE may have originated from the DNAPL in the aquifer, but the soil and groundwater data in the HRIA suggest that the bulk of the DNAPL-impacted soils remained in the upper zone. The split between the presence of contamination and lack thereof within the upper and lower zones in the shallow aquifer needs further characterization to establish where and why these changes occur, but the transition suggests stratification as a result of the groundwater flow regime in this area.

2.6 Risk Evaluation

CERCLA requires EPA to protect human health and the environment from current and possible future exposures to hazardous substances at Superfund sites. To evaluate exposure risks, EPA conducts studies called Baseline Risk Assessments (BLRAs). The BLRA estimates what risks the site poses if no remedial action were taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the interim remedial action. This section of the FS summarizes the results of the BLRA conducted for the Hamilton/Labree Superfund Site as it relates to the HRIA (CDM Smith 2011b).

Note: Human health toxicity data for PCE, TCE, cis-1,2-DCE, and methylene chloride, have been revised since publication of the draft 2011 Site-wide BLRA Report and the 2012 Proposed Plan. EPA Region 10 *risk assessors have updated the risk calculations using the new toxicity data. The Draft BLRA Report can still be used to show how the human health risk assessment was conducted.*

2.6.1 Human Health Risks

The potential adverse effects on human health from being exposed to contaminants from a Superfund Site are expressed in terms of cancer-causing (carcinogenic) risks (individual excess lifetime cancer risks) and non-carcinogenic hazard levels (hazard indices or HIs). EPA's acceptable range for carcinogenic risk is 1 in 10,000 to 1 in one million (1×10^{-4} to $1 \times 10^{-6)}$ individual excess lifetime risk of developing cancer from the contaminants at a site, and the acceptable non-carcinogenic target hazard level is an HI of less than 1.0. The estimated carcinogenic risks and non-cancer hazards for four categories of people who may be exposed to contamination within or near the HRIA are as follows:

Commercial/Industrial Workers

Individual excess lifetime cancer risks and non-cancer hazards were estimated for a long-term commercial/industrial employee working two hundred fifty, 8-hour days per year for 25 years indoors at either the main building or the paint shop on the United Rentals Property and doing incidental maintenance outside of the buildings on this property. Exposure to contaminants in soil, indoor and outdoor air, and groundwater were evaluated.

Under the current use scenario, the estimated individual excess lifetime cancer risks and non-cancer HI are 3×10^{-6} and 0.9, respectively, for commercial/industrial workers from ingestion and inhalation of soil contaminated with PCE and TCE in the HRIA.

The current risks to commercial/industrial workers from inhalation of indoor air contaminated with PCE, TCE, and methylene chloride are as follows: the main building estimated individual excess lifetime cancer risks and non-cancer HI are 1×10^{-7} and 0.01, respectively, and the paint shop estimated individual excess lifetime cancer risks and non-cancer HI are 3×10^{-8} and 0.01, respectively. The estimated individual excess lifetime cancer risk to commercial/industrial workers from inhalation of PCE, TCE, and methylene chloride in outdoor air is 4×10^{-8}, and the non-cancer HI is 0.01.

Currently, groundwater in the HRIA is not being used for drinking water or other purposes, such as showering; therefore, there is no significant current risk from this pathway. If chemical concentrations persist in groundwater and it is used as drinking water or for other purposes in the future, over time the estimated individual excess lifetime cancer risk for commercial /industrial workers would be 2×10^{-3} from ingestion, inhalation, and dermal contact with PCE, TCE, and methylene chloride. The non-cancer HI would be 386 from inhalation of PCE, TCE, and methylene chloride and ingestion and dermal contact with all four HRIA COPCs. The United Rentals Property is currently on the City of Chehalis municipal water-supply system, which makes this an unlikely future scenario.

Construction/Utility (Trench) Worker

Individual excess lifetime cancer risks and non-cancer hazards were also estimated for a short-term construction/utility worker (twenty, 8-hour days per year for 1 year) working outside within the HRIA. Exposure to contaminants in soil, air, and groundwater were evaluated.

Under current uses, the estimated individual excess lifetime cancer risks and non-cancer HI are 3×10^{-6} and 0.90, respectively, from ingestion and inhalation of soil contaminated with PCE and TCE. The inhalation pathway is the most current significant exposure route for short-term construction and utility workers who work in trenches within the HRIA, primarily from inhalation of PCE and TCE in groundwater vapors. Based on estimates of trench air concentrations at three HRIA subareas and assuming that a worker will have a total exposure time of 500 hours over 1 year (125 days/year at 4 hours/day), the estimated individual excess lifetime cancer risks range from 6 x 10^{-8} to 1 x 10^{-9}, and the non-cancer HI range from 7.5 to 457.[4]

If chemical concentrations persist in groundwater and it is used as a drinking water source in the future, over time the estimated individual excess lifetime cancer risks to construction/utility workers would be 4 x 10^{-6} from ingestion, inhalation, and dermal contact with PCE, TCE, and methylene chloride. The non-cancer HI would be 23.6 from inhalation of PCE, TCE, and methylene chloride, and from ingestion and dermal contact with all four HRIA COPCs. Due to the transient nature of construction and utility work, this future exposure scenario is unlikely.

Trespasser

The individual excess lifetime cancer risks and HI for a trespasser in the HRIA currently exposed to soil and outdoor air were estimated to be less than that of a short-term construction/utility worker (less than 3 x 10^{-6} and 0.9, respectively). This was based on the assumption that a trespasser would be exposed for a shorter period of time.

Berwick Creek Recreator

Current and future individual excess lifetime cancer risks and non-cancer HIs were estimated for adults and children recreating infrequently at Berwick Creek within the HRIA. The estimated individual excess lifetime cancer risks are 4 x 10^{-6} for both adults and children, which were predominately driven by ingestion and inhalation of PCE in creek bed sediment and bank surface soil. The non-cancer HI from ingestion and inhalation exposure to PCE in sediment and soil for both adults and children was less than 1.0.

The estimated individual excess lifetime cancer risk from ingestion and dermal contact with PCE, TCE, and cis-1,2-DCE in surface water within the HRIA is 8 x 10^{-8} for both adults and children.. The non-cancer HI for both adults and children was less than 1.0.

2.6.2 Ecological Risks

Estimates of risks to ecological receptors from Superfund site contaminants are expressed in terms of hazard quotients (HQs). The acceptable target hazard level is a HQ of less than 1.0. The estimated HQ's for four categories of ecological receptors within and near the HRIA are as follows:

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[4] In the Draft 2011 Site-wide BLRA Report, the estimated individual excess lifetime cancer risks ranged from 2 x 10^{-3} to 4 x 10^{-5}, and the non-cancer HIs ranged from 1.3 to 121. The differences between the 2011 estimates and those presented in this FS are due to the following: (1) the air exposure point concentrations (EPCs) used in the 2011 trench scenario risk calculations were derived by modeling whereas the recalculated values presented in this FS are based on groundwater concentrations as stipulated in the "Box Model" approach (Andelman 1985 and EPA 1999), which calculates the concentration of chemical in trench air (µg/m^3) by multiplying the groundwater concentration (µg/L) by the volatilization factor (VF) [liters per cubic meter (L/m^3)] and (2) new toxicity data for PCE, TCE, cis-1, 2-DCE, and methylene chloride published in EPA RSL Tables (EPA 2012).

Wildlife Receptors

Risks to wildlife receptors were estimated in terms of HQs. The acceptable target hazard level is an HQ of less than 1.0. Wildlife receptors evaluated in the HRIA included several types of birds (bald eagle, American robin, mallard duck) and mammals (short-tailed shrew, raccoon, white-tailed deer). No elevated risks for bald eagle were identified. However, risks for American robins (HQs = 1.3 to 11) and mallard ducks (HQs = 3) were elevated for PCE primarily due to their high sediment/soil ingestion rate and the elevated PCE concentrations identified in Berwick Creek sediments. Elevated risks were also found for short-tailed shrews in the HRIA primarily from inhalation of PCE-contaminated soil in burrow air (HQ = 50). Both raccoons (HQs = 8.5 to 43) and deer (HQs = 1.2 to 6.6) had elevated risks primarily from the high PCE concentrations found in Berwick Creek sediments.

Aquatic Receptors

Aquatic receptors, (e.g., salmon and rainbow trout), were evaluated for direct contact to mean (95% UCL) PCE and TCE concentrations in surface waters of Berwick Creek. Potential PCE and TCE risks to these receptors are negligible.

Benthic Receptors

Benthic organisms live at the bottom of water bodies and are important links in the food chain, providing a food source for fishes, birds, and mammals. Due to the lack of biologically relevant creek bed sediment samples taken in Berwick Creek, HQs were not able to be estimated. However, given that the maximum PCE concentrations measured in Berwick Creek exceed sediment quality benchmarks by 3 to 4 orders of magnitude, it is possible that benthic organisms are negatively impacted by contamination within the HRIA.

Terrestrial Plants

The terrestrial plant HQs from exposure to soils did not exceed 1.0 for any exposure area or COPC. However, the terrestrial plant HQ from exposure to groundwater within the HRIA exceeded 1.0. This suggests that plants with root systems deep enough to encounter PCE-contaminated groundwater may be adversely affected.

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Section 3
Remedial Action Objectives

Section 3 first discusses using a phased approach in addressing contamination at the Hamilton Labree Superfund Site, beginning with an interim action that focuses on the known sources of contamination in the HRIA OU1. It then identifies and defines applicable or relevant and appropriate federal and state environmental and state facility siting requirements (ARARs) and To Be Considered (TBC) standards and guidance that must be considered when evaluating the feasibility of various HRIA remedial alternatives. This section then presents the RAOs for the proposed interim action, followed by the associated preliminary remediation goals (PRGs) and the basis for them, and following those, a section which identifies and defines three remediation target zones that will be the focus for this interim remedial action.

3.1 A Phased Approach

According to the NCP [40 CFR 300.430(a)(1)(I)], the goal of the remedy selection process is “to select remedies that are protective of human health and the environment, maintain protection over time, and minimize untreated waste.” Expectations for contaminated groundwater as stated in the NCP are as follows: "EPA expects to return usable groundwaters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction." (Federal Register 1990; §300.430 (a)(1)(iii)(F), emphasis added.)

EPA Guidance, (specifically the *Presumptive Response Strategy And Ex-Situ Treatment Technologies For Contaminated Ground Water At CERCLA Sites*, OSWER Directive 9283.1-12, October 1996) recommends that site characterization should be coordinated with remedial actions and both should be implemented in a step-by-step or phased approach. In a phased approach, early or interim actions should be used to reduce site risks (by addressing known sources of contamination, reducing risks from exposure to contamination, and by reducing or preventing the further migration of contaminants) and to provide additional site data to be followed by a later, more comprehensive action (the long-term remedial action). Specific objectives for the long-term remedial action are not established until after performance of the earlier interim action is evaluated and used to assess the likelihood that groundwater restoration (or other appropriate objectives) can be attained. Separate decision documents are used in which remedial objectives are specified that are appropriate for each action.

EPA is using a phased approach to address the risks posed by the Site and to facilitate remediation. EPA plans to first address the known sources of PCE contamination to groundwater and prevent risks within the HRIA and to minimize further migration of contaminated groundwater from the HRIA. Doing so will also address the principal threat waste, identified as PCE DNAPL, in the HRIA. The proposed interim remedial action will be selected after considering public comments in a Record of Decision (ROD).

Although there appears to be other sources of contamination at the Site outside (downgradient) of the HRIA, more data need to be collected to better understand those sources before pursuing further remedial actions. The HRIA interim remedial action is necessary to address the known source of high levels of contamination in that area. Additional site-wide data collection and evaluation is needed for EPA to develop, select, and implement additional remedial action(s) for the Site that will achieve long-term objectives and protectiveness.

3.2 Applicable or Relevant and Appropriate Requirements

This section provides a preliminary discussion of the laws and regulations that are applicable or relevant and appropriate to the remediation of the contaminated media at the HRIA as well as nonpromulgated criteria, advisories, and guidance that are "to be considered" (TBCs).

3.2.1 Definition of ARARs and TBCs

CERCLA Section 121 requires that remedial actions at Superfund sites must attain a level of cleanup which, at a minimum, ensures protection of human health and the environment. CERCLA, the NCP, and EPA guidance and policy also require remedial actions to comply with the substantive provisions of ARARs from federal and state environmental and state facility siting laws during and at the completion of each remedial action unless legal waivers are obtained. A requirement may be either "applicable" or "relevant and appropriate" to a site-specific remedial action but not both. Remedial actions also must take into account nonpromulgated TBC criteria or guidelines if the ARARs do not address a particular site-specific situation.

The degree to which these environmental and facility siting requirements must be met varies, depending on the applicability of the requirements. Applicable requirements must be met to the full extent required by law. CERCLA provides that permits are not required when a response action is taken "onsite." The NCP defines the term "onsite" as "the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for the implementation of the response action" (40 CFR 300.5). Although permits are not required, the substance of the applicable permits must be met. On the other hand, only the relevant and appropriate portions of non-applicable requirements must be achieved and only to the degree that they are substantive rather than administrative in nature. Offsite actions are subject to the full requirements of the applicable standards or regulations, including all administrative and procedural requirements.

3.2.1.1 Applicable Requirements

Applicable requirements pertain to those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, state environmental, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable. Applicable requirements are defined in the NCP at 40 CFR 300.5—Definitions.

3.2.1.2 Relevant and Appropriate Requirements

Relevant and appropriate requirements pertain to those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, state environmental, or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site per se, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate. Relevant and appropriate requirements are defined in the NCP at 40 CFR 300.5—Definitions.

The determination that a requirement is relevant and appropriate is a two-step process that includes (1) the determination if a requirement is relevant and (2) the determination if a requirement is appropriate. In general, this involves a comparison of a number of site-specific factors, including an examination of the purpose of the requirement and the purpose of the proposed CERCLA action, the medium and substances regulated by the requirement and the proposed requirement, the actions or activities regulated by the requirement and the remedial action, and the potential use of resources addressed in the requirement and the remedial action. When the analysis results in a determination that a requirement is both relevant and appropriate, such a requirement must be complied with to the same degree as if it were applicable (EPA 1988).

3.2.1.3 TBCs

These requirements pertain to federal and state criteria, advisories, guidelines, or proposed standards that are not generally enforceable but are advisory and that do not have the status of potential ARARs. Guidance documents or advisories "to be considered" in determining the necessary level of remediation for protection of human health or the environment may be used where no specific ARARs exist for a chemical or situation or where such ARARs are not sufficient to be protective.

3.2.1.4 Waivers of Specific ARARs

Superfund specifies situations under which the ARARs may be waived (40 CFR 300.430: Remedial Investigation/Feasibility Study (f) Selection of Remedy). The situations eligible for waivers include:

- The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement.
- Compliance with the requirement will result in greater risk to human health and the environment than other alternatives.
- Compliance with the requirement is technically impracticable from an engineering perspective.
- The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.

With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state.

For fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of fund monies to respond to other sites that may present a threat to human health and the environment.

Where remedial actions are selected that do not attain ARARs, the lead agency must publish an explanation in terms of these waivers. It should be noted that the "fund balancing waiver" only applies to Superfund-financed remedial actions.

3.2.2 Identification of ARARs and TBCs

Three classifications of requirements are defined by EPA in the ARAR determination process. ARARs are defined as chemical-, location-, or action-specific. An ARAR can be one or a combination of all three types of ARARs; chemical-specific, location-specific. and action-specific ARARs.

Chemical-specific ARARs include those laws and regulations governing the release of materials possessing certain chemical or physical characteristics or containing specified chemical compounds. These ARARs and TBCs usually are numerical values that are health- or risk-based values or methodologies. They establish acceptable amounts or concentration of chemicals that may be found in, or discharged to, the ambient environment. They also may define acceptable exposure levels for a specific contaminant in an environmental medium. They may be actual concentration-based cleanup levels, or they may provide the basis for calculating such levels. Examples of chemical-specific ARARs are polychlorinated biphenyl (PCB) cleanup criteria for soils under the Toxic Substances and Control Act (TSCA) or MCLs specified for public drinking water that are applicable to groundwater aquifers used for drinking water.

Location-specific ARARs are design requirements or activity restrictions based on the geographical or physical positions of the site and its surrounding area. Location-specific requirements set restrictions on the types of remedial activities that can be performed based on site-specific characteristics or location. Examples include areas in a floodplain, a wetland, or a historic site. Location-specific criteria can generally be established early in the RI/FS process since they are not affected by the type of contaminant or the type of remedial action implemented.

Action-specific ARARs are technology-based, establishing performance, design, or other similar action-specific controls or regulations for the activities related to the management of hazardous substances or pollutants. Selection of a particular remedial action at a site will invoke the appropriate action-specific ARARs, which specify performance standards or technologies, as well as specific environmental levels for discharged or residual chemicals. An example includes transportation of hazardous waste regulations.

HRIA-specific potential ARARs are listed in **Appendix B Tables B-1** through **B-3**[5].

3.3 HRIA RAOs

As indicated in Section 2.6, the following COPCs and media of concern have been identified for the HRIA:

For human health

- PCE (sediment, soil, groundwater)
- TCE (groundwater)

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[5] The ARARs presented in the August 2004 EE/CA report also were considered for inclusion in this FS. With one exception, all the ARARs originally considered in the EE/CA were determined to be appropriate for consideration as ARARs and are included in **Tables B-1** through **B-3**. The EE/CA included Section 10 of the Rivers and Harbors Appropriations Act Regulations (33 CFR Parts 320,322) as a location-specific ARAR. Section 10 of this statute prohibits the unauthorized obstruction or alteration of navigable waters; however, it was determined that Berwick Creek is not considered navigable water, and the statute was not included in this FS.

- cis-1,2-DCE (groundwater)
- Methylene chloride (groundwater)

For ecological receptors

- PCE (sediment, soil)
- TCE (soil)

RAOs provide a general description of what a remedial action is intended to accomplish in terms of contaminants and media of concern, potential exposure pathways, and remediation goals. The following RAOs are defined for the HRIA interim action:

1. Prevent human exposure to groundwater in the HRIA containing COPCs above levels that are protective of drinking water.

2. Prevent human exposure to COPCs in HRIA sediment and soil above levels that are protective of commercial/industrial workers, construction/utility (trench) workers, and recreational users.

3. Prevent ecological exposure to COPCs in HRIA sediment and soil above levels that are protective of ecological receptors.

4. Reduce the DNAPL contaminant mass and subsurface soil contamination within the HRIA to minimize further migration of COPCs from the HRIA to downgradient groundwater.

These RAOs and the associated PRGs discussed below address COPCs (primarily PCE) in sediment, soil, and groundwater and the risks associated with these contaminants within the HRIA as identified in the risk assessment. Taking action to address these RAOs will also reduce or eliminate HRIA sources of contamination to downgradient groundwater. These RAOs also address the principal threat waste in the HRIA, identified as PCE DNAPL.

3.4 Preliminary Remedial Goals

PRGs are the more specific statements of what the remedial action's endpoint concentrations or risk levels, for each exposure route, are to be in order to provide adequate protection of human health and the environment. PRGs are developed based on ARARs from federal and state environmental standards. Where standards do not exist, PRGs are based on risk. CERCLA Section 121 requires that remedial actions at Superfund sites must achieve a level of cleanup which, at a minimum, ensures protection of human health and the environment. CERCLA and the NCP also require remedial actions to comply with the substantive provisions of ARARs during and at the completion of remedial actions unless legal waivers are obtained. Potential HRIA ARARs and TBCs are listed in **Appendix B Tables B-1** through **B-3.**

The alternatives considered for the HRIA will be an interim remedial action. Consequently, none of the alternatives evaluated are expected to be able to fully attain all of the ARARs for the HRIA. The ARARs that will be attained and those that will be waived will be specified in the HRIA ROD, which is expected to include the interim action waiver provided for in Section 121(d)(4)(A) of CERCLA. The HRIA ROD will be followed by a ROD for the HRIA or the Site that will fully address compliance with all ARARs, consistent with CERCLA, including any waivers. The key ARARs to be addressed by this interim action are discussed below.

3.4.1 Key Factors for Setting HRIA Interim Action PRGs

Key factors for setting HRIA PRGs include ARARs, risk-based calculations, and the decision to proceed with an interim remedial action at this time.

The key ARARs for establishment of groundwater PRGs include the Safe Drinking Water Act MCLs and the substantive provisions of Ground Water Cleanup Standards in Section 720 of the State of Washington's Model Toxic Control Act (MTCA) (WAC 73-340-720). MCLs apply to drinking water at the tap but are relevant and appropriate for groundwater that is a potential source of drinking water; therefore, these must be met or waived by completion of the remedial action. Another section of MTCA that is considered an ARAR for groundwater remedial actions is WAC 173-340-747 (Deriving soil concentrations for groundwater protection). This section requires soil remedial actions to achieve levels that will not cause an exceedance of groundwater cleanup levels and will not result in the accumulation of non-aqueous phase liquid on or in groundwater. All of the alternatives considered in this FS (except the No Action alternative) include institutional controls (ICs) to prevent human exposure to groundwater above MCLs, but full compliance with groundwater ARARs, such as those identified above, is beyond the scope of this interim remedial action.

The key ARARs considered in the establishment of a sediment and soil PRG for the interim remedial action include MTCA Section 705 (WAC 173-340-705 [Use of Method B]) and MTCA Section 740 (WAC 173-340-740 [Unrestricted land use soil cleanup standards]). Applying unrestricted soil levels is more appropriate than the less stringent industrial levels under MTCA Method C (WAC 173-340-706) because the current and reasonably anticipated future land use includes recreational uses (e.g., swimming in Berwick Creek) in addition to commercial and industrial uses. For both sediment and soil at this Site, the substantive requirements in these sections of MTCA, to the extent they are more stringent than federal requirement, are considered ARARs such that PRGs must be established at:

- Concentrations that are estimated to result in no acute or chronic toxic effects on human health as determined using an HQ of 1 (this requirement is equivalent to the NCP requirement)
- Concentrations for which the upper bound on the estimated excess cancer risk is less than or equal to one in one million (1×10^{-6}) for individual known or suspected carcinogens
- Concentrations of individual hazardous substances that are adjusted downward to take into account exposure to multiple hazardous substances and/or exposure resulting from more than one pathway of exposure, if, without these adjustments, the HI would exceed 1 or the total excess cancer risk would exceed one in one hundred thousand (1×10^{-5})

Other key factors that form the basis for the PRGs include:

- The Superfund program goal and expectations in the NCP Section 300.430(a)(iii)(F) is "to return usable groundwaters to their beneficial uses, wherever practicable, within a timeframe that is reasonable given the circumstances of the site. When restoration of groundwater to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk reduction." The alternatives considered for the HRIA would do the latter.
- Baseline Risk Assessment (BLRA) and Regional Screening Levels (RSLs): The BLRA was used to identify exposed populations and exposure pathways by media and protective site-specific levels where adequate data were available. Where adequate data were not available, RSLs were

used to help evaluate risk and set a conservative PRG and performance measures. RSLs are risk-based, contaminant-specific levels or concentrations that set concentration limits based on an estimated risk of $1x10^{-6}$ for human carcinogens and an HI of 1.0 for human and ecological exposure to systemic contaminants under specific exposure conditions. Based on the RSLs, a PCE soil concentration of 22 mg/kg would be protective of humans from exposure via ingestion and inhalation of sediments and soils and would be even more protective than the MTCA Method B standard method value of 480 mg/kg for protection from direct contact. The most sensitive ecological receptor of concern from ingestion and inhalation exposures to soil contamination is the short-tailed shrew, a terrestrial ecological receptor, which according to EPA RSLs faces an unacceptable risk from PCE concentrations above 10 mg/kg. Based on the requirements for protectiveness of all these receptors, the selected sediment and soil PRG for PCE is 10 mg/kg.[6]

- Technology limitations and uncertainties associated with the proposed interim remedial actions.

3.4.2 HRIA PRGs for Each Remediation Target Zone

To achieve the RAOs for the proposed interim remedial action, PRGs for PCE are established for three, media-specific areas within the HRIA that are targeted for cleanup. These areas are called "remediation target zones." The mass, volume, and surface area of each zone is presented in **Table 2-2**. A summary of each zone, the associated PRG and the RAOs these would address are shown in **Table 3-1** and discussed in more detail below. Note there is no PRG proposed or discussed below for RAO 1 because the MCL for human consumption of groundwater is 5 μg/L, and achievement of the MCL is beyond the scope of this interim remedial action (it will be addressed in subsequent decisions). For this interim remedial action, institutional controls to prohibit use of HRIA groundwater for drinking are the only means of achieving RAO 1.

3.4.1.1 Creek Bed Sediment and Bank Surface Soil Remediation Target Zone

Figure 3-1 shows the proposed remediation target zone where creek bed sediment and bank surface soils at depths less than or equal to 5 feet bgs within the Berwick Creek channel are currently contaminated with PCE at levels equal to or greater than 0.468 mg/kg. 0.468 mg/kg PCE was used to define this zone's boundary based on EPA's fresh water RSLs for protection of aquatic organisms from PCE in sediments and because the majority of the surface soil contamination found to date within the HRIA is within the bed and banks of the current Berwick Creek channel. According to the conceptual site model, this zone represents the area where PCE was directly released and is delineated separately from surface soil outside of the creek channel, and from subsurface soil and groundwater.

The PRG established for this remediation target zone is to reduce creek bed sediment and bank surface soil to 10 mg/kg PCE. Maximum PCE concentrations in this zone ranged from 685 mg/kg to 5,220 mg/kg. These values are indicative of DNAPL as they exceed the soil saturation limit for PCE in the HRIA (38 mg/kg). However, due to the difficulty in analyzing DNAPL in soil borings and uncertainty in the data quality of the soil samples, there was a need to establish a more conservative "cutoff" concentration to account for the characterization uncertainty. A value of 10 mg/kg PCE was chosen instead of 38 mg/kg for this zone.

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[6] The EPA RSL for protection of terrestrial ecological receptors from TCE in sediment and soil is 12.4 mg/kg, and it is 0.91 mg/kg protection of humans under a residential use scenario. The currently identified maximum TCE level in OU1 creek bed sediment and bank surface soil is 0.19 mg/kg, which is below both RSLs.

Meeting this PRG would ensure residual soil concentrations would be protective for direct contact exposures, contaminant mass and migration to groundwater would be reduced, and principal threat wastes would be addressed. These goals would be well below the MTCA Method B cleanup level for human direct contact exposure with soils, which requires cleanups to attain the $1x10^{-6}$ risk level for protection of human direct contact exposure. The PCE concentration, which equates to a $1x10^{-6}$ risk from direct contact, is 22 mg/kg assuming residential use, 110 mg/kg assuming industrial/commercial and construction/utility (trench worker) use, and 924 mg/kg assuming recreational use.

Meeting this PRG would also reduce exposure from contaminated surface soil for terrestrial ecological receptors living outside of the current Berwick Creek channel. For example, the ecological risk assessment estimated an HQ of 50 for the short-tailed shrew based on inhalation of surface soil in burrow air. Reducing PCE contamination to 10 mg/kg would reduce the HQ to 1.7 based on conservative estimates. The EPA RSL that is protective for shrews is 9.92 mg/kg PCE, which is slightly less than the 10 mg/kg PRG, but this RSL is conservative and is based on ingestion of soil and food uptake. While only low levels of COPCs have been found in these soils to date, due to issues associated with soil sampling methods used in prior years, additional surface soil sampling would be conducted as part of the design process to better determine the extent of surface soil contamination outside of the current Berwick Creek channel.

While not a PRG, protection of benthic and freshwater organisms within the creek bed sediment and bank soils of the Berwick Creek channel from PCE concentrations > 0.468 mg/kg would be accomplished when restoring the creek channel. The 0.468 mg/kg level was set based on an EPA fresh water benchmark RSL for PCE in sediments.

In summary, in order to mitigate the principal threat waste in the HRIA, identified as PCE DNAPL, from current creek bed sediment and bank surface soil (and surface soil outside of the current creek bed sediment and bank surface soil), the following zone-specific PRG must be achieved:

- *Reduce creek bed sediment and bank surface soil PCE concentrations within the current Berwick Creek channel to 10 mg/kg PCE as soon as technically achievable in order to reduce DNAPL and reduce the risk of direct contact, ingestion, and inhalation of contaminated sediment and/or surface soils. Requirements that are protective of ecological receptors would need to be met for relocation or reconstruction of the Berwick Creek channel bed and banks, e.g., 0.468 mg/kg PCE based on EPA's RSLs for freshwater sediments.*

Achievement of this PRG would address RAOs 2 and 3 as they pertain to the creek bed sediment and bank soil of the current Berwick Creek channel and surface soils within the HRIA.

3.4.1.2 Subsurface Soil Remediation Target Zone

Figure 3-2 shows the proposed remediation target zone for subsurface soils. This zone is defined as the area where subsurface soils at depths between 5 to 50 feet bgs are contaminated with PCE levels greater than 10 mg/kg.

As with the Creek Bed Sediment and Bank Surface Soil Remediation Target Zone, a PRG of 10 mg/kg PCE was set for the Subsurface Soil Remediation Target Zone based on the potential for DNAPL to be present in subsurface soil. Maximum PCE concentrations in HRIA subsurface soils ranged from 53 mg/kg to 858 mg/kg. Using the 10 mg/kg value provides a good safety factor (26% of the PCE saturation limit of 38 mg/kg) and is below the MTCA Method B cleanup standards for direct contact with soil for PCE, which equates to a risk level of $1x10^{-6}$.

In summary, in order to reduce PCE DNAPL and soil source mass, the PRG for the Subsurface Soil Remediation Target Zone is:

- *Reduce PCE DNAPL present in subsurface soil as quickly as technically achievable. This will be determined by reducing PCE concentrations within this zone to 10 mg/kg.*

Achievement of this PRG would address RAOs 2 and 4 as they pertain to subsurface soil.

3.4.1.3 High Concentration Groundwater Remediation Target Zone

Figure 3-2 shows the remediation target zone for high concentration groundwater. This zone is defined as the area where groundwater at depths between 5 to 50 feet bgs are contaminated with PCE levels greater than 4,000 µg/L.

The 4,000 µg/L level was set based on the potential for DNAPL to be present and because approximately 87% of the contaminant mass in subsurface soil and groundwater found in the HRIA is within the >4,000 µg/L isocontour. The maximum PCE concentration in groundwater was detected at MW-602 (2,720,000 µg/L) under the suspected release area. Concentrations that exceed 10% of a contaminant's solubility limit in groundwater are indicative of DNAPL. PCE's solubility limit is 200,000 µg/L; therefore, concentration of 20,000 µg/L or higher in groundwater are indicative of PCE DNAPL within the HRIA.

For the HRIA, while concentration-based data provide information about contaminant levels at specific measuring points, it does not address the level which contaminants are being mobilized from the source area into the downgradient areas. Measuring mass discharge (Md) of contaminants from a source area combines chemical data, groundwater flow velocity, and discharge area into a single measurement (expressed as mass/time or grams/day). Using Md as a performance measure or PRG is a more direct way to measure contaminant migration from the HRIA DNAPL source zone. Generally, it can be expected that a one order of magnitude reduction in contaminant mass discharge can be achieved with targeted DNAPL source treatment with most commonly used technologies. A 90% reduction in PCE Md from the high concentration groundwater remediation target zone should be achievable based on reductions in organic compound concentrations that were achieved at similar sites where DNAPL source treatment was conducted (McDade et al. 2005, McGuire et al. 2006).

The use of mass discharge as a PRG is not currently a widespread practice, and regulations do not address the reduction of mass discharge as a RAO. However, there is significant utility in using mass discharge as a PRG to evaluate DNAPL source treatment because it conveys important information about source strength, aquifer attenuation rates, and/or areas to what extent mobile contaminant mass is moving. In fact, EPA points to the following reasons, among others, for using mass discharge estimates during site characterization and remediation, as discussed in Interstate Technology and Regulatory Council (ITRC) 2010.

- "The flux [discharge] is the best estimate of the amount of contaminant leaving the source area. This information would be needed to scale an active remedy if necessary."
- "The flux [discharge] estimate across the boundary to a receptor is the best estimate of loading to a receptor."

A contaminant Md reduction of 90% is expected to significantly reduce contaminant source strength, thereby reducing the continued discharge of contaminants. In addition, concentrations in the downgradient dissolved-phase plume are expected to decrease although no specific goal has been specified yet for these downgradient areas.

Even so, a reduction of PCE mass discharge across the 4,000 µg/L boundary will result in a greater understanding of the relationship between the OU1 DNAPL source area and the downgradient plume response that can help shape future remedial decision-making.

For instance, the reduction in mass discharge from the HRIA may be sufficient to observe a desired rate of contaminant plume retraction to allow for less-intensive cleanup to address remaining downgradient contamination and achieve long-term ARARs within the desired timeframe (e.g., MCLs at downgradient compliance and/or interim performance monitoring points). Alternatively, it may be determined that contaminant mass discharge from other sources located outside of the HRIA, but within the Site, contribute a much greater overall mass loading to the site-wide contaminant plume than the remaining contamination within the HRIA and thus are a priority for any additional remedial actions as part of the comprehensive site-wide strategy.

In summary, the PRG for the High Concentration Groundwater (PCE > 4,000 µg/L) Remediation Target Zone is :

- *Reduce migration (mass discharge or flux) of PCE contamination by 90% from the high concentration groundwater (greater than 4,000 µg/L PCE) to the downgradient dissolved phase plume as quickly as technically achievable.*

Achievement of this PRG will address and evaluate progress towards achieving RAO 4 as it pertains to subsurface soil, DNAPL, and high concentration groundwater in OU1. It would contribute to but not fully achieve RAO 1.

3.5 Future RAOs and PRGs

The RAOs described in this section were developed to guide the development and evaluation of a range of alternatives and associated interim PRGs to address the known sources of contamination in the HRIA, primarily PCE DNAPL in sediments and soils. After the HRIA interim remedial action is selected and implemented and additional data collection has occurred, RAOs and PRGs will be developed to guide the development, selection, and implementation of the long-term remedy or additional interim actions as appropriate.

Section 4

Identification and Screening of General Response Actions, Remedial Technologies, and Process Options

4.1 Overview

This section identifies GRAs, remedial technologies, and process options that are potentially useful to address the HRIA RAOs and PRGs identified in Section 3 for the contaminated media. Screening of the GRAs, remedial technologies, and process options is then performed in accordance with the NCP to retain representative technologies and process options that can be assembled into remedial alternatives as discussed in Section 5.

The identification and screening process consists of the following general steps:

- Develop GRAs for the contaminated media that will satisfy the HRIA RAOs and PRGs identified in Section 3.
- Compile remedial technologies and process options for each GRA that are potentially viable for remediation of the contaminated media.
- Screen the remedial technologies and process options with respect to technical implementability for the contaminated media at the site. Technologies and process options that are not technically implementable relative to the contaminated media are eliminated from further consideration.
- Evaluate and screen the retained remedial technologies and process options with respect to effectiveness, ease of implementability, and relative cost. Technologies and process options that have low effectiveness, low implementability, or high cost relative to the contaminated media are eliminated from further consideration.
- Assemble the retained technologies and process options for the contaminated media into remedial alternatives for the HRIA as presented in Section 5.

The remainder of this section categorizes the contaminated media and evaluates GRAs, technologies, and process options for each contaminated medium that are potentially viable for addressing the HRIA ARARs and RAOs discussed in Section 3.

4.2 Contaminated Media

The purpose of this subsection is to group and categorize the various contaminated media to facilitate identification of GRAs, remedial technologies, and process options that can be used to address the HRIA RAOs and PRGs.

The nature and extent of contamination at the Site and the human health and ecological risks posed by the various contaminated media were summarized in Section 2. Three main categories of contaminated media have been identified as posing potential risks to human health and/or the environment: creek bed sediment/ bank surface soil, subsurface soil, and groundwater. Several chlorinated solvents have been detected in these three media; however, PCE has been detected more frequently and at much higher concentrations than other chlorinated solvents and is the primary risk driver according to the baseline risk assessment. Therefore, PCE is considered the primary contaminant of concern at the Site.

Contaminated media will be addressed in the context of three remediation target zones. These include:

- Creek Bed Sediment/Bank Surface Soil Zone (creek bed sediment and bank surface soils at depths less than or equal to 5 feet bgs within the Berwick Creek channel with PCE concentrations > 0.468 mg/kg) (**Figure 3-1**).
- Subsurface Soil (subsurface soils at depths between 5 to 50 feet bgs contaminated with PCE concentrations > 10 mg/kg) (**Figure 3-2**).
- High Concentration Source Zone (groundwater at depths between 5- to 50 feet bgs with PCE concentrations > 4,000 μg/L) (**Figure 3-2**).

4.3 General Response Actions

GRAs are initial broad response actions considered to address the HRIA RAOs and PRGs for the contaminated media at the Site. GRAs include several remedial categories, such as containment, removal, disposal, and treatment of contamination within the media. Site-specific GRAs are first identified to satisfy the HRIA RAOs and PRGs for the contaminated media and then are evaluated as part of the screening of remedial technologies and process options for the contaminated media.

The GRAs considered for remediation of the contaminated media (i.e., creek bed sediment/surface soil, subsurface soil, and groundwater) include the following:

- No action
- Monitoring
- Institutional controls
- Engineered controls
- Containment
- Removal, transport, and disposal
- Treatment

No action leaves contaminated media in their existing condition with no control or remedial action planned. In accordance with the NCP, this GRA must be considered to provide a baseline against which other options can be compared.

Monitoring involves physical measures applied to the site to determine if there is contaminant migration. Monitoring is not intended to substitute any engineering aspect of a selected remedy and does not physically address contaminants.

Institutional controls *(ICs)* are administrative and legal restrictions intended to control or prevent present and future use of contaminated media. ICs are not intended to substitute for engineering aspects of a selected remedy.

Engineered controls are physical restrictions intended to control or prevent present and future access to contaminant media.

Containment involves physical measures applied to contaminated media to control the release of contaminants and/or prevent direct contact or exposure to the contaminants.

Removal, transport, and disposal involve a partial or complete removal of contaminated media, followed by transportation and disposal of the contaminated materials at an onsite/offsite location.

Treatment involves biological, chemical, thermal, and/or physical measures applied to the contaminated media that reduce toxicity, mobility, and/or volume of the contaminants present.

4.4 Identification and Screening of Remedial Technologies and Process Options

A list of remedial technologies and process options applicable to contaminated sediment, surface soil, subsurface soil, and groundwater were developed through a review of the following EPA guidance documents:

- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 1988).
- Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites (EPA 1996).
- Site Characterization and Technology Selection for CERCLA Sites With Volatile Organic Compounds in Soils (EPA 1993).

Other CERCLA site feasibility studies, the Federal Remediation Technologies Roundtable (FRTR) Remediation Technologies Screening Matrix and Reference Guide, Version 4.0 (FRTR 2007), and vendor sources were also reviewed and evaluated by CDM Smith to create a listing of remedial technologies and process options for contaminated sediment, surface soil, subsurface soil, and groundwater. The screening of technologies and process options for technical implementability, effectiveness, and cost were combined within one table for each contaminated media. The results of the technology screening evaluations are summarized in **Appendix C** in **Table C-1** for contaminated creek bed sediment/bank surface soil, **Table C-2** for contaminated groundwater, and **Table C-3** for contaminated subsurface soil.

A given technology or process option was eliminated from further consideration on the basis of technical implementability if site conditions or site characterization data indicated that the technology or process option is incompatible with the contaminants or contaminated media, or cannot be implemented effectively due to physical limitations or constraints at the site. The process options eliminated from further consideration for the contaminated media (with the rationale for elimination) are indicated on the tables using grey shading.

Screening of Remedial Technologies for Effectiveness, Implementability, and Relative Cost

Each of the technically implementable remedial technologies and process options were further evaluated for effectiveness, implementability, and relative cost. The criteria used, as defined in this step of the FS process, are described below.

Effectiveness

The evaluation of the effectiveness of a remedial technology or process option focuses on:

- Potential effectiveness in handling the estimated volumes of contaminated media and meeting the goals identified in the HRIA RAOs and PRGs
- Potential impacts to human health and the environment (including assessment of potential vapor intrusion) during construction and implementation
- How proven the remedial technology or process option is with respect to the contaminants and conditions at the site

Implementability

Technically implementable technologies and process options are evaluated with respect to both the technical and administrative feasibility of implementing a remedial technology or process option. Technical implementability was used as an initial screening step to eliminate remedial technologies and process options that were clearly ineffective or unworkable at the site. The screening criteria place greater emphasis on the institutional aspects of implementability. These criteria include:

- Ability to obtain permits for offsite actions
- Availability and capacity of treatment, storage, and disposal services
- Availability of necessary equipment and skilled workers

Relative Cost

Cost plays a limited role in the screening of remedial technologies and process options. Relative capital and operations and maintenance (O&M) costs are used rather than detailed estimates. The cost analysis is evaluated based on engineering judgment and is ranked relative to other process options in the same technology type.

Each remedial technology or process option was qualitatively evaluated using these three criteria to determine whether they should be eliminated from further consideration in the FS or retained for assembly into remedial alternatives. Remedial technologies or process options deemed to have low effectiveness, low administrative implementability, and/or high relative cost for the contaminated medium are eliminated from further consideration in the FS.

Technologies and process options that were retained for one or more remediation target zones are marked with a "Y" in the "Retained" column. Technologies retained through the screening process were used to develop a range of remedial alternatives for the Site.

Section 5

Development of Remedial Alternatives

5.1 Overview

In this section, remedial action alternatives (herein referred to as remedial alternatives) are assembled by combining the retained remedial technologies and process options presented in Section 4 for each contaminated media. Remedial alternatives are developed from either stand-alone process options or combinations of the retained process options.

These remedial alternatives are then screened for effectiveness, implementability, and cost. The purpose of alternative screening is to reduce the number of remedial alternatives retained for detailed analyses in Section 6.

The remedial alternatives for the HRIA span a range of categories defined by the NCP as follows:

- No action alternative
- Alternatives that address the principal threats but involve little or no treatment include those where protection would be by prevention or control of exposure through actions such as containment, engineered controls, and/or ICs
- Alternatives that, as their principal element, employ treatment that reduces the toxicity, mobility, or volume of the contaminants
- Alternatives that remove or destroy contaminants to the maximum extent, eliminating or minimizing long-term management
- Alternatives that include innovative treatment technologies

5.2 Assumptions Affecting Development of Remedial Alternatives

Several fundamental assumptions affect the development of remedial alternatives evaluated in this FS (other than a "no action alternative"). These assumptions are driven by requirements of the RAOs and PRGs and site limitations and constraints that cannot be overcome by using one or more remedial technology/ process options as described in Section 4. These fundamental assumptions were taken into consideration during development of remedial alternatives for this FS and include the items listed in **Exhibit 5-1**. Note that changes to site conditions or the current understanding of site conditions may affect these current fundamental assumptions, which in turn, may impact the remedial alternatives developed for the HRIA.

Exhibit 5-1: Assumptions Affecting Development of Remedial Alternatives

Fundamental Assumption	Rationale
Exclusion of contaminated groundwater associated with OU2 in remedial alternative development	The focus of this FS is site contamination associated with and occurring within the HRIA. Although monitoring within OU2 may be conducted as part of the HRIA interim remedial action, the distal extent of the HRIA plume outside the boundary of the HRIA and the contaminated groundwater plume associated with the Breen Property, Thurman Berwick Creek Area, and other downgradient areas west of Labree Road will be addressed as part of the final remedy for OU2.
Institutional Controls and Monitoring are Essential GRA Components of all Alternatives	Contaminated soil and groundwater have been identified during previous monitoring and Site investigations. After implementing a remedial alternative, there may be unidentified portion(s) of the Site outside the remediated areas containing residual non-aqueous phase liquid (NAPL) in the subsurface, diffused contaminants in low-permeability zones within the aquifer, sorbed contaminants on soils, and/or dissolved contaminants in groundwater, which could pose a risk to human health. Thus, it is assumed that ICs and monitoring are essential GRA components of all remedial alternatives (except the "no action" alternative required by the NCP) and will be implemented during and after implementation of a remedial action while contaminant levels remain at concentrations that could pose a risk to human health.
Approach of GRAs within Alternatives	The GRAs provided and combined within the alternatives address the contaminants and risks for the HRIA based on identified remediation target zones (i.e., Creek Bed Sediment/Bank Surface Soil, Subsurface Soil, and High Concentration Groundwater).
Approach of GRAs for Berwick Creek Bed Sediment/Surface Soil	Alternatives developed for Berwick Creek bed sediment bank /surface soil are based on data collected during previous investigations and presented in the RI; however, flooding in 2009 appears to have scoured the creek down to the underlying silt deposits. Any creek sediments that are present now most likely reflect recent sedimentation and are presumably clean. An updated characterization of the Berwick Creek sediments will be required prior to implementation of the selected remedial alternative.
Use of Currently Existing Wells in the HRIA within Alternatives	The current wells in the HRIA may not be amendable for injection, pumping, or monitoring. A survey and analysis of existing wells will need to take place during remedial design.
Inclusion of Treatability Studies within Alternatives	Each alternative that includes in-situ or ex-situ chemical, biological, or thermal treatment technologies also includes the completion of remediation target zone specific treatability and/or pilot studies to confirm that selected technologies will adequately address contamination.
Monitoring Used to Determine Protectiveness and Need for Additional Remedial Measures	It is assumed that monitoring (consisting of soil, groundwater, and air sampling) will be performed to determine protectiveness of the remedy after implementation and the need for any future additional remedial measures for remaining contamination. These additional remedial measures are excluded from the screening and evaluation of remedial alternatives since they would be a contingency measure, another interim action, or could be enacted as part of a final comprehensive site-wide remedy.
30-Year Period of Evaluation for Groundwater Alternatives	Remedial alternatives that require an indefinite duration of O&M due to implementation of ICs and monitoring will be evaluated for a default 30-year period because evaluation of long durations of O&M is cumbersome and is generally not necessary for comparative evaluation between alternatives due to cost discounting under present worth analysis. Alternatives that are able to meet RAOs in a shorter time frame will have a shorter period of evaluation.

5.3 Description of Remedial Alternatives for HRIA OU1

The GRAs provided and combined within the alternatives address the contaminants and risks for the site based on identified remediation target zones (i.e., creek sediment/bank surface soil, subsurface soil, and high concentration groundwater). **Tables 5-1** and **5-2** provide a comprehensive list of the remedial technologies/process options that were used to assemble the remedial alternatives. The fundamental site assumptions and factors described in Sections 5.2 were also considered during development of the remedial alternatives.

For contaminated creek bed sediment/bank surface soil (SD), (with PCE concentrations greater than 0.468 mg/kg), the remedial alternatives include:

- Alternative SD-1: No Action
- Alternative SD-2: Removal of Contaminated Creek Bed Sediment/Bank Surface Soil with Offsite Treatment and Disposal, and Re-routing of Stream
- Alternative SD-3a: Removal of Contaminated Creek Bed Sediment /Bank Surface Soil with Ex-Situ Chemical Oxidation, Onsite Disposal, and Re-routing of Stream
- Alternative SD-3b: Removal of Contaminated Creek Bed Sediment/Bank Surface Soil with Ex-Situ Bioremediation, Onsite Disposal, and Re-routing of Stream

The remedial alternatives to address both the Subsurface Soil (with PCE concentrations greater than 10 mg/kg) and High Concentration Groundwater (HC), (PCE concentrations greater than 4,000 µg/L) remediation target zones include:

- Alternative HC-1: No Action
- Alternative HC-2: Hydraulic Containment and ICs with Monitoring
- Alternative HC-3: In-Situ Thermal Treatment and ICs with Monitoring
- Alternative HC-4: In-Situ Chemical Oxidation and ICs with Monitoring
- Alternative HC-5: Enhanced In-Situ Bioremediation and ICs with Monitoring

5.3.1 Creek Bed Sediment/Bank Surface Soil Remediation Target Zone

Figure 3-1 identifies the location of this remediation target zone.

5.3.1.1 Alternative SD-1: No Action

A "no action" alternative is required by the NCP to provide an environmental baseline against which impacts of the various remedial alternatives can be compared.

Under this alternative, no action would be taken to remedy the shallow contaminated creek bed sediment/bank surface soil or to monitor VOC concentrations to address the associated risks to human health or the environment.

Five-year site reviews would be performed as required by the NCP to evaluate whether adequate protection of human health and the environment is provided. Monitoring (consisting solely of visual inspections) would be performed as necessary to complete the 5-year site reviews.

5.3.1.2 Alternative SD-2: Removal of Contaminated Sediment/Bank Surface Soil with Offsite Treatment and Disposal and Re-routing of Stream

Alternative SD-2 provides protection of human health through removal (excavation) of shallow (less than 5 feet bgs) VOC-contaminated creek bed sediment/bank surface soil with PCE at levels greater than 0.468 mg/kg, offsite disposal at a RCRA-permitted Subtitle C or D landfill based on results of Toxicity Characteristic Leaching Procedure (TCLP) testing, and reconstruction of the creek bed. The boundary of the remediation target zone is defined by soil borings (oriented southeast to northwest) with estimated PCE concentrations above 0.468 mg/kg. Maximum PCE concentrations were observed at SB-411 (685 mg/kg), SB-410 (1,610 mg/kg), and SB-409 (5,220 mg/kg). These values are indicative of DNAPL as they exceed the soil saturation limit for PCE (see Section 3.5.1. for detail). An estimated 1,400 cy of contaminated creek bed sediment/bank surface soil would be excavated from an approximately 40-ft wide by 200-ft long stretch of Berwick Creek at the HRIA (See **Figure 5-1**). Prior to excavation of sediment/bank surface soil, Berwick Creek would require diversion around the excavation area. The re-routing of the creek could either be a temporary or a permanent diversion. A temporary diversion would consist of routing the creek through a 48-inch diameter high density polyethylene (HDPE) pipe around the excavation area and back into the existing creek channel downstream of the excavation area. The diversion would include an estimated 200 feet of 48-inch diameter HDPE and earthen berms at the upstream and downstream ends of the diversion. Upon completion of the excavation, the creek bed would be reconstructed and the temporary diversion removed. A permanent diversion of the creek bed would involve creation of a new creek channel that flows around the contaminated creek bed sediment/soil area prior to initiation of excavation activities. Permanent diversion of the creek bed would include installation of a geosynthetic clay liner (GCL) or similar liner into the creek bed and replacement of fish habitat. Habitat restoration would include planting of native vegetation and installation of fish spawning habitat, such as spawning gravel. The design for the creek diversion and creation of a new stream and habitat would be done in consultation with the appropriate natural resource agencies. For purposes of this FS, it is assumed the creek diversion would be permanent. Diversion of the creek bed would be planned during a seasonally dry period within the instream work window.

Removal of the fine-grained semi-confining layer from the creek bed may allow groundwater to enter the excavation area; thus, the excavation area will likely require dewatering prior to excavation. Construction dewatering would be accomplished by pumping wells MW-601 through MW-603. Prior to initiation of construction activities, an investigation using direct push technology (DPT) methods should be conducted in and near the creek to determine the extent of creek bed sediment/bank surface soil contamination, the thickness of the fine-grained layer, and the water level. In order to effectively manage dewatering within the excavation area, it may be necessary to stage the excavation into a series of cells. The excavation would start in the downstream cell and progress upstream. Once excavation and backfill is completed in one cell as indicated by confirmation sampling, removal activities will commence on the next cell. The contaminated material in the creek bed and banks would be removed using a tracked excavator or similar. Following excavation of the sediment/bank surface soil, the former creek bed area would be backfilled. Prior to backfilling the excavated area, a GCL or similar liner would be installed to reconstruct the fine-grained semi-confining layer and to minimize discharge of contaminated groundwater to the ground surface.

Prior to dewatering of the work area, fish would be moved from the excavation area and relocated downstream. The pumped water would be treated using a portable GAC treatment system and discharged to Berwick Creek or used for dust suppression. Approximately 1,400 cy of contaminated creek bed sediment/surface soil would be removed from Berwick Creek and the adjacent area and would be disposed of at an offsite facility.

Excavated material would be loaded into dump trucks and transported to a RCRA Subtitle C or D landfill for disposal, as applicable. For purposes of this FS, it is assumed that creek bed sediment/bank surface soil would be suitable for disposal at a Subtitle C landfill due to the high VOC concentrations contained within the sediment/bank surface soil. The maximum PCE concentration detected in creek bed sediment/bank surface soil was 5,220 mg/kg, which is above the treatment standards established in the Land Disposal Restrictions (LDRs) in 40 CFR 268.40. Per the LDRs, PCE and TCE contaminated soil must meet a treatment standard of 6.0 mg/kg prior to land disposal. In order to comply with LDRs, the excavated material will be treated at the Subtitle C facility prior to disposal. The Subtitle C facility identified in Arlington, Oregon provides treatment of hazardous material and will likely treat the excavated material via ex-situ bioremediation prior to disposal based on information obtained from their website.

This alternative is expected to be completed in 1 year.

5.3.1.3 Alternative SD-3a: Removal of Contaminated Sediment/Bank Surface Soil with Ex-Situ Chemical Oxidation, Onsite Disposal, and Re-routing of Stream

The scope and essential components of Alternative SD-3a are similar to those presented for Alternative SD-2; the only difference between these two alternatives is that the excavated creek bed sediment/bank surface soil would be treated via ex-situ chemical oxidation and disposed of onsite. The conceptual design for Alternative SD-3a is provided on **Figure 5-2**. The discussion presented in 5.3.1.2 for excavation and dewatering would be applicable for this alternative as well. The differences between Alternative SD-2 and SD-3a are presented below.

For this alternative, the excavated sediment/bank surface soil would be treated using ex-situ chemical oxidation. Excavated material will be placed in a treatment area, and chemical oxidants would be injected or mixed into the sediment/bank surface soil. The oxidizing agent added to the contaminated material would oxidize the PCE and TCE. Oxidizing agents are non-specific and will react with any naturally occurring organic matter present in the contaminated sediment. Typical chemical oxidants include hydrogen peroxide (H_2O_2), sodium persulfate ($Na_2S_2O_8$), and potassium permanganate ($KMnO_4$). Fenton's reagent can also be used to treat groundwater by adding a metal catalyst, usually iron, to H_2O_2, which generates a hydroxyl radical that oxidizes organic contaminants (Sellers 1998). However, Fenton's reagent requires acidic conditions (a pH between 2 and 4) for an optimum reaction to occur (Ground-Water Remediation Technologies Analysis Center [GWRTAC] 1999). In addition, with a half-life on the order of hours, H_2O_2 readily decomposes to water. $KMnO_4$ and $Na_2S_2O_8$ are more persistent reagents, which may require that it be flushed or washed from the treated zone after oxidation is complete. $KMnO_4$ has been shown to be more effective in the destruction of chlorinated compounds with double bonds, such as PCE and TCE, than those without double bonds. Chemical oxidation of chlorinated VOCs typically results in non-toxic end products, such as water, carbon dioxide, and dilute hydrochloric acid.

An impermeable liner will be used under the treatment area to minimize the risk of leaching contaminants into the underlying soil during the treatment process. In addition, a system to capture off-gases would be required during excavation and mixing. Treated soil would be disposed of onsite, covered with topsoil, and revegetated.

This alternative would be expected to be completed in less than 1 year. Treatability testing would be required to determine the optimum chemical oxidant dosage needed to achieve contaminant destruction.

5.3.1.4 Alternative SD-3b: Removal of Contaminated Sediment/Surface Soil with Ex-Situ Bioremediation, Onsite Disposal, and Re-routing of Stream

The scope and essential components of Alternative SD-3b are similar to those presented for Alternative SD-3a; the only difference between these two alternatives is that the excavated creek bed sediment/bank surface soil will be treated via ex-situ bioremediation rather than chemical oxidation. The conceptual design for Alternative SD-3b is also provided on **Figure 5-2**.

For this alternative, the excavated sediment/bank surface soil would be treated using biopiling. Biopile treatment is a technology in which excavated sediment is mixed with soil amendments and placed on a treatment area. This method of ex-situ bioremediation uses engineered systems buried under the excavated sediment/bank surface soil for irrigation/drainage systems to inject and re-circulate nutrient enhanced water (to control moisture and nutrient loadings) and cover systems to prevent heat loss and to control runoff, evaporation, and volatilization. During treatment, the excavated material would need to be kept fully saturated. Treated material would be disposed of onsite, covered with topsoil, and revegetated.

An impermeable liner will be used in the treatment area to minimize the risk of leaching of contaminants into the underlying soil. The vapors volatilizing from the sediment/bank surface soil may require treatment via GAC adsorption to remove or destroy VOCs before being discharged to the atmosphere. If vinyl chloride is observed at the site, then a catalytic oxidizer or chemical oxidant would be used in place of GAC since vinyl chloride does not effectively adsorb to carbon. In addition, the drainage from the treatment area may also require treatment before recycling or discharge.

This alternative would be expected to be completed in less than 1 year. Treatability testing would be required to determine the optimum nutrient loading rates needed to achieve contaminant degradation.

5.3.2 Remediation Target Zones 2 and 3: Subsurface Soil and High Concentration Groundwater Remediation Target Zones

Figure 3-2 identifies the location of the High Concentration Groundwater and Subsurface Soil Remediation Target Zones.

5.3.2.1 Alternative HC-1: No Action

A "no action" alternative is required by the NCP to provide an environmental baseline against which impacts of the various remedial alternatives can be compared.

Under this alternative, no action would be taken to remedy the contaminated high concentration groundwater or to monitor VOC concentrations to address the associated risks to human health or the environment.

Five-year site reviews would be performed as required by the NCP to evaluate whether adequate protection of human health and the environment is provided. Monitoring (consisting solely of visual inspections) would be performed as necessary to complete the 5-year site reviews.

5.3.2.2 Alternative HC-2: Hydraulic Containment and Institutional Controls with Monitoring Conceptual Design for Subsurface Soil Remediation Target Zone 2

It is noted here that alternative HC-2 would not address subsurface soil contamination. The technology would simply capture contaminated groundwater migrating out of the Subsurface Soil Remediation Target Zone and prevent migration to downgradient locations.

Conceptual Design for High Concentration Groundwater Remediation Target Zone

Alternative HC-2 provides protection of human health through containment of the high concentration contaminated groundwater plume coupled with ICs (legal and administrative controls and informational devices) to restrict access, future development, improvement, and use of areas contaminated with VOCs. Monitoring would be performed to ensure that these controls are protective of human health.

This alternative consists of capturing groundwater with high dissolved VOC concentrations before it can migrate outside the high concentration groundwater remediation target zone. Alternative HC-2 would contain the PCE in the area where it is inferred to be present as DNAPL, thus, cutting off the constant source area from the downgradient areas of the site. Several monitoring wells located along the leading edge of the high concentration contaminated groundwater plume and within the core of the source area would be pumped continuously to create a hydraulic barrier to contaminant migration.

The existing wells that would be pumped include MW-600 through MW-605, MWR-1, MWR-2, MWR-4, MWR-5, MW-R9, and MWR-10; however, it should be noted that the current wells in the HRIA may not be amendable for injection, pumping, or monitoring. A survey and analysis of existing wells will need to take place during remedial design. The conceptual design for Alternative HC-2 is shown on **Figure 5-3**. A numerical tool was developed for the HRIA to estimate the expected capture zone for Alternative HC-2 under the proposed well pumping network. The numerical model used an assumed pumping rate of approximately 8 gpm per well. The assumed pumping rate was based on calculations presented in the EE/CA (URS 2004) and would be confirmed during pre-design investigation activities. Numerical tool results indicated the expected capture zone for this well configuration would include most of the groundwater exhibiting PCE concentrations greater than 4,000 μg/L. The only area that may not be captured is a small portion of the plume west of MWR-4. More aggressive treatment could be accomplished for this alternative through the addition of more wells to the network of wells selected for continuous pumping.

The extracted groundwater would be treated by a system located in the area of MW-5, with discharge of the treated water to Berwick Creek. The aboveground treatment system would consist of a pre-manufactured, skid-mounted unit, including an equalization tank, sediment filtration, air stripping, and activated carbon polishing. The treatment system will be sized to accommodate approximately 85 gpm. The air stripper will consist of a stainless steel, low profile tray stripper with four 3-ft by 6-ft removable trays. Partially treated water from the air stripper would be polished using liquid-phase GAC before discharging to Berwick Creek. The vapor from the stripper will be treated using vapor-phase GAC prior to release to the atmosphere. If vinyl chloride is observed, then a catalytic oxidizer or chemical oxidant would be used in place of GAC since vinyl chloride does not effectively adsorb to carbon.

The types of ICs employed at the remediation target zones would include activity and use restrictions enacted through proprietary (e.g., easements, covenants) and/or governmental (e.g., zoning requirements) controls to prevent use of the property that would pose an unacceptable risk to receptors (i.e., for residential use). Other ICs could include restrictions on installation of shallow aquifer drinking water wells, restrictions on shallow aquifer groundwater use at locations within the HRIA plume footprint, and restrictions on home or building construction within the HRIA plume footprint. Information device ICs (warning signs, advisories, additional public education, deed notices, Notices of Environmental Contamination) would also be employed to limit access to contaminated groundwater.

An additional component of this alternative involves the continued monitoring of groundwater at the HRIA. For cost estimating purposes, it was assumed that 15 wells would be monitored semi-annually for VOCs for a period of 30 years. In addition, the influent and effluent for the treatment system (both water and vapor) will be monitored to ensure protection of human health and the environment.

The protectiveness of this alternative would be maintained by conducting each of the following on a periodic basis:

- Long-term O&M would be performed to maintain the integrity of the extraction wells and treatment system. As part of the O&M, ICs would be evaluated and updated if necessary to ensure protectiveness.
- Performance monitoring of the hydraulic containment system would be conducted, including periodic monitoring of the system.
- Monitoring (consisting of groundwater sampling and water level measurements) would be performed to verify hydraulic containment and document mass removal and to ensure that protection of human health is maintained. The monitoring program would also include components for vapor intrusion monitoring and for monitoring outside the HRIA (i.e., OU2) to assess impacts of the remedial alternative on the downgradient plume.

Five-year site reviews would be performed since VOC contamination is left in place, preventing unrestricted use of the site.

Achievement of Subsurface Soil Target Zone PRG
Alternative HC-2 would not achieve the subsurface soil target zone PRG to remove PCE DNAPL present in subsurface soil as quickly as technically achievable by reducing PCE concentrations within the high concentration soils (> 10 mg/kg PCE) to 10 mg/kg or less.

Achievement of High Concentration Groundwater Target Zone PRG
The total pumping time is assumed to range up to 5 years to reduce mass discharge of VOC contamination by 90% from the high concentration groundwater to the dissolved phase plume.

5.3.2.3 Alternative HC-3: In-Situ Thermal Treatment and Institutional Controls with Monitoring

Alternative HC-3 would address both subsurface soil and high concentration groundwater contamination. The technologies would extract and treat PCE, including DNAPL, and treat contaminated groundwater in-situ, preventing downgradient migration.

Conceptual Design for Subsurface Soil and High Concentration Groundwater Remediation Target Zones

Alternative HC-3 provides protection of human health through removal of VOC mass from subsurface soil and groundwater by implementation of in-situ thermal treatment. In addition, ICs would be implemented to restrict access, future development, improvement, and use of areas contaminated with VOCs. Monitoring would be performed to ensure that these controls are protective of human health. For the FS, electrical resistance heating (ERH) is presented as the representative technology for in-situ thermal treatment; however, other methods (e.g., conduction and steam injection) are also available and may meet site requirements. A full suite of in-situ thermal remediation technologies (e.g., ERH, steam or conduction) would be considered as part of the remedial design.

ERH is an in-situ, three-phase electrical heating technology that uses electricity and applies it into the ground through electrodes. The electrodes can be installed either vertically or horizontally and can even be placed underneath buildings. ERH raises the temperature of groundwater, increasing volatilization of contaminants that are subsequently removed in the vapor phase. As ERH dries the vadose-zone soil, it also creates a source of steam that strips contaminants from soils. Volatilized contaminants are removed from the subsurface via a vapor extraction system. Since the vadose zone at the Site is extremely thin, other vapor recovery options, such as construction of a permeable trench and/or multi-phase extraction, will need to be explored during the design phase. In addition, the presence of the impermeable silt and clay layer across the site further complicates vapor collection. This may necessitate the installation of a series of trenches containing horizontal soil vapor extraction (SVE) wells. Finally, because the groundwater table is located close to the surface, it is possible that fluctuations in water levels or upwelling of groundwater could flood the SVE wells. The combination of these conditions will make it difficult to collect vapors generated during ERH.

This alternative consists of the installation of electrodes, temperature monitoring points (TMPs), vapor recovery wells below the silt, and horizontal vapor recovery piping above the silt. Prior to implementation of ERH, existing monitoring wells that were not constructed to withstand the high temperatures induced heat would be abandoned consistent with Washington State well decommissioning procedures.

Alternative HC-3 includes removal of VOC mass in the subsurface soil and high concentration groundwater via thermal treatment coupled with ICs and long-term monitoring. A grid of electrodes separated, on average, by approximately 22 feet and installed to depths ranging from 4 feet to 42 feet is assumed. A grid of co-located vapor recovery wells will also be installed. The conceptual design for Alternative HC-3 is shown on **Figure 5-4**.

A total of 48 TMPs would be installed within the overall treatment area; also, it is assumed that 10 confirmatory soil borings with 8 soil samples per boring will be collected to verify completion of treatment. Hydraulic control would be implemented during treatment to minimize the flux of cold groundwater into the remediation zone during heating. The vapor recovery will be approximately 940 standard cubic feet per minute (scfm/min). The vapor will be treated using GAC prior to release to the atmosphere. If vinyl chloride is observed, then a catalytic oxidizer or chemical oxidant would be used in place of GAC since vinyl chloride does not effectively adsorb to carbon. Condensate is expected to be generated at a rate of approximately 12 gpm.

During operation, temperature, groundwater quality, vapor emissions, and condensate/discharge will be monitored. The total heating/treatment time is assumed to range from 6 to 9 months to reduce mass discharge of VOC contamination by 90% from the high concentration groundwater to the dissolved phase plume as quickly as technically achievable and to reduce subsurface soil PCE concentration to 10 mg/kg or less.

Increasing the biodegradation rates in groundwater that is warmed outside of the remediation zone has been shown to be a secondary benefit of thermal treatment; thus, biodegradation rates may increase in downgradient areas. The increased biodegradation rates could be further enhanced through the injection of amendments.

The types of ICs employed at the remediation target zones would include activity and use restrictions enacted through proprietary (e.g., easements, covenants) and/or governmental (e.g., zoning requirements) controls to prevent use of the property that would pose an unacceptable risk to receptors (i.e., for residential use). Other ICs could include restrictions on installation of shallow aquifer drinking water wells, restrictions on shallow aquifer groundwater use at locations within the HRIA plume footprint, and restrictions on home or building construction within the HRIA plume footprint. Information device ICs (warning signs, advisories, additional public education, deed notices, Notices of Environmental Contamination) would also be employed to limit access to contaminated groundwater.

An additional component of this alternative involves the continued monitoring of groundwater at the HRIA. For cost estimating purposes, it was assumed that 15 wells would be monitored semi-annually for VOCs for a period of 30 years after the heating period is ended. It should be noted that the current wells in the HRIA may not be amendable for injection, pumping, or monitoring. A survey and analysis of existing wells will need to take place during remedial design.

The protectiveness of this alternative would be maintained by conducting each of the following on a periodic basis:

- Performance monitoring during heating of temperature, groundwater, air/vapor, and vapor control. The following monitoring is proposed during thermal treatment:
  - Groundwater and soil temperatures would be monitored via temperature monitoring sensors.
  - Contaminant concentrations would be monitored monthly via groundwater sampling within the high concentration groundwater remediation target zone.
  - Air/vapor samples from the soil vapor extraction system would be collected weekly to evaluate when the remedy is nearing a point of diminishing return in terms of NAPL, aqueous phase COPCs, and vapor extraction and treatment.
  - Vacuum gauges would be used to monitor conditions in the vadose zone in order to ensure pneumatic control and prevent migration of vapors, steam, and air from the remediation target zones.
- Confirmation sampling of subsurface soil to verify achievement of the HRIA RAOs within the remediation zone.
- Monitoring (consisting of groundwater sampling and water level measurements) would be performed to document mass removal and ensure that protection of human health is maintained. The monitoring program would also include components for vapor intrusion

monitoring and to monitor outside the HRIA (i.e., OU2) to assess impacts of the remedial alternative on the downgradient plume.

- ICs would be evaluated and updated if necessary to ensure protectiveness.

Five-year site reviews would be performed since VOC contamination is left in place, preventing unrestricted use of the site.

As previously indicated, ERH is the in-situ thermal remediation technology used to develop costs for this FS; however, other methods (e.g., conduction and steam injection) are also available and may meet site requirements and would therefore be considered as part of the remedial design.

For example, one of the methods, steam injection or steam enhanced extraction, could be implemented in two ways. The first method consists of direct injection of steam generated ex-situ into the shallow aquifer through injection wells to vaporize volatile and semi-volatile contaminants. The vaporized compounds would then rise to the vadose zone where they are removed by vacuum extraction and treated. The second method simply uses heater-vacuum wells to raise the soil temperature and groundwater temperature to boiling across the treatment volume generating steam in-situ. This results in steam distillation of the contaminants, similar to steam flooding or ERH. The major differences between steam enhanced extraction and steam flooding or ERH are that in-situ thermal destruction occurs as vapors are drawn into the hot regions in close proximity to heater-vacuum wells. In addition, enhancement of gas permeability and vapor capture also occurs in the high-temperature regions around the heater wells.

Achievement of Subsurface Soil Remediation Target Zone PRG

Alternative HC-3 would achieve the subsurface soil target zone performance goal to remove PCE DNAPL present in subsurface soil by reducing PCE concentrations within the high concentration soils (> 10 mg/kg PCE) to 10 mg/kg or less. It is estimated that these reductions could be achieved within 6 to 9 months after technology implementation.

Achievement of High Concentration Groundwater Remediation Target Zone PRG

Alternative HC-3 would reduce mass discharge of VOC contamination by 90% from the high concentration groundwater to the dissolved phase plume. It is estimated that these reductions could be achieved within 9 months to 2 years after technology implementation.

5.3.2.4 Alternative HC-4: In-Situ Chemical Oxidation and Institutional Controls with Monitoring

Conceptual Design for Subsurface Soil and High Concentration Groundwater Remediation Target Zones

Alternative HC-4 provides protection of human health through destruction of VOC mass from subsurface soil and groundwater by injection of chemical oxidants. ICs would be implemented to restrict access, future development, improvement, and use of areas contaminated with VOCs. Monitoring would be performed to ensure that these controls are protective of human health. Chemical oxidants would be injected through the contaminated soil and groundwater zone using hollow stem auger (HSA). DPT and/or rotosonic drilling equipment may be used to deliver the chemical oxidants if site conditions indicate these are more cost-effective methods.

In-situ chemical oxidation (ISCO) uses chemical oxidants to destroy contaminants by converting them into innocuous compounds (carbon dioxide and water). The oxidizing agent added to the contaminated soil and groundwater would oxidize the PCE and TCE. Oxidizing agents are non-specific and will react with any naturally occurring organic matter present in the contaminated groundwater.

Typical chemical oxidants include potassium or sodium permanganate ($KMnO_4$) and sodium persulfate ($Na_2S_2O_8$). Fenton's reagent can also be used to treat groundwater by adding a metal catalyst, usually iron, to H_2O_2 which generates a hydroxyl radical that oxidizes organic contaminants (Sellers 1998). However, Fenton's reagent requires acidic conditions (a pH between 2 and 4) for an optimum reaction to occur (GWRTAC 1999). In addition, with a half-life on the order of hours, H_2O_2 readily decomposes to water. Alternatively, permanganate and persulfate are persistent reagents that have been demonstrated as highly effective for PCE. Chemical oxidation of chlorinated VOCs typically results in non-toxic end products, such as water, carbon dioxide, and dilute hydrochloric acid.

Alternative HC-4 assumes the use of $KMnO_4$ as a representative oxidant at the Site based on the following chemical reaction:

$$KMnO4 + 3C_2Cl_4 + 4H_2O \longrightarrow 6CO_2 + 4MnO_2 + 4K^+ + 12Cl^- + 8H^+$$

A different oxidant or oxidants could be selected during the design phase based on the results of treatability testing. Bench-scale testing would be required to determine the optimum chemical oxidant dosage needed to achieve contaminant destruction and to determine whether a pilot test is required prior to full-scale implementation.

For this alternative, $KMnO_4$ would be injected via well clusters spaced approximately 25 feet apart throughout the remediation zone (based on the expected radius of influence). Approximately 79 injection locations consisting of three injection points would be installed using a hollow stem auger rig. Each injection point cluster would be installed to allow oxidant injection at three different 10-foot depth intervals. A conceptual injection scheme is shown in **Figure 5-5**. Several injection events would likely be required to meet RAOs and PRGs. The costing for this alternative assumes that three injection events would be required over a 36-month period. Monitoring of VOC concentrations and other field parameters (i.e., pH, conductivity, oxidation reduction potential, turbidity, dissolved oxygen, manganese concentration) would be performed during and between injections.

The types of ICs employed at the remediation target zones would include activity and use restrictions enacted through proprietary (e.g., easements, covenants) and /or governmental (e.g., zoning requirements) controls to prevent use of the property that would pose an unacceptable risk to receptors (i.e., for residential use). Other ICs could include restrictions on installation of shallow aquifer drinking water wells, restrictions on shallow aquifer groundwater use at locations within the HRIA plume footprint, and restrictions on home or building construction within the HRIA plume footprint. Information device ICs (warning signs, advisories, additional public education, deed notices, Notices of Environmental Contamination) would also be employed to limit access to contaminated groundwater.

An additional component of this alternative involves the continued monitoring of groundwater. For cost estimating purposes, it was assumed that 15 wells would be monitored semi-annually for VOCs for a period of 30 years after the injections are completed. It should be noted that the current wells in the HRIA may not be amenable for injection, pumping, or monitoring. A survey and analysis of existing wells will need to take place during remedial design.

The protectiveness of this alternative would be maintained by conducting each of the following on a periodic basis:

- Performance monitoring prior to and following each round of ISCO injections would be conducted to assess the degradation process. Monitoring would include groundwater sampling to determine contaminant concentrations and collection of general chemistry parameters and environmental indicators.
- Confirmation sampling of subsurface soil and groundwater sampling to verify achievement of the HRIA PRGs within the remediation target zones.
- Monitoring (consisting of groundwater sampling and water level measurements) would be performed to document mass removal, contaminant mass discharge reduction, and ensure that protection of human health is maintained. The monitoring program would also include components for vapor intrusion monitoring and to monitor outside the HRIA (i.e., OU2) to assess impacts of the remedial alternative on the downgradient plume.
- Evaluation of ICs and updating as necessary to ensure protectiveness.

Five-year site reviews would be performed since VOC contamination is left in place, preventing unrestricted use of the HRIA.

Achievement of Subsurface Soil Remediation Target Zone PRG
Alternative HC-4 would achieve the subsurface soil target zone performance goal to remove PCE DNAPL present in subsurface by reducing PCE concentrations within the high concentration soils (> 10 mg/kg PCE) to 10 mg/kg or less. It is estimated that these reductions could be achieved within 5 to 10 years after technology implementation. Note that it may take more than the three assumed oxidant injections to achieve this PRG.

Achievement of High Concentration Groundwater Remediation Target Zone PRG
Alternative HC-4 would reduce mass discharge of VOC contamination by 90% from the high concentration groundwater to the dissolved phase plume. It is estimated that these reductions could be achieved within 9 months to 2 years after technology implementation.

5.3.2.5 Alternative HC-5: In-Situ Enhanced Bioremediation and Institutional Controls with Monitoring

Conceptual Design for Subsurface Soil and High Concentration Groundwater Remediation Target Zones
Alternative HC-5 provides protection of human health through bioremediation of VOC mass from subsurface soil and groundwater by injection of amendments to stimulate the anaerobic degradation processes. In addition, ICs will be implemented to restrict access, future development, improvement, and use of areas contaminated with VOCs.

Bioremediation amendments include both amendments that primarily stimulate biotic reactions, such as electron donors (e.g., whey, lactate, emulsified oil) and those that also stimulate biotic/abiotic reactions such as zero-valent iron (ZVI) alone and in combination with biotic amendments (e.g., commercially available EHC™ by Adventus Americas). Monitoring would be performed to ensure that these controls are protective of human health.

The predominant mechanism for biological degradation of chlorinated ethylenes, such as PCE, is reductive dechlorination. The primary degradation pathway for PCE is microbially mediated reductive dechlorination, whereby its chlorine atoms are successively stripped off to form less chlorinated compounds. Biotic reductive dechlorination is a sequential process that results in the generation of byproducts TCE, cis-1,2-DCE, and vinyl chloride [VC] and ultimately can lead to complete detoxification (e.g., ethylene). The process is strictly anaerobic and can occur under sulfate-reducing redox conditions but is most efficient (i.e., results in ethylene generation) under methanogenic redox conditions. A factor limiting the biological transformation of chlorinated ethylenes is typically the lack of sufficient electron donor to drive the dechlorination process, or in some cases, the lack of bacteria capable of carrying out the complete transformation process to ethylene (*Dehalococcoides* is the only genus of bacteria demonstrated to reduce cis-1,2-DCE to VC and ethylene).

In order to bolster biotic transformation processes, amendments that also contain reactants that abiotically transform contaminants (i.e., reductive iron such as zero-valent iron) are also considered. Reductive iron stimulates reductive beta-elimination where PCE (or other chloroethylenes such as TCE and cis-1,2-DCE) is converted to chloroacetylene, acetylene, ethylene, and then ethane. The benefit of the abiotic reactions is that there is little/no accumulation of degradation byproducts. In addition, combining reductive iron within biological amendments creates much more reduced conditions than biotic amendments alone, which also makes biological reactions much more favorable (and efficient).

Alternative HC-5 consists of in-situ treatment of contaminated subsurface soil and groundwater through enhanced in-situ bioremediation. PCE, TCE, and cis-1,2-DCE could be effectively biodegraded through biotic and/or abiotic reductive mechanisms under anaerobic conditions. The aquifer geochemistry results presented in the EE/CA (**Table 5-3**) indicate that the groundwater in the high concentration zone is generally aerobic (indicated by the presence of oxygen) with some pockets of mildly reducing conditions (indicated by low oxidation reduction potential [ORP] and depleted sulfate and nitrate). Based on the geochemistry results, conditions within these remediation target zones are not optimal for anaerobic degradation of contaminants and would need to be driven to strongly reducing conditions through injection of amendments. In addition, it is possible that bioaugmentation also may be necessary to deliver contaminant-degrading bacteria (e.g., Dehalococcoides spp.) to the remediation zone. For purposes of this FS, it is assumed that bioaugmentation will be necessary once reducing conditions have been reached (approximately 3 months after amendment injection) and can be accomplished through injections at two injection well locations. Case histories suggest that groundwater contaminant concentration reductions of more than 90% are achievable as a result of bioremediation.

Commercially available amendments come in both solid and liquid forms and vary considerably with respect to longevity. Typical biotic amendments include lactate, whey, and emulsified vegetable oil (EVO). Available placement techniques include direct-push, trenching, injection wells, and fracturing. For purposes of this FS, direct injection of EVO was used to develop the cost estimate. A full suite of amendments would be evaluated based on results from the pre-design investigation, and a phased approach would be implemented during the remedial action. In addition, the remedial design would include an evaluation of the addition of an abiotic reductant such as ZVI.

ZVI is a strong reducing agent that has been successfully used in permeable reactive wall applications to treat chlorinated organic compounds in groundwater. Injecting fluidized micron-scale or nanoscale zero-valent iron (NZVI) into a contaminated source zone is an extension of that concept. In addition to achieving an abiotic reduction, the introduction of ZVI would also create conditions conducive to and reduce the carbon load required for biological degradation.

It is recommended that a pilot-scale treatability study be conducted prior to full-scale implementation. The treatability study should be located in the area of highest VOC concentrations along the downgradient periphery of the 4,000 μg/L PCE remediation target zone. If the results of the treatability study are successful, the treatment area would be expanded. **Figure 5-6** presents the selected distribution of wells to be installed to deliver the amendment. The wells are aligned such that amendment will be delivered into the subsurface and travel through the remediation target zones following the hydraulic gradient. Seven rows of wells are proposed so that amendment is distributed adequately within the subsurface. This technique establishes proper conditions for microbial degradation while taking advantage of the groundwater flow velocities and gradients.

The optimal well spacing within each row depends on a variety of factors, including formation, drilling costs, amendment costs, desired injection period, and the vertical thickness of the remediation target zones. Based on 25-foot injection well spacing, 79 injection well clusters (defined as a set of 3 injection wells for a given locations each screened at different depth intervals) dispersed in rows that transect the subsurface soil and high concentration groundwater remediation target zones would be needed. The injection well rows would be installed starting along the downgradient edge of the high concentration groundwater remediation target zone to cut off contaminant mass discharge to the larger dissolved phase plume as quickly as possible (i.e., in effect creating a barrier first). Injection well installation would proceed from the most downgradient first to the most upgradient injection well row. This strategy would help mitigate any enhanced mass flux that occurs during injection of amendments in areas that contain residual contaminant mass (either through desorption or dissolution of sorbed/residual mass into the aqueous phase). A short-term pilot injection test should be conducted prior to full scale implementation to confirm the optimal radius of influence.

The injection wells would be constructed with 2-inch diameter schedule 40 PVC. Each well cluster would include wells screened across three different 10-foot depth intervals across the approximate thickness of the shallow aquifer. It is assumed that they would be installed via HSA rig without sampling other than bulk soil cuttings to confirm disposal options. The wellheads would be modified for hose fittings and finished with a simple flush mounted casing.

Amendment Injection

Once the injection wells have been installed, the initial injection event would occur one row at a time. EVO adheres to soil particles and slowly dissolves into the aqueous phase, potentially diffusing into both high-and low- permeability zones within the aquifer. Temporary aboveground piping and hoses would be used to distribute the amendment to the injection wells. For the cost estimate of this FS, it is assumed that a trailer-mounted distribution system would be constructed for injection to all the wells in a given row simultaneously, and two water trucks would be used to transport potable water from a metered hydrant.

Once injection to all rows of wells has been completed, the temporary injection equipment would be removed and no activity would be required other than periodic groundwater monitoring for 1 year. It is assumed that an additional full-scale injection event would take place approximately 18 months (the estimated longevity of the EVO) after the first injection.

In-Situ Bioremediation Performance Monitoring

Fifteen existing wells will be monitored to track the progress of the remedy. Well locations would be selected to allow for monitoring conditions both inside the remediation target zones and upgradient, crossgradient, and downgradient of the remediation target zones, which would address concerns for lateral movement of the amendment, and allow for evaluation of whether PRGs were achieved.

The required analyte list would include VOCs, ethylene, ethane, methane, sulfate, ferrous iron, alkalinity, total organic carbon or chemical oxygen demand, and water quality parameters (DO, conductivity, temperature, oxidation reduction potential, and pH). While it is possible that the EVO product could maintain desired carbon levels for at least 3 years (i.e., about two times longer than the currently estimated injection interval of 18 months), it is unlikely given the flow field at the Site. Results from the monitoring program would be used to determine when a second injection is necessary. Quarterly sampling is assumed for the first year beyond the last injection, with the frequency reduced to twice a year thereafter. Monitoring will continue at 15 wells for 30 years. It should be noted that the current wells in the HRIA may not be amendable for injection, pumping, or monitoring. A survey and analysis of existing wells will need to take place during remedial design.

The types of ICs employed at the remediation target zones would include activity and use restrictions enacted through proprietary (e.g., easements, covenants) and/or governmental (e.g., zoning requirements) controls to prevent use of the property that would pose an unacceptable risk to receptors (i.e., for residential use). Other ICs could include restrictions on installation of shallow aquifer drinking water wells, restrictions on shallow aquifer groundwater use at locations within the plume footprint, and restrictions on home or building construction within the plume footprint. Information device ICs (warning signs, advisories, additional public education, deed notices, Notices of Environmental Contamination) would also be employed to limit access to contaminated groundwater.

The protectiveness of this alternative would be maintained by conducting each of the following on a periodic basis:

- Confirmation sampling of subsurface soil and groundwater to verify achievement of the HRIA PRGs within the remediation target zones.
- Monitoring (consisting of groundwater sampling and water level measurements) would be performed to document mass removal, contaminant mass discharge reduction and ensure that protection of human health is maintained. The monitoring program would also include components for vapor intrusion monitoring and to monitor outside the HRIA (i.e., OU2) to assess impacts of the remedial alternative on the downgradient plume.
- Evaluation of ICs and updating as necessary to ensure protectiveness.

Five-year site reviews would be performed since VOC contamination is left in place, preventing unrestricted use of the site.

Achievement of Subsurface Soil Remediation Target Zone PRG

Alternative HC-5 would achieve the subsurface soil remediation target zone performance goal to remove PCE DNAPL present in subsurface soil by reducing PCE concentrations within the high concentration soils (> 10 mg/kg PCE) to 10 mg/kg or less. It is estimated that these reductions could be achieved within 5 to 10 years after technology implementation. Note that it may take more than the two assumed EVO injections to achieve this PRG.

Achievement of High Concentration Groundwater Remediation Target Zone PRG
Alternative HC-5 would reduce mass discharge of VOC contamination by 90% from the high concentration groundwater to the dissolved phase plume. It is estimated that these reductions could be achieved within 9 months to 2 years after technology implementation.

5.4 Summary of Alternatives Screening

Under typical FS procedures, the list of alternatives is screened using the effectiveness, implementability, and cost criteria. However, because a fairly small set of alternatives focused on achieving the HRIA PRGs developed in this section, the alternative screening step has been omitted, and all alternatives developed for each media are carried forward for evaluation against seven of EPA's nine evaluation criteria: overall protection of human health and the environment; compliance with ARARs; compliance with PRGs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. The remaining two EPA evaluation criteria, support agency and community acceptance, will be addressed in future actions by the EPA. The nine EPA evaluation criteria are described in Section 6.

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Section 6
Detailed Analysis of Retained Alternatives

The remedial alternatives developed in Section 5 are evaluated using nine evaluation criteria. These criteria address statutory requirements and considerations for remedial actions in accordance with the NCP and additional technical and policy considerations that have proven to be important for selecting among remedial alternatives (EPA 1988). The nine evaluation criteria are separated into three groups. Threshold criteria are standards that an alternative must meet to be eligible for selection as a remedial action unless an ARAR waiver is used. Balancing criteria weigh the tradeoffs among alternatives. Modifying criteria are fully evaluated after comments on the FS and the interim proposed plan have been received by EPA. The following subsections describe the nine evaluation criteria used in the detailed analysis of remedial alternatives and the priority in which the criteria are considered as well as the detailed and comparative analysis of alternatives.

6.1 Overall Protection of Human Health and the Environment

Each alternative is assessed to determine whether it can provide adequate protection of human health and the environment (short- and long-term) from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at a site. This criterion evaluates whether an alternative eliminates, reduces, or controls risks to public health and the environment through treatment, engineering, or ICs.

Criteria Used to Evaluate Remediation Alternatives Address Multiple Areas

Threshold Criteria

- Protection of Human Health and Environment
- Compliance with ARARs

Balancing Criteria

- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

Modifying Criteria

- State Acceptance
- Community Acceptance

6.2 Compliance with ARARs

This criterion evaluates whether an alternative meets federal, state, and tribal environmental statutes, regulations, and other requirements that pertain to the site and/or whether a waiver is justified. If the evaluation indicates an ARAR will not be met, then the basis for justifying one of the six ARAR waivers allowed under CERCLA is discussed.

These ARAR waivers are detailed in **Exhibit 6-1.** The HRIA remedial action (RA) will be an interim RA. Consequently, none of the alternatives evaluated are expected to be able to fully attain all of the ARARs for the HRIA. The ARARs that will be attained and those that will be waived will be specified in the interim ROD, which is expected to include the interim action waiver provided for in Section 121(d)(4)(A) of CERCLA. The interim ROD will eventually be followed by a final ROD for the HRIA or the site that will fully address compliance with all ARARs, consistent with CERCLA, including any waivers. The key ARARs to be addressed by this interim action are discussed below.

Exhibit 6-1: ARAR Waivers

Waiver	Description
Interim Measures	The remedial action selected is only part of a total remedial action that will attain such level or standard of control when completed. (CERCLA §121(d)(4)(A))
Greater Risk to Health and the Environment	Compliance with such requirement at the facility will result in greater risk to human health and the environment than alternative options. (CERCLA §121(d)(4)(B))
Technical Impracticability	Compliance with such requirement is technically impracticable from an engineering perspective. (CERCLA §121(d)(4)(C))
Equivalent Standard of Performance	The remedial action selected will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, criteria, or limitation through use of another method or approach. (CERCLA §121(d)(4)(D))
Inconsistent Application of State Requirements	With respect to a state standard, requirement, criteria, or limitation, the state has not consistently applied (or demonstrated the intention to consistently apply) the standard, requirement, criteria, or limitation in similar circumstances at other remedial actions. (CERCLA §121(d)(4)(E))
Fund Balancing	In the case of a remedial action to be undertaken solely under section 104 using the fund, selection of a remedial action that attains such level or standard of control will not provide a balance between the need for protection of public health and welfare and the environment at the facility under consideration and the availability of amounts from the fund to respond to other sites, which present or may present a threat to public health or welfare or the environment, taking into consideration the relative immediacy of such threats. (CERCLA §121(d)(4)(F))

6.3 Long-Term Effectiveness and Permanence

Long-term effectiveness evaluates the likelihood that the remedy will be successful and the permanence that it affords. Factors to be considered, as appropriate, include the following:

- Magnitude of residual risk remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residuals are considered to the degree that they remain hazardous, taking into account their toxicity, mobility, or volume and propensity to bioaccumulate.

- Adequacy and reliability of controls that are used to manage treatment residuals and untreated waste remaining at a site. This factor includes an assessment of containment systems and ICs to determine if they are sufficient to ensure that any exposure to human and ecological receptors is within protective levels. This factor also addresses the long-term reliability of management controls for providing continued protection from residuals, the assessment of the potential need to replace technical components of the alternative, and the potential exposure pathways and risks posed should the remedial action need replacement.

6.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Each alternative is assessed for the degree to which it employs technology to permanently and significantly reduce toxicity, mobility, or volume, including how treatment is used to address the principal threats posed by a site. Factors to be considered, as appropriate, include the following:

- The treatment processes, the alternatives used, and materials they will treat
- The amount of hazardous substances, pollutants, or contaminants that will be destroyed or treated, including how the principal threat(s) will be addressed
- The degree of expected reduction in toxicity, mobility, or volume of the waste due to treatment
- The degree to which the treatment is irreversible
- The type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate such hazardous substances and their constituents
- Whether the alternative would satisfy the statutory preference for treatment as a principal element of the remedial action

6.5 Short-Term Effectiveness

This criterion reviews the effects of each alternative during the construction and implementation phase of the remedial action until remedial response objectives are met. The short-term impacts of each alternative are assessed, considering the following factors, as appropriate:

- Short-term risks that might be posed to the community during implementation of an alternative
- Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures
- Potential adverse environmental impacts resulting from construction and implementation of an alternative and the reliability of the available mitigation measures during implementation in preventing or reducing the potential impacts
- Time until protection is achieved for either an entire site or individual elements associated with specific site areas or threats

In addition to the factors listed above, an evaluation of short-term effectiveness also allows a consideration of the potential for implementing best management practices (BMPs) for green sustainable remediation. Green remediation is defined as the practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of remedial actions (EPA 2008b). BMPs for green remediation emphasize a "whole-site" approach that closely evaluates core elements of a cleanup project:

- Energy requirements
- Air emissions
- Water requirements and associated impacts on water resources
- Impacts on land and ecosystems
- Material consumption and waste generation
- Impacts on long-term stewardship of a site

The evaluation of short-term effectiveness for each alternative includes consideration of opportunities to employ sustainable practices that work to minimize the environmental and energy footprints of actions taken during the life of a project.

6.6 Implementability

The technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation is evaluated under this criterion. The ease or difficulty of implementing each alternative will be assessed by considering the following factors detailed in **Exhibit 6.2**.

Exhibit 6-2: Implementability Factors to be Considered during Alternative Evaluation

Criterion	Factors to be Considered
Technical Feasibility	Technical difficulties and unknowns associated with the construction and operation of a technology Reliability of the technology, focusing on technical problems that will lead to schedule delays Ease of undertaking additional remedial actions, including what, if any, future remedial actions would be needed and the difficulty to implement additional remedial actions Ability to monitor the effectiveness of the remedy, including an evaluation of risks of exposure should monitoring be insufficient to detect a system failure
Administrative Feasibility	Activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for offsite actions)
Availability of Services and Materials	Availability of adequate offsite treatment, storage capacity, and disposal capacity and services Availability of necessary equipment and specialists and provisions to ensure any necessary additional resources Availability of services and materials plus the potential for obtaining competitive bids, which is particularly important for innovative technologies Availability of prospective technologies

6.7 Cost

Types of costs that are assessed for each alternative include the following:

- Capital costs
- Annual O&M costs
- Periodic costs
- Present worth of capital and annual O&M costs

Cost estimates are developed according to *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (EPA 2000). Flexibility is incorporated into each alternative for the location of remedial facilities, the selection of cleanup levels, and the period in which remedial action will be completed. Assumptions of the project scope and duration are defined for each alternative to provide cost estimates for the various remedial alternatives. Important assumptions specific to each alternative are summarized in the description of the alternative. Additional assumptions are included in the detailed cost estimates in **Appendix D**.

The levels of detail employed in making these estimates are conceptual but are considered appropriate for making choices between alternatives. The information provided in the cost estimate is based on the best available information regarding the anticipated scope of the remedial alternatives.

The costs are evaluated with respect to the following categories:

- Capital costs are those expenditures that are required to construct a remedial action. They are exclusive of costs required to operate or maintain the action throughout its lifetime. Capital costs consist primarily of expenditures initially incurred to build or install the remedial action (e.g., construction of a water treatment system and related site work). Capital costs include all labor, equipment, and material costs (including contractor markups, such as overhead and profit) associated with activities, such as mobilization/demobilization; monitoring site work; installation of extraction, containment, or treatment systems; and disposal. Capital costs also include expenditures for professional/technical services that are necessary to support construction of the remedial action.

- Annual O&M costs are those post-construction costs necessary to ensure or verify the continued effectiveness of a remedial action. These costs are estimated mostly on an annual basis. Annual O&M costs include all labor, equipment, and material costs (including contractor markups, such as overhead and profit) associated with activities, such as monitoring; operating and maintaining extraction, containment, or treatment systems; and disposal. Annual O&M costs also include expenditures for professional/technical services necessary to support O&M activities.

- Periodic costs are those costs that occur only once every few years (e.g., 5-year reviews, equipment replacement) or expenditures that occur only once during the entire O&M period or remedial timeframe (e.g., site closeout, remedy failure/replacement). These costs may be either capital or O&M costs but, because of their periodic nature, it is more practical to consider them separately from other capital or O&M costs in the estimating process.

- The present worth of each alternative, also referred to as the present value, provides the basis for the cost comparison. The present worth cost represents the amount of money that, if invested in the initial year of the remedial action at a given rate, would provide the funds required to make future payments to cover all costs associated with the remedial action over its planned life. Future O&M and periodic costs are included and reduced by the appropriate present worth discount rate as outlined in *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study (*EPA 2000*)*. Per the guidance, the present worth analysis was performed on remedial alternatives using a 7% discount (interest) rate over the period of evaluation for each alternative. Inflation and depreciation were not considered in preparing the present worth costs.

- The cost of each proposed alternative is rated on a comparative basis with other alternatives using a scale determined from the range of costs for the screened alternatives. Due to the likely alternative costs for the HRIA, the cost ranges for the ratings categories are rather large. The cost rating categories are as follows in **Exhibit 6-3**:

Exhibit 6-3: Cost Qualitative Ratings System

Cost Ratings Categories		Cost Ranges (Present Worth Dollars)
$	Low	Less than 1 million dollars
$$	Low to moderate	Between 1 million and 5 million dollars
$$$	Moderate	Between 5 million and 9 million dollars
$$$$	Moderate to high	Between 9 million and 13 million dollars
$$$$$	High	Greater than 13 million dollars

6.8 State Acceptance

This criterion evaluates the technical and administrative issues and concerns the state may have regarding each of the alternatives. EPA has requested comments from the state on the RI/FS and will request comments on the draft interim proposed plan prior to releasing it for public comment. Final assessment of state concerns will be completed after comments on the FS and the interim proposed plan have been received by EPA and are addressed in the interim ROD. Thus, the state acceptance criterion is not considered in the detailed evaluation of alternatives presented in this FS.

6.9 Community Acceptance

Assessment of concerns from the public will be completed after comments on the FS and interim proposed plan have been received by EPA and are addressed in the interim ROD. Thus, community acceptance is not considered in the detailed evaluation of alternatives presented in this FS.

6.10 Criteria Priorities

The nine evaluation criteria are separated into three groups to establish priority among these criteria during detailed evaluation of the remedial alternatives as detailed in **Exhibit 6-4.**

Exhibit 6-4: Criteria Priorities

Group	Criteria	Definition
Threshold Criteria	Overall Protection of Human Health and the Environment Compliance with ARARs	Must be satisfied by the remedial alternative being considered as the preferred (unless an ARAR waiver is granted).
Balancing Criteria	Long-Term Effectiveness and Permanence Reduction of Toxicity, Mobility, or Volume through Treatment Short-Term Effectiveness Implementability Cost	Technical criteria evaluated among those alternatives satisfying the threshold criteria.
Modifying Criteria	State Acceptance and Community Acceptance	Not evaluated in this FS; evaluated after comments received on the FS and interim proposed plan.

6.11 Detailed Analysis of Retained Alternatives

In this section, remedial alternatives retained in Section 5 undergo detailed analysis. During detailed analysis, each alternative is assessed using the two threshold criteria and five balancing criteria presented in Sections 6.1 through 6.10. The results of the detailed analysis for each remedial alterative are then arrayed to perform a comparative analysis of the alternatives and identify the key tradeoffs between them.

The following alternatives were retained for detailed analysis:

For the contaminated creek bed sediment/bank surface soil remediation target zone, the remedial alternatives include:

- Alternative SD-1: No Action
- Alternative SD-2: Removal of Contaminated Sediment /Bank Surface Soil with Offsite Treatment and Disposal and Re-routing of Stream
- Alternative SD-3a: Removal of Contaminated Sediment/Bank Surface Soil with Ex-Situ Chemical Oxidation, Onsite Disposal, and Re-routing of Stream
- Alternative SD-3b: Removal of Contaminated Sediment/Bank Surface Soil with Ex-Situ Bioremediation, Onsite Disposal, and Re-routing of Stream

The remedial alternatives to address both the subsurface soil (PCE concentrations greater than 10 mg/kg) and high concentration groundwater (PCE concentrations greater than 4,000 μg/L) remediation target zones include:

- Alternative HC-1: No Action
- Alternative HC-2: Hydraulic Containment and ICs with Monitoring
- Alternative HC-3: In-Situ Thermal Treatment and ICs with Monitoring
- Alternative HC-4: In-Situ Chemical Oxidation and ICs with Monitoring
- Alternative HC-5: In-Situ Enhanced Bioremediation and ICs with Monitoring

6.12 Secondary Assumptions Affecting Detailed Analysis of Remedial Alternatives

Fundamental assumptions that were used to develop remedial alternatives for the HRIA were presented in Section 5. In addition to those fundamental development-related assumptions, there are several categories of secondary assumptions that potentially affect implementation of the alternatives. The basis for the detailed analysis of alternatives against EPA threshold and balancing criteria presented in Sections 6.13 and 6.14 is that these secondary assumptions will generally be met; however, a consideration of what the impact might be if they are not met also should factor into the evaluation and ultimate selection of an alternative. These assumptions are driven mainly by site limitations and constraints and are common to most if not all of the alternatives developed for the HRIA. **Exhibit 6-5** presents the secondary assumptions and potential impact on remedy implementation if the assumption is not met.

Exhibit 6-5: Secondary Assumptions Affecting Refinement and Detailed Analysis of Remedial Alternatives

Secondary Assumption Category	Secondary Assumption Description	Rationale	Impact if Assumption Not Met
Land Use Control Assumptions	Land use controls for privately owned parcels are primarily ICs and community awareness activities	Restrictions on well-drilling in the shallow aquifer can be established as an IC. Establishment of access control, such as posted warnings, may be difficult on privately owned parcels that are occupied and are actively used. It is also uncertain whether legal authority exists to install access controls extensively on privately owned parcels. However, the legal authority exists to implement certain types of ICs (for instance informational devices) as well as community awareness activities. Thus, land use controls for privately owned parcels are assumed to be primarily ICs and community awareness activities.	If ICs cannot be used to effectively control access, engineering controls (e.g., fencing) may be required, which may cause minor impact to remedial costs and schedule (relative to other components).
Remediation zone	Dimensions of remediation zone	The estimated lateral and vertical extent of the High Concentration Groundwater (>4,000 µg/L PCE) remediation zone was established with data available to date and used to develop the remedial alternatives. However, data gaps remain in the current understanding of extent of contamination associated with HRIA and OU2, which means there is some uncertainty associated with the defined dimensions of the remediation zone.	Project schedule and costs could be severely impacted as alternative may need to be re-evaluated to determine continued applicability to a remediation zone that proves to be substantially larger than estimated as data gaps are filled. Even if the alternative continues to be applicable, an increase in the size of the remediation zone and amount of material to be addressed will lead to a lengthening of project schedule and an increase in project costs.

Exhibit 6-5: Secondary Assumptions Affecting Refinement and Detailed Analysis of Remedial Alternatives (cont.)

Secondary Assumption Category	Secondary Assumption Description	Rationale	Impact if Assumption Not Met
Site Setting	Impact on remedy implementation	Proximity of Hamilton Road to Berwick Creek may preclude or limit the use of certain technologies as it will not be possible to divert or close off this major trucking route during remediation. In addition, a new interchange was installed just north of the HRIA allowing even more traffic from I-5 to be diverted to Hamilton Road. In addition, the proximity of the eastern portion of the high concentration area to I-5 may preclude or limit the use of certain technologies or warrant alternate methods of implementation. Finally, the valley in which the Site is located is prone to flooding every few years and the flooding could impact the effectiveness of equipment employed for long-term treatment. The potential for flooding could be further increased as a result of climate change.	Limitations due to site setting may limit the types of thermal treatment for consideration or the re-design of in-situ treatment or monitoring components of an interim remedial action (e.g., use of slant drilling for injection wells) causing delay to project schedule. The potential or increased possibility of flooding due to climate change would likely limit location and time frame in which remedy components could be implemented effectively. Costs also would likely increase.
Community and Stakeholders	Community and stakeholders acceptance	It is assumed that the community and stakeholders will approve remedial activities proposed for the site.	Project schedule will be delayed if proposed activities are not approved and must be replaced or approval process is slow.
Technology Vendors	Vendor/Contractor availability and experience	Qualified, experienced vendors are available for each of the technologies that will be employed to remediate the site.	Project schedule would be delayed as additional time would be required to find and procure vendors and contractors. Project costs may increase significantly if work completed by a vendor/contractor is substandard and has to be re-done.

Exhibit 6-5: Secondary Assumptions Affecting Refinement and Detailed Analysis of Remedial Alternatives (cont.)

Secondary Assumption Category	Secondary Assumption Description	Rationale	Impact if Assumption Not Met
Treatability Studies	Technology applicability	Each alternative that relies on in-situ or ex-situ chemical or biological treatment (SD-3a, SD-3b, HC-4, and HC-5) includes the completion of site-specific treatability studies before or during design to confirm that selected technologies will adequately address contamination.	Project schedule and cost impact if treatability studies indicate that selected technologies do not sufficiently address contamination. The selected remedy may need to be re-designed or contingency remedy may need to be employed.
Energy Costs	Unit energy costs (electricity, fuel, etc.) needed to complete remedial activities	No rapid, substantial increase in energy costs is anticipated as project progresses from FS to remedy implementation.	Rapid, sustained increases in energy costs will increase overall project costs. Energy-intensive alternatives will be most affected and may require reconsideration if energy cost increases are substantial.
Geological Materials for Reclamation	Uncontaminated subsoil and topsoil borrow sources	All sediment alternatives except Alternative SD-1 would require the use of uncontaminated soil for creek bed reconstruction. Onsite materials are not assumed because most of the site has the potential to be contaminated with VOCs. It is assumed that the offsite soil borrow area would be located on private property within 10 miles of the site.	Minor impact to overall cost if borrow source is more than 10 miles from the site. Adequate planning of site activities would minimize impact to schedule.
Onsite Construction – Removal Activities	Dust suppression	Dust suppression will be implemented under all sediment alternatives except Alternative SD-1. Water will be used as the primary option for dust suppression to meet ARARs.	If dust suppression is not carried out, additional measures will likely be required to protect site workers and would most likely increase project costs.
Institutional Controls and Monitoring	ICs and monitoring	It is assumed that ICs and monitoring are an integral part of all groundwater alternatives and will be implemented.	If ICs are not employed, remedial alternatives will be limited to those that quickly treat or remove contaminated material from the site in order to protect human health, and project costs will increase substantially.

Exhibit 6-5: Secondary Assumptions Affecting Refinement and Detailed Analysis of Remedial Alternatives (cont.)

Secondary Assumption Category	Secondary Assumption Description	Rationale	Impact if Assumption Not Met
Offsite Disposal Facilities	Authorized disposal facilities	There is one Subtitle D facility in Washington and two in Oregon and one Subtitle C facility in Oregon. For cost purposes, haul distance and disposal fees for all these facilities were averaged.	Use of disposal facilities beyond the anticipated haul distance will increase project costs.
Schedule	Berwick Creek in-stream work window	Instream work windows have been established for all waters of the State of Washington. These are in place to protect fish species at critical life history stages. For Berwick Creek, the in-stream work window is July 1 to September 30. It may be possible, however, to obtain a waiver from the state in order to work during the fish window.	If work window is missed and a waiver cannot be obtained, the sequence of remedial activities will need to be reconsidered in order to avoid delays to the overall project schedule. If the planned sequence of activities cannot be revised sufficiently, project schedule will be delayed significantly.
Green Remediation	Alternatives would incorporate relevant elements of EPA Region 10's Clean & Green Policy except where protectiveness is affected	It is assumed that all alternatives would address relevant elements of EPA Region 10's Clean & Green policy (EPA 2009) to the extent possible. Under the policy, use of the indicated elements and other green remediation technologies are standard unless a site-specific evaluation demonstrates impracticability or favors an alternative green approach. The elements of the "Clean & Green" policy include: ▪ 100% use of renewable energy (green power) and energy conservation and efficiency approaches, including Energy Star® equipment ▪ Cleaner fuels, diesel emissions controls and retrofits, and emission reduction strategies ▪ Water conservation and efficiency approaches including WaterSense products ▪ Sustainable site design ▪ Industrial material reuse or recycling within regulatory requirements ▪ Recycling of materials generated at or removed from the site ▪ Environmentally preferable purchasing ▪ Greenhouse gas emission reduction technologies	The environmental footprint of the alternatives would likely be larger than necessary if relevant elements of Region 10's Clean & Green Policy are not considered for inclusion.

Exhibit 6-5: Secondary Assumptions Affecting Refinement and Detailed Analysis of Remedial Alternatives (cont.)

Secondary Assumption Category	Secondary Assumption Description	Rationale	Impact if Assumption Not Met
Green Remediation (cont.)		▪ Concrete made with coal combustion products replacing a portion of traditional cement ▪ Environmental Management System practices, such as reducing the use of paper by moving to fully electronic transmittal of project documents and implementation of waste reduction and recycling programs at all work sites The Clean & Green Policy does not fundamentally change how and why cleanup decisions are made but calls for more sustainable methods of implementing those cleanups. Some of these elements may not be relevant to the alternatives considered for the site (for instance, there is no anticipated need for collection of landfill gasses). The policy also does not preclude remedy components that are required to ensure protectiveness. The use of Clean & Green practices will be considered during implementation of a selected remedy at the site.	

6.13 Detailed Analysis of Alternatives for Creek Bed Sediment/Bank Surface Soil Remediation Target Zone

6.13.1 Alternative SD-1: No Action

6.13.1.1 Remedial Alternative Component Descriptions

A description of the remedial components of Alternative SD-1 is provided in Section 5.3.1.1. The following is a summary of the remedial components of this alternative.

Alternative SD-1 is required by the NCP as a baseline for comparison against other remedial alternatives. Under this alternative, no action would be taken to remedy the contaminated creek bed sediment/soil or to monitor VOC concentrations to address the associated risks to human health or the environment. The only other actions that would be implemented would be 5-year site reviews as required by the NCP. Thus, conceptual sequencing of remedial alternative components is simply periodic compliance monitoring to determine whether contaminants are migrating offsite or not.

6.13.1.2 Remedial Action Objectives

Alternative SD-1 No Action would not achieve the remedial action objectives established for the HRIA or the PRGs established for the creek bed sediment/ bank surface soil remediation target zone. That is, direct exposure pathways would not be mitigated, contaminant mass would not be reduced, and PCE levels would not be reduced to below 10 mg/kg.

6.13.1.3 Overall Protection of Human Health and the Environment

No action would not be protective of human health and the environment. Creek bed Sediment/bank surface soil that is contaminated with COPCs will remain at the HRIA. Direct contact with these materials by tenants, trespassers, and ecological receptors would pose a risk. In addition, the contamination left in place would continue to provide a source to groundwater contamination. The No Action Alternative fails to meet this threshold criterion of protectiveness. The overall rating on this criterion for Alternative SD-1 is "No."

6.13.1.4 Compliance with ARARs

The No Action Alternative would not comply with ARARs that require the removal or remediation of contaminants released to the environment, the protection of future human health and the environment, and restoration of contaminated aquifers, including the chemical-specific ARAR for freshwater sediment (WAC 173-204-570) and the chemical-specific ARAR for soils (WAC 173–340-740). ARARs evaluated for this alternative are included in **Appendix B**. The overall rating on this criterion for Alternative SD-1 is "No."

6.13.1.5 Long-Term Effectiveness and Permanence

Since the No Action Alternative does not address treatment of contaminated creek bed sediment/bank surface soil, the contamination left in place would continue to provide a source to groundwater contamination. Thus, this alternative has no long-term effectiveness and permanence. The overall rating on this criterion for Alternative SD-1 is none.

6.13.1.6 Reduction of Toxicity, Mobility, or Volume through Treatment

No remedial action would be taken under the No Action Alternative; thus, there would be no reduction in toxicity, mobility, or volume of contaminated creek bed sediment/bank surface soil. The overall rating on this criterion for Alternative SD-1 is none.

6.13.1.7 Short-Term Effectiveness

No construction activities are required for the No Action Alternative; thus, there are no short-term impacts to workers and the community from implementation. However, since the contaminated creek bed sediment/bank surface soil is left in place, continued release, including exposure to principal threat waste, to surface and groundwater will occur and protection is not achieved. This alternative minimizes greenhouse gas emissions, air pollutants, energy consumption, and water use since no action will be taken. The overall rating on this criterion for Alternative SD-1 is moderate.

6.13.1.8 Implementability

No remedial action would be taken under this alternative; thus, no implementability is required. The overall implementability rating on this criterion for Alternative SD-1 is high.

6.13.1.9 Cost

There are no costs associated with the no action alternative since no remedial activities would be performed.

6.13.2 Alternative SD-2: Removal, Offsite Treatment and Disposal, and Re-Routing of Stream

6.13.2.1 Remedial Alternative Component Descriptions

A description of the remedial components of Alternative SD-2 is provided in Section 5.3.1.2. The following is a summary of the remedial components of this alternative.

Alternative SD-2 includes the excavation, transportation, and offsite disposal of contaminated creek bed sediment/bank surface soil at the HRIA. An estimated 1,400 cy of contaminated creek bed sediment/bank surface soil would be excavated from an approximately 40-ft wide by 200-ft long stretch of Berwick Creek at the HRIA (See **Figure 5-1**). Excavation would be conducted with conventional earth moving equipment and will be staged in a series of cells, starting downstream and moving upstream. Excavated material would be loaded into dump trucks and transported to a RCRA Subtitle C landfill for disposal. Per the LDRs, PCE and TCE contaminated soil must meet a treatment standard of 6.0 mg/kg prior to land disposal. In order to comply with LDRs, the excavated material will be treated at the Subtitle C facility prior to disposal. The Subtitle C facility identified in Arlington, Oregon provides treatment of hazardous material prior to disposal in the landfill. Prior to excavation, Berwick Creek would require diversion around the excavation area. For purposes of this FS, it was assumed that the diversion would be permanent.

Because the water table is shallow in this area, dewatering of the excavated area will likely be necessary. The excavated area would be backfilled after a GCL or similar liner is installed to reconstruct the fine-grained semi-confining layer. Removal of the contaminated sediment/bank surface soil would reduce the threat to groundwater by eliminating a continuing source of groundwater contamination.

6.13.2.2 Remedial Action Objectives

Alternative SD-2 would achieve the remedial action objectives established for the HRIA as well as the PRGs established for the creek bed sediment and bank surface soil remediation target zone. That is, direct exposure pathways would be mitigated, contaminant mass would be reduced, and PCE levels would be reduced to below 10 mg/kg.

6.13.2.3 Overall Protection of Human Health and the Environment

By removing the volume of sediments and bank surface soil containing >0.486 mg/kg PCE as soon as technically achievable, Alternative SD-2 would eliminate exposure pathways and significantly reduce the level of risk at the HRIA, providing protection of human health and the environment. The overall rating on this criterion for Alternative SD-2 is "Yes."

6.13.2.4 Compliance with ARARs

Excavation, treatment, and disposal of creek bed sediment and surface soil would be completed in accordance with local, state, and federal regulations. Alternative SD-2 would comply with the MTCA Method B cleanup level for human direct contact exposure with soils which requires cleanups to attain the $1x10^{-6}$ risk level for protection of human direct contact exposure (WAC 173–340-740). The PCE concentration, which equate to a $1x10^{-6}$ risk from direct contact, is 22 mg/kg assuming residential use, 110 mg/kg assuming industrial/commercial and construction/utility (trench worker) use, and 924 mg/kg assuming recreational use within the HRIA creek bed sediments and bank surface soils. The creek bed sediment/bank surface soil PRG is 10 mg/kg PCE, which far exceeds the 1×10^{-6} protection level.

Alternative SD-2 would also meet EPA's RSL of 0.468 mg/kg PCE for protection of benthic and freshwater organisms in creek bed sediment and bank surface soil when the impacted creek channel is relocated or reconstructed. This action is also expected to meet the chemical-specific ARAR for freshwater sediment (WAC 173-204-570). Note that under that standard, the state determines on a case by case basis the criteria, methods, and procedures necessary to meet the intent of the chapter. Therefore, the overall rating on this criterion for Alternative SD-2 is "Yes."

6.13.2.5 Long-Term Effectiveness and Permanence

This alternative provides long-term effectiveness and permanence by removing contaminated creek bed sediment/bank surface soil with PCE concentrations greater than 0.468 mg/kg from the HRIA. Excavating sediments/bank surface soil to this concentration would encompass the area likely containing residual DNAPL, which is a principal threat waste. In addition, removing the high concentration contaminated sediment/bank soil included within the 0,468 mg/kg footprint from the HRIA reduces a continuing source of groundwater contamination, thus, allowing the groundwater remediation to be accomplished sooner. The overall rating on this criterion for Alternative SD-2 is high.

6.13.2.5 Reduction of Toxicity, Mobility, or Volume through Treatment

Contaminated creek bed sediment/bank surface soil will be excavated from the HRIA and treated at the Subtitle C facility prior to disposal in order to comply with LDRs. Treatment at the Subtitle C facility would provide a reduction in toxicity. Additionally, physical removal of contaminated sediment/bank surface soil from the site would address principal threat waste and cause a reduction in mobility and volume. The overall rating on this criterion for Alternative SD-2 is high.

6.13.2.6 Short-Term Effectiveness

Excavation of contaminated creek bed sediment/bank surface soil will provide an immediate reduction in the volume of contaminated sediment/bank surface soil at the HRIA. The potential for short-term risks due to airborne transport of contaminated materials would be greatly increased during construction activities. These short-term risks would be mitigated through the use of standard construction practices, such as dust suppression with water or chemicals, foam application, a structure over the excavation, or a vacuum manifold to capture emissions, which also minimizes generation of dust and air pollutants and provides a mechanism to capture vapors. Additional short-term issues include noise levels associated with the use of heavy equipment, which can be mitigated through safety measures and engineering controls. Personal protective equipment (PPE) would be required to protect workers during onsite removal activities.

Applicable BMPs for excavation and surface restoration can be employed in the execution of this alternative to help implement it as a greener remedy. Early and integrated project planning would set the stage for sharing resources, infrastructures, and processes, and green requirements could be incorporated into product and service procurements. Energy requirements can be reduced by selecting local providers for field operations, identifying opportunities for resource sharing with other waste haulers, coordinating outside services and service providers to minimize transport of equipment, and using energy efficient equipment. Air emissions could be reduced by employing BMPs, such as using cleaner fuels (e.g., ultra-low sulfur diesel or biodiesel) to power equipment and limiting onsite vehicle speeds. Impacts on water can be reduced by considering the use of geotextile bags or nets to contain excavated sediment and facilitate sediment drying and undercutting the creek banks in ways that mimic natural conditions, repositioning dead trees as habitat snags, and selecting and placing appropriately sized and typed stones into water beds and banks. Impacts on land and ecosystems can be lessened by establishing minimally intrusive traffic patterns for onsite activities, installing silt fences and basins to capture sediment runoff along sloped areas, and limiting noise and artificial lighting that may disturb sensitive species. Material consumption and waste can be reduced by considering product life cycles during purchasing; giving preference to products, packing material, and disposable equipment with reuse or recycling potential; and considering products with recycled or bio-based content rather than petroleum-based contents. Finally, long-term sustainability can be encouraged by prompt revegetation of backfilled areas and installation of native rather than imported plants (EPA 2008b).

The overall rating on this criterion for Alternative SD-2 is moderate to high.

6.13.2.7 Implementability

This alternative would require the use of readily available conventional construction equipment to remove contaminated creek bed sediment/bank surface soil and re-route the creek bed. Removal and disposal of contaminated sediment/bank surface soil is relatively straightforward; however, the proximity of Hamilton Road to Berwick Creek and limited space in the roadway right-of-way will require extensive planning regarding the diversion of Berwick Creek. In addition, control and temporary diversion of traffic flow on Hamilton Road, which is a major trucking route, and a portion of I-5 will be needed and will require significant planning and coordination with Washington Department of Transportation (DOT).

Measures to prevent airborne transport of contaminants during construction activities would be required, such as foam application, a structure over the excavation, or a vacuum manifold to capture emissions. Representative creek bed sediment/bank surface soil samples would be collected and presented to the receiving landfill for their acceptance evaluation. Periodic monitoring would be done as part of the 5-year review process. Regulatory and facility approval for offsite disposal at permitted disposal facilities should be obtainable. The offsite disposal facility should have sufficient capacity to accept sediment/bank surface soil for disposal as the volume of contaminated sediment/bank surface soil for offsite disposal in this alternative should be relatively small. The overall rating on this criterion for Alternative SD-2 is high.

6.13.2.8 Cost

The capital costs associated with Alternative SD-2 are estimated to be $3.01 million. The annual O&M cost for this alternative is estimated to be $34,000. The 30-year present worth cost associated with this alternative is approximately $3.04 million. Detailed cost estimates for this alternative are included in **Appendix D**.

6.13.3 Alternative SD-3a: Removal, Ex-situ Chemical Oxidation, Onsite Disposal, and Re-Routing of Stream

6.13.3.1 Remedial Alternative Component Descriptions and Sequencing

A description of the remedial components of Alternative SD-3a is provided in Section 5.3.1.3. The following is a summary of the remedial components of this alternative.

Alternative SD-3a includes the excavation, ex-situ chemical oxidation, and onsite disposal of contaminated creek bed sediment/bank surface soil at the HRIA. An estimated 1,400 cy of contaminated creek bed sediment/bank surface soil would be excavated from an approximately 40-ft wide by 200-ft long stretch of Berwick Creek at the HRIA (See **Figure 5-2**). Excavation would be conducted with conventional earth moving equipment and will be staged in a series of cells, starting downstream and moving upstream. Excavated creek bed sediment/bank surface soil would be transported to a lined treatment and staging area located within the HRIA, which would be selected at the time of the remedial design. The contaminated creek bed sediment/bank surface soil would be treated through chemical oxidation prior to onsite disposal. Excavated material would be placed on an impermeable liner (geomembrane, plastic sheeting, lined containers, or containment areas). A strong chemical oxidant will then be mixed with the contaminated creek bed sediment/bank surface soil using conventional construction equipment. The oxidizing agent added to the contaminated creek bed sediment/bank surface soil would oxidize the VOCs that would serve as the reducing agents. Oxidizing agents are non-specific and will react with any reducing agent, such as naturally occurring organic matter, present in the contaminated sediment. Typical oxidizing agents include potassium permanganate, persulfate, hydrogen peroxide, and Fenton's Reagent. Chemical oxidation of chlorinated VOCs typically results in non-toxic end products, such as water, carbon dioxide, and dilute hydrochloric acid. Bench-scale testing would be required to determine the optimum chemical oxidant and dosage needed to achieve contaminant destruction.

Treated creek bed sediment/bank surface soil would be disposed of onsite, covered with topsoil, and revegetated. Because the water table is shallow in this area, dewatering of the excavated area will likely be necessary. The excavated area would be backfilled after a GCL or similar liner is installed to reconstruct the fine-grained semi-confining layer. Removal of the contaminated creek bed sediment/bank surface soil would reduce the threat to groundwater by eliminating a continuing source of groundwater contamination.

Prior to excavation, Berwick Creek would require diversion around the excavation area. For purposes of this FS, it was assumed that the diversion would be permanent.

6.13.3.2 Remedial Action Objectives

Alternative SD-3a would achieve the remedial action objectives established for the HRIA as well as the PRGs established for the creek bed sediment and bank surface soil remediation target zone. That is, direct exposure pathways would be mitigated, contaminant mass would be reduced, and PCE levels would be reduced to below 10 mg/kg.

6.13.3.3 Overall Protection of Human Health and the Environment

By removing and treating the volume of sediments and surface soil containing >0.468 mg/kg PCE as soon as technically achievable, Alternative SD-3a would eliminate exposure pathways and significantly reduce the level of risk at the HRIA, providing protection of human health and the environment. The overall rating on this criterion for Alternative SD-3a is "Yes."

6.13.3.4 Compliance with ARARs

Excavation, ex-situ treatment, and onsite disposal of creek bed sediment and surface soil would be completed in accordance with local, state, and federal regulations. Alternative SD-3a would comply with the MTCA Method B cleanup level for human direct contact exposure with soils, which requires cleanups to attain the $1x10^{-6}$ risk level for protection of human direct contact exposure (WAC 173–340-740). The PCE concentration, which equate to a $1x10^{-6}$ risk from direct contact, is 22 mg/kg assuming residential use, 110 mg/kg assuming industrial/commercial and construction/utility (trench worker) use, and 924 mg/kg assuming recreational use within the HRIA creek bed sediments and bank surface soils. The creek bed sediment/bank surface soil PRG is 10 mg/kg PCE, which far exceeds the 1×10^{-6} protection level.

Alternative SD-3a would also meet EPA's RSL of 0.468 mg/kg PCE for protection of benthic and freshwater organisms in creek bed sediment and bank surface soil when the impacted creek channel is relocated or reconstructed. This action is also expected to meet the chemical-specific ARAR for freshwater sediment (WAC 173-204-570). Note that under that standard, the state determines on a case by case basis the criteria, methods, and procedures necessary to meet the intent of the chapter. The overall rating on this criterion for Alternative SD-3a is "Yes."

6.13.3.5 Long-Term Effectiveness and Permanence

This alternative provides long-term effectiveness and permanence by removing and treating contaminated creek bed sediment and surface soils with PCE concentrations greater than 0.468 mg/kg from the HRIA. Excavating and treating the sediments and surface soils to this concentration would encompass the area likely containing residual DNAPL, which is a principal threat waste. In addition, removing and treating the high concentration contaminated creek bed sediment/bank surface soil included within the 0.468 mg/kg footprint from the HRIA reduces a continuing source of groundwater contamination, thus, allowing the groundwater remediation to be accomplished sooner. The overall rating on this criterion for Alternative SD-3a is high.

6.13.3.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Contaminated creek bed sediment/bank surface soil excavated from the HRIA would be treated via chemical oxidation; thus, Alternative SD-3a would cause a reduction in toxicity, mobility, and volume through treatment. The overall rating on this criterion for Alternative SD-3a is high.

6.13.3.7 Short-Term Effectiveness

Excavation of contaminated creek bed sediment/bank surface soil will provide an immediate reduction in the volume of contaminated creek bed sediment/bank surface soil at the HRIA. The potential for short-term risks due to airborne transport of VOCs would be greatly increased during construction activities. These short-term risks would be mitigated through the use of standard construction practices, foam application, a structure over the excavation, or a vacuum manifold to capture emissions, such as dust suppression with water or chemicals, which also minimizes generation of dust and air pollutants. Additional short-term issues include noise levels associated with the use of heavy equipment, which can be mitigated through safety measures and engineering controls. PPE would be required to protect workers during onsite removal activities. The potential risks to the public posed by chemical oxidants would be reduced through standard health and safety practices. The risks to workers from the chemical oxidants during treatment would be reduced through the use of PPE and standard health and safety practices.

Applicable BMPs for excavation and surface restoration can be employed in the execution of this alternative to help implement it as a greener remedy. Early and integrated project planning would set the stage for sharing resources, infrastructures, and processes, and green requirements could be incorporated into product and service procurements. Energy requirements can be reduced by selecting local providers for field operations, identifying opportunities for resource sharing with other waste haulers, coordinating outside services and service providers to minimize transport of equipment, and using energy efficient equipment. Air emissions could be reduced by employing BMPs, such as using cleaner fuels (e.g., ultra-low sulfur diesel or biodiesel) to power equipment and limiting onsite vehicle speeds. Impacts on water can be reduced by considering the use of geotextile bags or nets to contain excavated sediment and facilitate sediment drying and undercutting the creek banks in ways that mimic natural conditions, repositioning dead trees as habitat snags, and selecting and placing appropriately sized and typed stones into water beds and banks. Impacts on land and ecosystems can be lessened by establishing minimally intrusive traffic patterns for onsite activities, installing silt fences and basins to capture sediment runoff along sloped areas, and limiting noise and artificial lighting that may disturb sensitive species. Material consumption and waste can be reduced by considering product life cycles during purchasing; giving preference to products, packing material, and disposable equipment with reuse or recycling potential; and considering products with recycled or bio-based content rather than petroleum-based contents. Finally, long-term sustainability can be encouraged by prompt revegetation of backfilled areas and installation of native rather than imported plants (EPA 2008b).

The overall rating on this criterion for Alternative SD-3a is moderate to high.

6.13.3.8 Implementability

This alternative would require the use of readily available conventional construction equipment to remove contaminated creek bed sediment/bank surface soil and re-route the creek bed. Removal of contaminated creek bed sediment/soil is relatively straightforward; however, the proximity of Hamilton Road to Berwick Creek and limited space in the roadway right-of-way will require extensive planning regarding the diversion of Berwick Creek. In addition, control and temporary diversion of traffic flow on Hamilton Road, which is a major trucking route, and a portion of I-5 will be needed and will require significant planning and coordination with Washington DOT.

Measures to prevent airborne transport of contaminants during construction activities would be required, such as foam application, a structure over the excavation, or a vacuum manifold to capture emissions. Ex-situ chemical oxidation would require staging and treatment areas for contaminated sediment/bank surface soil for implementation, which may pose difficulties in finding adequate space in a developed area for treatment. Chemical oxidants would be delivered to the contaminated sediment using readily available conventional construction equipment. Bench-scale tests would be required to determine the dose of chemical oxidant required to achieve contaminant destruction. Lower permeability soils create difficulties in evenly distributing oxidant within the soils. Additional implementability issues arise from the creation of a slurry during this treatment process from chemical oxidant solution injections. The formation of a slurry out of the excavated material creates material handling issues and creates a need for dewatering of the material prior to onsite disposal. Water and vapor generated during dewatering, excavation, and mixing would require treatment prior to discharge. The overall rating on this criterion for Alternative SD-3a is moderate.

6.13.3.9 Cost

The capital costs associated with Alternative SD-3a are estimated to be $3.1 million. The annual O&M cost is estimated to be $54,000. The 30-year present worth cost associated with this alternative is approximately $3.2 million. Detailed cost estimates for this alternative are included in **Appendix D**.

6.13.4 Alternative SD-3b: Removal, Ex-situ Bioremediation, Onsite Disposal, and Re-Routing of Stream

6.13.4.1 Remedial Alternative Component Descriptions and Sequencing

A description of the remedial components of Alternative SD-3b is provided in Section 5.3.1.4. The following is a summary of the remedial components of this alternative.

Alternative SD-3b includes the excavation, ex-situ bioremediation, and onsite disposal of contaminated creek bed sediment/bank surface soil at the HRIA. An estimated 1,400 cy of contaminated creek bed sediment/bank surface soil would be excavated from an approximately 40-ft wide by 200-ft long stretch of Berwick Creek at the HRIA (See **Figure 5-2**). Excavation would be conducted with conventional earth moving equipment and will be staged in a series of cells, starting downstream and moving upstream. Excavated creek bed sediment/bank surface soil would be transported to a lined treatment and staging area located within the HRIA, which would be selected at the time of the remedial design. The contaminated creek bed sediment/bank surface soil would be treated through bioremediation prior to onsite disposal. Excavated material would be placed on an impermeable liner (geomembrane, plastic sheeting, lined containers, or containment areas). Excavated material would be mixed with soil amendments to promote biological activity and placed over an engineered system of PVC piping lying on an impermeable liner (geomembrane or plastic sheeting). The engineered PVC system would be used to inject and re-circulate nutrient enhanced water to control moisture and nutrient loadings. Off-gas would be treated by GAC adsorption. If vinyl chloride is observed at the site, then a catalytic oxidizer would be used in place of activated carbon since vinyl chloride does not effectively adsorb to carbon.

Drainage from the treatment area would also require treatment prior to recycling or discharge. The excavated sediment/bank surface soil could be amended to provide bulk to the material to increase the porosity of the material. The excavated pile would also be covered by plastic sheeting or geomembrane to prevent heat loss and to control runoff, evaporation, and volatilization. Bench-scale and treatability tests would be required to determine amendment mixtures that best promote microbial activity, potential toxic degradation byproducts, percent reduction and lower concentration limit of contaminant achievable, and the potential degradation rate.

Treated soil would be disposed of onsite, covered with topsoil, and revegetated. Because the water table is shallow in this area, dewatering of the excavated area likely will be necessary. The excavated area would be backfilled after a GCL or similar liner would be installed to reconstruct the fine-grained semi-confining layer. Removal of the contaminated sediment/soil would reduce the threat to groundwater by eliminating a continuing source of groundwater contamination.

Prior to excavation, Berwick Creek would require diversion around the excavation area. For purposes of this FS, it was assumed that the diversion would be permanent.

6.13.4.2 Remedial Action Objectives

Alternative SD-3b would achieve the remedial action objectives established for the HRIA as well as the PRGs established for the creek bed sediment and bank surface soil remediation target zone. That is, direct exposure pathways would be mitigated, contaminant mass would be reduced, and PCE levels would be reduced to below 10 mg/kg.

6.13.4.3 Overall Protection of Human Health and the Environment

By removing and treating the volume of sediments and surface soil containing >0.468 mg/kg PCE as soon as technically achievable, Alternative SD-3b would eliminate exposure pathways and significantly reduce the level of risk at the HRIA, providing protection of human health and the environment. The overall rating on this criterion for Alternative SD-3b is “Yes.”

6.13.4.4 Compliance with ARARs

Excavation, ex-situ treatment, and onsite disposal of creek bed sediment and surface soil would be completed in accordance with local, state, and federal regulations. Alternative SD-3b would comply with the MTCA Method B cleanup level for human direct contact exposure with soils which require cleanups to attain the 1×10^{-6} risk level for protection of human direct contact exposure (WAC 173–

340-740). The PCE concentration, which equates to a $1x10^{-6}$ risk from direct contact, is 22 mg/kg assuming residential use, 110 mg/kg assuming industrial/commercial and construction/utility (trench worker) use, and 924 mg/kg assuming recreational use within the HRIA creek bed sediments and bank surface soils. The creek bed sediment/bank surface soil PRG is 10 mg/kg PCE, which far exceeds the 1×10^{-6} protection level.

Alternative SD-3b would also meet EPA's RSL of 0.468 mg/kg PCE for protection of benthic and freshwater organisms in creek bed sediment and bank surface soil when the impacted creek channel is relocated or reconstructed. This action is also expected to meet the chemical-specific ARAR for freshwater sediment (WAC 173-204-570). Note that under that standard, the state determines on a case by case basis the criteria, methods, and procedures necessary to meet the intent of the chapter. The overall rating on this criterion for Alternative SD-3b is "Yes."

6.13.4.5 Long-Term Effectiveness and Permanence

This alternative provides long-term effectiveness and permanence by removing and treating contaminated creek bed sediment and surface soils with PCE concentrations greater than 0.468 mg/kg from the HRIA. Excavating and treating the sediments and surface soils to this concentration would encompass the area likely containing residual DNAPL, which is a principal threat waste. In addition, removing and treating the high concentration contaminated sediment/bank surface soil included within the 0.468 mg/kg footprint from the HRIA reduces a continuing source of groundwater contamination, thus, allowing the groundwater remediation to be accomplished sooner.

This treatment process is expected to take longer to achieve RAOs than Alternatives SD-2 and SD-3a, and the attainment of RAOs is less certain due to the complexities involved with the treatment process. The overall rating on this criterion for Alternative SD-3b is moderate to high.

6.13.4.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Contaminated creek bed sediment/bank surface soil excavated from the HRIA would be treated via bioremediation; thus, Alternative SD-3b would cause a reduction in toxicity, mobility, and volume through treatment. Chlorinated VOCs (CVOCs) would be biotransformed to ethylene, ethane, and methane. Any residual CVOCs (except VC) would be transferred to the GAC media, which would then be regenerated, permanently destroying the VOC contaminants. Mobility of contaminants would also be reduced by removal and treatment of the contaminated sediment/bank surface soil. The overall rating on this criterion for Alternative SD-3b is high.

6.13.4.7 Short-Term Effectiveness

Excavation of contaminated creek bed sediment/bank surface soil will provide an immediate reduction in the volume of contaminated creek bed sediment/bank surface soil at the site. The potential for short-term risks due to airborne transport of contaminated materials would be greatly increased during construction activities. These short-term risks would be mitigated through the use of standard construction practices, such as dust suppression with water or chemicals, which also minimizes generation of dust and air pollutants. Additional short-term issues include noise levels associated with the use of heavy equipment, which can be mitigated through safety measures and engineering controls. PPE would be required to protect workers during onsite removal activities. Risks to site workers during treatment will be reduced by wearing the appropriate PPE to minimize exposure to contamination and as protection from physical hazards. Another potential impact to the community is the amount of water that would be needed for amendment delivery, which may need to be taken from a nearby hydrant. The potential for vinyl chloride generation prior to conversion to ethylene would be another issue posed by this treatment technology, representing an additional short-term risk. The treatment time for ex-situ bioremediation is expected to be longer than the treatment time for ex-situ chemical oxidation.

Applicable BMPs for excavation and surface restoration can be employed in the execution of this alternative to help implement it as a greener remedy. Early and integrated project planning would set the stage for sharing resources, infrastructures, and processes, and green requirements could be incorporated into product and service procurements. Energy requirements can be reduced by selecting local providers for field operations, identifying opportunities for resource sharing with other waste haulers, coordinating outside services and service providers to minimize transport of equipment, and using energy efficient equipment. Air emissions could be reduced by employing BMPs such as using cleaner fuels (e.g., ultra-low sulfur diesel or biodiesel) to power equipment and limiting onsite vehicle speeds. Impacts on water can be reduced by considering the use of geotextile bags or nets to contain excavated sediment and facilitate sediment drying and undercutting the creek banks in ways that mimic natural conditions, repositioning dead trees as habitat snags, and selecting and placing appropriately sized and typed stones into water beds and banks. Impacts on land and ecosystems can be lessened by establishing minimally intrusive traffic patterns for onsite activities, installing silt fences and basins to capture sediment runoff along sloped areas, and limiting noise and artificial lighting that may disturb sensitive species. Material consumption and waste can be reduced by considering product life cycles during purchasing; giving preference to products, packing material, and disposable equipment with reuse or recycling potential; and considering products with recycled or bio-based content rather than petroleum-based contents. For the bioremediation component of the alternative, the use of innovative reagents from nontraditional sources could potentially reduce consumption of virgin natural resources and should be evaluated. Finally, long-term sustainability can be encouraged by prompt revegetation of backfilled areas and installation of native rather than imported plants (EPA 2008b).

The overall rating on this criterion for Alternative SD-3b is moderate.

6.13.4.8 Implementability

Implementation of Alternative SD-3b would be more complicated and would likely take longer than Alternatives SD-2 and SD-3a. The soil would need to be kept fully saturated for bioremediation to occur, and there are many more factors involved in keeping the treatment process operating as compared to the other alternatives. Bioaugmentation may be necessary to achieve an adequate colony of active microorganisms.

This alternative would require the use of readily available conventional construction equipment to remove contaminated creek bed sediment/bank surface soil and re-route the creek bed. Removal of contaminated sediment/bank surface soil is relatively straightforward; however, the proximity of Hamilton Road to Berwick Creek and limited space in the roadway right-of-way will require extensive planning regarding the diversion of Berwick Creek. In addition, control and temporary diversion of traffic flow on Hamilton Road, which is a major trucking route, and a portion of I-5 will be needed and will require significant planning and coordination with Washington DOT.

Measures to prevent airborne transport of contaminants during construction activities would be required. Ex-situ bioremediation would require staging and treatment areas for contaminated sediment for implementation, which may pose difficulties in finding adequate space in a developed area for treatment. Nutrients would be delivered to the contaminated creek bed sediment/bank surface soil using readily available conventional equipment. Bench-scale and treatability tests would be required to determine amendment mixtures that best promote microbial activity, potential toxic degradation byproducts, percent reduction and lower concentration limit of contaminant achievable, and the potential degradation rate. Lower permeability soils create difficulties in evenly distributing moisture, air, and nutrients. Additional implementability issues arise from the creation of a slurry during this treatment process from nutrient and moisture injections. The formation of a slurry out of the excavated material creates material handling issues and creates a need for dewatering of the material prior to onsite disposal. The treatment time for ex-situ bioremediation is also expected to be longer than Alternative SD-3a. Water generated during dewatering would require treatment prior to discharge. The overall rating on this criterion for Alternative SD-3b is low.

6.13.4.9 Cost

The capital costs associated with Alternative SD-3b are estimated to be $3.1 million. The annual O&M cost is estimated to be $54,000. The 30-year present worth cost associated with this alternative is approximately $3.2 million. Detailed cost estimates for this alternative are included in **Appendix D**.

6.14 Detailed Analysis of Alternatives for Subsurface Soil and High Concentration Groundwater Remediation Target Zones

6.14.1 Alternative HC-1: No Action

6.14.1.1 Remedial Alternative Component Descriptions and Sequencing

A description of the remedial components of Alternative HC-1 is provided in Section 5.3.2.1. The following is a summary of the remedial components of this alternative.

Alternative HC-1, the No Action Alternative is required by the NCP as a baseline for comparison against other remedial alternatives. Under this alternative, no action would be taken to remedy the contaminated groundwater/ subsurface soil or to monitor VOC concentrations to address the associated risks to human health or the environment. The only other actions that would be implemented would be 5-year site reviews as required by the NCP.

6.14.1.2 Remedial Action Objectives

Alternative HC-1 No Action would not achieve the PRGs established for the subsurface soil and high concentration groundwater remediation target zones. That is, PCE concentrations would not be reduced to below 10 mg/kg in subsurface soil nor would there be a reduction of mass discharge of VOC contamination by 90% from the high concentration groundwater to the dissolved phase plume as quickly as technically achievable. Alternative HC-1 would not contribute to achieving the RAOs for the HRIA; i.e., it would not help prevent human or ecological exposure nor would it achieve the reduction of mass discharge (the measure of contaminant migration) of VOCs from the HRIA to the downgradient contaminant plume.

6.14.1.3 Overall Protection of Human Health and the Environment

The No Action Alternative would not be protective of human health and the environment. Source area groundwater/subsurface soil contaminated with COPCs will remain at the site. In addition, the contamination left in place in subsurface soil would continue to provide a source to groundwater contamination. This alternative does not include the implementation of any ICs, such as deed restrictions or future groundwater monitoring. The No Action Alternative fails to meet this threshold criterion of protectiveness. The overall rating on this criterion for Alternative HC-1 is “No.”

6.14.1.4 Compliance with ARARs

ARARs evaluated for this alternative are included in **Appendix B**. The No Action Alternative would not comply with ARARs that require the removal or remediation of contaminants released to the environment, the protection of future human health and the environment, and restoration of contaminated aquifers, including the chemical-specific ARARs for groundwater (40 CFR 141-11-.16 [MCLs] and WAC 173-340-720) and the chemical-specific ARAR for soils (WAC 173–340-740). However, because Alternative HC-1 would be carried out as an interim measure, it is anticipated that pursuant to (CERCLA §121(d)(4)(A)), the interim measures ARARs waiver would be applied, and subsurface soil and groundwater ARARs would be addressed in the final remedy for the HRIA. The overall rating on this criterion for Alternative HC -1 is "No."

6.14.1.5 Long-Term Effectiveness and Permanence

Since the No Action Alternative does not address treatment of contaminated groundwater/subsurface soil, the contamination left in place in subsurface soil would continue to provide a source to groundwater contamination, and the status of the groundwater contamination would remain unchanged. Thus, this alternative has no long-term effectiveness and permanence. The overall rating on this criterion for Alternative HC -1 is none.

6.14.1.6 Reduction of Toxicity, Mobility, or Volume through Treatment

No remedial action would be taken under the No Action Alternative; thus, there would be no reduction in toxicity, mobility, or volume of contaminated groundwater/subsurface soil. The overall rating on this criterion for Alternative HC -1 is none.

6.14.1.7 Short-Term Effectiveness

No construction activities are required for the No Action Alternative; thus, there are no short-term impacts to workers and the community from implementation. However, since the contaminated subsurface soil is left in place, continued release to groundwater will occur and protection is not achieved. This alternative minimizes greenhouse gas emissions, air pollutants, energy consumption, and water use since no action will be taken. The overall rating on this criterion for Alternative HC -1 is moderate.

6.14.1.8 Implementability

No remedial action would be taken under this alternative; thus, no implementation is required. The overall implementability rating on this criterion for Alternative HC -1 is high.

6.14.1.9 Cost

There are no costs associated with the no action alternative since no remedial activities would be performed.

6.14.2 Alternative HC-2: Hydraulic Containment and Institutional Controls with Monitoring

6.14.2.1 Remedial Alternative Component Descriptions and Sequencing

A description of the remedial components of Alternative HC-2 is provided in Section 5.3.2.2. The following is a summary of the remedial components of this alternative.

Alternative HC-2 includes capturing contaminated groundwater within the high concentration groundwater remediation target zone and containing the PCE in the area where it is inferred to be present as DNAPL, thus, cutting off the source area from the downgradient areas of the Site. Several existing recovery and monitoring wells located along the leading edge of the high concentration contaminated groundwater plume and within the core of the plume would be converted to extraction wells, as applicable, and pumped continuously to create a hydraulic barrier to contaminant migration. Continuous pumping would be performed from 11 existing monitoring wells and 2 new monitoring wells. Assuming they are accessible, the existing wells that will be pumped include MW-600 through MW-605, MWR-1, MWR-2, MWR-4, MWR-5, MW-R9, and MWR-10. The actual existing wells to be used and the number of new wells that may be required would be considered further in the remedial design as many of the existing wells may not be optimally screened for capturing/containing contamination.

Extracted groundwater would be treated by a pre-manufactured, skid-mounted air-stripping unit and discharged to Berwick Creek. Vapor from the air stripper will be treated via GAC prior to release to the atmosphere. If vinyl chloride is observed at the site, then a catalytic oxidizer would be used in place of activated carbon since vinyl chloride does not effectively adsorb to carbon.

Five year site reviews would be performed at the site as discussed for Alternative HC-1 and would be periodically conducted as required by CERCLA to assess the effectiveness of the remedial action.

6.14.2.2 Remedial Action Objectives

Alternative HC-2 could achieve the groundwater reduction of mass discharge PRG, and ICs would help contribute to the RAOs for the HRIA of mitigating direct exposure pathways to high concentrations of PCE contamination. However, Alternative HC-2 would not likely achieve the PRG for subsurface soil, i.e., the removal of PCE DNAPL as quickly as technically achievable, thus, leaving a continuing source of contamination in place.

6.14.2.3 Overall Protection of Human Health and the Environment

Although concentrations would take a long time to reduce, Alternative HC-2 would result in the reduction of dissolved VOC concentrations in the groundwater and would contain the PCE in the area where it is inferred to be present as DNAPL, thus, cutting off flux of contaminants from the source area to the downgradient areas of the Site. This would reduce the potential for migration of contaminated groundwater outside the high concentration groundwater remediation target zone. ICs would protect human health by restricting the use of and access to contaminated groundwater. The removal and treatment of contaminated groundwater will significantly reduce the level of risk at the HRIA, providing protection of human health and the environment. The overall rating on this criterion for Alternative HC-2 is “No.”

6.14.2.4 Compliance with ARARs

ARARs evaluated for this alternative are presented in **Appendix B** and include WAC 173-340-720 and 40 CFR 141.11-.16 for groundwater cleanup and WAC 173-340-740 for soil cleanup. Because Alternative HC-2 would constitute an interim measure to contain contaminant migration in subsurface soil and groundwater, it is anticipated that pursuant to (CERCLA §121(d)(4)(A)), the interim measures ARARs waiver would be applied, and groundwater ARARs would be addressed in the final remedy for the HRIA; however, Alternative HC-2 would not likely comply with the ARAR for soil cleanup. Therefore, the overall rating on this criterion for Alternative HC -2 is “No.”

6.14.2.5 Long-Term Effectiveness and Permanence

This alternative provides long-term effectiveness and permanence by removing and treating contaminated groundwater from the high concentration groundwater remediation target zone. Additionally, removal of contaminated groundwater cuts off the source area from downgradient areas through containment and minimizes the downgradient migration of contaminants.

Currently, water flow in Berwick Creek is very low in the summer. The long-term effect of year round discharge of approximately 100 gpm to Berwick creek that would be carried out as part of this alternative may alter the characteristics of the creek and adjacent area.

Residual DNAPL, sorbed VOCs, and VOCs diffused into low permeability zones would not effectively be treated under this alternative, thus, leaving in place a source of contamination to the groundwater through dissolution, diffusion, and desorption of VOCs into groundwater in primary flow paths. Mass removal under this alternative would be minimal as pump and treat technology is not highly effective at removing residual DNAPL, which is inferred to be present at the site based on PCE concentrations. Based on past site experience, this alternative would not be able to achieve the HRIA RAOs within the HRIA source area within a reasonable timeframe if no additional remedial actions are taken.

The air stripper would require periodic cleaning to avoid operational problems. This alternative also requires O&M of the treatment system, semi-annual groundwater monitoring, and 5-year site reviews until the HRIA RAOs are achieved. Monitoring also would be conducted to assess whether the remedial alternative exacerbates potential for vapor intrusion so appropriate mitigation procedures could be employed if vapor intrusions issues are found as a result of the remedial alternative. The overall rating on this criterion for Alternative HC-2 is low.

6.14.2.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Contaminated groundwater extracted from the high concentration groundwater remediation target zone would be treated via air stripping and polished with GAC; thus, Alternative HC-2 would cause a reduction in toxicity, mobility, and volume through treatment. However, the water pumped out will have minimal effect on the site mass such that toxicity, mobility, and volume will be minimally affected. In addition, contaminated subsurface soil would not be treated under this alternative; thus, no reduction in toxicity, mobility, or volume would be realized for subsurface soil. Minimal mass removal would occur under this alternative. The overall rating on this criterion for Alternative HC-2 is low.

6.14.2.7 Short-Term Effectiveness

Extraction of contaminated groundwater from the high concentration groundwater remediation target zone will provide an immediate reduction in risk through containment of contaminated groundwater that would be achieved within a few hours of system startup. The potential for short-term risks to the community would be mitigated through the implementation of site control and traffic control measures during construction and placement of the system and the system infrastructure. The system would be placed on unused public land away from current use and would be surrounded by fencing to further reduce risks to the community and environment. Additional short-term issues include noise levels associated with the use of heavy equipment, which can be mitigated through safety measures and engineering controls. The risks to workers performing remedial and monitoring activities would be mitigated through the use of PPE and standard health and safety practices.

Discharge of treated water to Berwick Creek at 100 gpm may put unwanted stresses on the Creek and surrounding environment. Rather than discharging to Berwick Creek, treated water could be re-injected to provide aquifer recharge at the Site (this could be explored further during the design phase).

The implementation of an extraction/treatment alternative offers many opportunities to increase sustainability. Early and integrated project planning would set the stage for sharing resources, infrastructures, and processes, and green requirements could be incorporated into product and service procurements. Energy and materials use is impacted by the rate of groundwater extraction. If feasible, conservative hydraulic capacity could be planned for the treatment system by increasing pipe size, which would then allow for treatment modifications and future modular increases or decreases in the extraction rate. If pulsed pumping becomes feasible, additional gains in energy conservation may be possible by pumping during off-peak utility periods. Electricity use can be made more efficient by sizing pumps, fans, and motors appropriately and using energy efficient motors. Fuel consumption and air emission can be reduced by retrofitting engines to accommodate diesel emission controls or replacing obsolete engines. Additionally, renewable energy sources, such as solar panels, could be used to provide power to the treatment system. If treated water is re-injected into the aquifer, energy requirements may lessen, as the need to include a polishing GAC treatment to meet sub-parts per billion water quality criteria for discharge to Berwick Creek is eliminated. Impacts on land and ecosystems can be lessened by establishing minimally intrusive traffic patterns for onsite activities and limiting noise and artificial lighting that may disturb sensitive species. Material consumption and waste can be reduced by considering product life cycles during purchasing; giving preference to products, packing material, and disposable equipment with reuse or recycling potential; and considering products with recycled or bio-based content rather than petroleum-based contents.

The overall rating on this criterion for Alternative HC-2 is moderate to high.

6.14.2.8 Implementability

Hydraulic containment is technically and administratively feasible. Pump and treat technology is well established and could be readily implemented at the HRIA. This alternative would require the use of readily available conventional construction equipment to extract contaminated groundwater. Several existing recovery wells exist within the HRIA, at the site in locations ideal for hydraulic containment of the high concentration groundwater plume; however, a well inventory would need to be conducted to determine which of the existing wells will actually be useable. It is estimated that two new wells would be installed for this alternative. The additional wells, well vaults, and underground piping and electrical lines would be constructed with standard drilling and construction equipment. Additional modeling would be required during the design phase to assess the expected capture zone and confirm the adequacy of the existing and proposed well network. Periodic groundwater monitoring would be easily implementable using readily available services and materials. The overall rating on this criterion for Alternative HC-2 is moderate to high.

6.14.2.8 Cost

The capital costs associated with Alternative HC-2 are estimated to be $1.3 million. The annual O&M cost is estimated to be $411,000. The 30-year present worth cost associated with this alternative is approximately $5.4 million. Detailed cost estimates for this alternative are included in **Appendix D**.

6.14.3 Alternative HC-3: In-Situ Thermal Treatment and Institutional Controls with Monitoring

6.14.3.1 Remedial Alternative Component Descriptions and Sequencing

A description of the remedial components of Alternative HC-3 is provided in Section 5.3.2.3. The following is a summary of the remedial components of this alternative.

Alternative HC-3 includes removal of VOC mass in subsurface soil and groundwater via thermal treatment coupled with ICs and long-term monitoring. Monitoring also would be conducted to assess whether the remedial alternative exacerbates the potential for vapor intrusion so appropriate mitigation procedures could be employed if vapor intrusions issues are found as a result of the remedial alternative. For evaluation and costing purposes, thermal treatment technology ERH was assumed in the FS. A grid of electrodes separated, on average, by 22 feet and installed to depths ranging from 4 feet to 42 feet is assumed. A grid of co-located vapor recovery wells will also be installed. A total of 48 TMPs will be installed within the overall treatment area, and it is assumed that 20 confirmatory soil borings with 8 soil samples per boring will be collected to verify completion of treatment. Vapor and condensate recovered during system operation will be treated using GAC prior to discharge. If vinyl chloride is observed at the site, then a catalytic oxidizer or chemical oxidant would be used in place of GAC since vinyl chloride does not effectively adsorb to carbon. During operation, temperature, groundwater quality, vapor emissions, and condensate/discharge will be monitored. The total heating/treatment time is assumed to be up to 10 months to achieve RAOs.

The presence of the impermeable silt and clay layer across the HRIA may necessitate the installation of a series of trenches containing horizontal SVE wells. Since the groundwater table is located close to the surface it is possible that fluctuations in water levels or upwelling of groundwater could flood the SVE wells. The combination of these conditions will make collection of vapors generated during thermal treatment difficult.

Bioremediation could potentially be used in conjunction with thermal to reduce the overall treatment volume or as a polishing step for this alternative through the injection of amendments before, during, and/or after completion of thermal at the Site.

Five year site reviews would be performed at the site as discussed for Alternative HC-1 and would be periodically conducted as required by CERCLA to assess the effectiveness of the remedial action.

6.14.3.2 Remedial Action Objectives

Alternative HC-3 could achieve the groundwater PRG (reduction of mass discharge) and the PRG for subsurface soil (remove PCE DNAPL as quickly as technically achievable by reducing subsurface soil PCE concentrations to below 10 mg/kg). Alternative HC-3 would therefore also achieve the RAOs for the HRIA, i.e., mitigating any direct exposure pathways to high concentrations of PCE contamination reducing DNAPL contaminant mass within the HRIA to reduce source material in the HRIA and reducing contaminant mass discharge (the measure of contaminant migration) of VOCs from the HRIA to downgradient groundwater.

6.14.3.3 Overall Protection of Human Health and the Environment

Alternative HC-3 would be protective of human health and the environment by reducing the mass of VOC contamination in both subsurface soil and groundwater in the remediation target zone. Achieving these reductions would substantially reduce contaminants within the residual source area so that downgradient concentrations would decrease at a more rapid rate. The reduction in VOC mass would also reduce the baseline risk to human health and the environment, eliminate exposure pathways, and reduce the potential for migration of contamination to local production wells. ICs would protect human health by restricting the use of and access to contaminated groundwater. The overall rating on this criterion for Alternative HC-3 is "Yes."

6.14.3.4 Compliance with ARARs

Remedial action activities for this alternative would be designed to comply with all action-specific and location-specific ARARs. Permit equivalencies would be addressed. ARARs evaluated for this alternative are presented in **Appendix B** and include WAC 173-340-720 and 40 CFR 141.11-.16 for groundwater cleanup and WAC 173-340-740 for soil cleanup. However, because Alternative HC-3 would constitute an interim measure to contain contaminant migration in subsurface soil and groundwater, it is anticipated that pursuant to (CERCLA §121(d)(4)(A)), the interim measures ARARs waiver would be applied, Therefore, the overall rating on this criterion for Alternative HC -3 is "Yes, with waivers."

6.14.3.5 Long-Term Effectiveness and Permanence

This alternative provides long-term effectiveness and permanence by removing contaminant mass and reducing contaminant concentrations in the subsurface soil and groundwater over time. Reductions in plume concentration and size would be tracked by the long-term groundwater monitoring program. Additionally, thermal treatment would be effective at removing DNAPL at the Site, which would reduce or eliminate this residual source of contamination to the groundwater. Reducing the residual source strength also reduces contaminant mass flux to groundwater and the time for overall restoration of the aquifer. The presence of the silt and clay layer in the HRIA presents challenges to effectively capturing vapor generated during thermal treatment. Installation of permeable trenches with horizontal SVE wells would likely be necessary. The shallow groundwater table presents an additional challenge to vapor recovery as it is possible that the SVE wells in the trenches could flood with contaminated groundwater if water levels fluctuate at the site.

The potential for future exposure of contaminated groundwater to receptors would be minimized through implementation of ICs, such as well drilling and groundwater use restrictions in the plume area. This alternative also requires long-term groundwater monitoring and 5-year site reviews until chemical-specific ARARs are achieved or the alternative is incorporated into a site-wide final remedy. The overall rating on this criterion for Alternative HC-3 is high.

6.14.3.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Thermal treatment would reduce the toxicity, mobility, and volume of residual DNAPL mass, contaminated soil, and groundwater in the high concentration groundwater remediation zone through removal of contaminant mass and reductions in contaminant concentrations. Heated VOCs would be extracted with SVE wells and the volatilized contaminants treated via GAC system prior to discharge. The VOCs would be transferred to the carbon media, which would be regenerated, thereby destroying the VOC contaminants through thermal treatment processes. If vinyl chloride is observed at the site, then a catalytic oxidizer or chemical oxidant would be used in place of GAC since vinyl chloride does not effectively adsorb to carbon. Thermal treatment may temporarily increase VOC mobility if vapor extraction is not properly designed or implemented. Thermal treatment could also increase the toxicity in the short term by enhancing the chemical breakdown of PCE to TCE and vinyl chloride, which are more toxic compounds. Increasing the biodegradation rates in groundwater that is warmed outside of the remediation zone has been shown to be a secondary benefit of ERH; thus, biodegradation rates may increase in downgradient areas. The overall rating on this criterion for Alternative HC-3 is high.

6.14.3.7 Short-Term Effectiveness

It is estimated that construction of the thermal treatment system could be completed within 12 months of site mobilization and the heating phase would last approximately 10 months. The estimate may differ based on the collection of additional data (e.g., if more mass is identified). Thermal treatment is moderately effective in the short term as the full benefit of treatment would not be realized for approximately 6 months after beginning onsite action. Additionally, thermal treatment could increase toxicity in the short term by enhancing the biodegradation of PCE to TCE, producing more toxic daughter products, such as vinyl chloride.

The potential for short-term risks to the community would be mitigated through the implementation of site control and traffic control measures during construction and placement of the system and the system infrastructure. The system would be placed on unused public land away from current public use and would be surrounded by fencing. The risks to workers performing remedial and monitoring activities would be mitigated through the use of PPE, traffic control, air monitoring, limited access to the treatment system/power delivery stations, and standard health and safety practices. This alternative also requires long-term groundwater monitoring and 5-year site reviews until chemical-specific ARARs are achieved or the alternative is incorporated into a site-wide final remedy.

Thermal treatment is an aggressive remediation technology that has to be actively managed and maintained. However, treatment can generally be completed within 1 year, limiting the need for long-term operational maintenance. Fuel consumption and air emissions related to drilling operations can be reduced by retrofitting engines to accommodate diesel emission controls or replacing obsolete engines. Air emissions also could be reduced by employing BMPs, such as using cleaner fuels (e.g., ultra-low sulfur diesel or biodiesel) to power equipment and limiting onsite vehicle speeds. Impacts on land and ecosystems can be lessened by establishing minimally intrusive traffic patterns for onsite activities and limiting noise and artificial lighting that may disturb sensitive species. Material consumption and waste can be reduced by considering product life cycles during purchasing; giving preference to products, packing material, and disposable equipment with reuse or recycling potential; and considering products with recycled or bio-based content rather than petroleum-based contents. It may also be possible to reduce the energy footprint by minimizing the thermal treatment volume and using less energy intensive technologies (i.e., bioremediation) where practical.

The overall rating on this criterion for Alternative HC-3 is moderate to high.

6.14.3.8 Implementability

Thermal treatment is technically and administratively feasible; however, few vendors are able to provide this proprietary technology. Construction of the thermal treatment system could be completed using conventional construction equipment and services, with contractors that specialize in this innovative technology. Conditions at the site (density of the aquifer soils and drill locations beneath overhead power lines and beside Berwick Creek) may present challenges to the large-scale DPT drilling program required for installation of borings for electrodes, TMPs, and recovery wells. These difficulties can be overcome using a tracked drilling rig and by using more aggressive drilling techniques, such as air rotary or sonic drilling. For FS cost estimating purposes, use of a hollow stem auger rig is assumed. The necessary electric power and wires for running the treatment system are located near the site; however, a new transformer may need to be installed to supply the necessary power for soil heating.

The presence of the silt and clay layer at the site presents challenges to implementation from the standpoint of effective vapor capture. Installation of permeable trenches with horizontal SVE wells would likely be necessary. The shallow groundwater table presents an additional challenge to implementation and vapor recovery as it is possible that the SVE wells in the trenches could flood with contaminated groundwater if water levels fluctuate at the site.

A pilot test may be necessary in the source area prior to full-scale implementation. For cost purposes, this FS has assumed the in-situ thermal remediation technology will be ERH; however, if data are collected that suggest a different technology is more cost-effective (e.g., steam), then that technology would be used. Treatment of VOCs in the air discharge using GAC is a proven technology and is readily implementable. However, if vinyl chloride is observed at the site, then a catalytic oxidizer or chemical oxidant would be used in place of GAC since vinyl chloride does not effectively adsorb to carbon. A catalytic oxidizer or chemical oxidant would also be readily implementable and is a proven technology.

The regulatory and permitting requirements associated with installation of electrode and SVE wells, laying piping, constructing the treatment system, and securing approval for air emissions are considered to be moderately administratively intensive. Periodic groundwater monitoring would be easily implementable using readily available services and materials. The overall rating on this criterion for Alternative HC-3 is moderate.

6.14.3.9 Cost

The capital costs associated with Alternative HC-3 are estimated to be $7.7 million. The annual O&M cost is estimated to be $3.5 million. The 30-year present worth cost associated with this alternative is approximately $12.8 million. Detailed cost estimates for this alternative are included in **Appendix D**.

6.14.4 Alternative HC-4: In-Situ Chemical Oxidation and Institutional Controls with Monitoring

6.14.4.1 Remedial Alternative Component Descriptions and Sequencing

A description of the remedial components of Alternative HC-4 is provided in Section 5.3.2.4. The following is a summary of the remedial components of this alternative.

Alternative HC-4 uses chemical oxidants to destroy dissolved contaminants by converting them into innocuous compounds (carbon dioxide and water) coupled with ICs and long-term groundwater monitoring. For cost estimating purposes, it was assumed that permanganate ($KMnO_4$) would be used in the remediation target zone; however, a different oxidant or oxidants could be selected during the design phase based on the results of treatability testing. $KMnO_4$ would be injected via well clusters spaced approximately 25 feet apart throughout the remediation zone (based on the expected radius of influence). Approximately 79 injection locations consisting of three injection points would be installed to allow oxidant injection at three different 10-foot depth intervals. Several injection events likely would be required to meet the HRIA RAOs at the Site. The costing for this alternative assumes that three injection events would be required over a 12-month period, with approximately 2 months between events. Monitoring of VOC concentrations and other field parameters (i.e., pH, conductivity, oxidation reduction potential, turbidity, dissolved oxygen, manganese concentration) would be performed during and between injections. Monitoring also would be conducted to assess whether the remedial alternative exacerbates potential for vapor intrusion so appropriate mitigation procedures could be employed if vapor intrusions issues are found as a result of the remedial alternative.

6.14.4.2 Remedial Action Objectives

Alternative HC-4 could achieve the groundwater mass discharge PRG. Alternative HC-4 could also achieve the PRG for subsurface soil of removing PCE DNAPL and reducing PCE concentrations to below 10 mg/kg, but it would not occur as quickly as technically achievable. The time frame would be on the order of decades due to mass transfer limitations of DNAPLs. Chemical oxidation reactions can only occur once DNAPL is dissolved into the aqueous phase. Because of the low solubility of PCE DNAPL, dissolution is very slow, resulting in chemical treatment timeframes on the order of decades for significant PCE DNAPL removal. In addition, the fast reactivity of chemical oxidants results in the need for multiple injections to sustain reactions until the DNAPL mass is depleted to ensure that rebound does not occur.

By achieving the groundwater and (eventually) the subsurface soil RAOs, Alternative HC-4 would achieve the RAOs for the HRIA, i.e., preventing human and ecological exposure to high concentrations of PCE contamination, reducing DNAPL contaminant mass within the HRIA to reduce the overall source material in the HRIA and reducing contaminant mass discharge to downgradient groundwater.

6.14.4.3 Overall Protection of Human Health and the Environment

Alternative HC-4 would result in the chemical destruction of VOC contaminants in subsurface soil and groundwater, which would be protective of human health and the environment in the HRIA and reduce the potential for VOCs to migrate in the groundwater aquifer. The reduction in VOC mass discharge in groundwater would reduce the baseline risk to human health and the environment, eliminate exposure pathways, and reduce the potential for migration of contamination to local production wells. ICs would protect human health by restricting the use of and access to contaminated groundwater. Injection of certain chemical oxidants may produce unfavorable byproducts (e.g., MnO_2), which may present a risk to the underlying groundwater aquifer. Proper selection of a chemical oxidant will reduce the likelihood for formation of unfavorable byproducts. The overall rating on this criterion for Alternative HC-4 is “Yes.”

6.14.4.4 Compliance with ARARs

Remedial action activities for this alternative would be designed to comply with all action-specific and location-specific ARARs. Permit equivalencies would be addressed. ARARs evaluated for this alternative are presented in **Appendix B** and include WAC 173-340-720 and 40 CFR 141.11-.16 for groundwater cleanup and WAC 173-340-740 for soil cleanup. However, because Alternative HC-4 would constitute an interim measure to contain contaminant migration in subsurface soil and groundwater, it is anticipated that pursuant to (CERCLA §121(d)(4)(A)), the interim measures ARARs waiver would be applied, Therefore, the overall rating on this criterion for Alternative HC -4 is “Yes, with waivers.”

6.14.4.5 Long-Term Effectiveness and Permanence

This alternative provides long-term effectiveness and permanence by reducing contaminant concentrations in groundwater, and to a lesser extent in subsurface soil, over time. Reducing the concentration of contaminants in this remediation target zone will also allow groundwater remediation to be accomplished sooner. Chemical oxidation will result in immediate reduction of VOC concentrations in groundwater, thereby not requiring a long treatment time to achieve PRGs for high concentration groundwater. However, treatment of subsurface soil contamination and DNAPL treatment is much slower and would require long treatment timeframes (on the order of decades for DNAPL) in order to meet the subsurface soil PRGs and overall RAOs. One weakness of chemical oxidation is that inadequate distribution of chemical oxidants into the subsurface during direct injection may lead to areas where contamination is untreated. This is particularly true if zones containing DNAPL or high-level contamination are isolated from injection points by low-permeability soils. In this case, the remaining contamination will continue to contribute VOCs to the groundwater aquifer, and so oxidant must remain in the system to treat these released contaminants until these residual sources are depleted to prevent contaminant rebound in the treatment area.

In permeable zones that are hydraulically connected to wells, ISCO would not likely be an effective technology for DNAPL occurring in pools but could be applicable to DNAPL distributed as residuals. The key design factor is delivering sufficient oxidant to the source zone for a long enough period of time for dissolution and oxidation of DNAPL to occur. Potential options for improving the effectiveness of ISCO in treating DNAPLs are completing additional injections of oxidant; evaluating and using oxidant substrates that enhance dissolution, such as surfactants, and delivering oxidant near the DNAPL/water interface; and/or initiating combined depletion technologies (e.g., thermal plus ISCO).

The potential for future exposure of contaminated groundwater to receptors would be minimized through implementation of ICs, such as well drilling and groundwater use restrictions in the plume area. This alternative also requires long-term groundwater monitoring and 5-year site reviews until chemical specific ARARs are achieved or the alternative is incorporated into a site-wide final remedy. The overall rating on this criterion for Alternative HC-4 is low to moderate.

6.14.4.6 Reduction of Toxicity, Mobility, or Volume through Treatment

The use of chemical oxidants to destroy dissolved VOCs will provide a significant reduction in toxicity, mobility, and volume of contaminated groundwater. Subsurface soil contaminant toxicity also would be reduced but over a much longer time frame. The overall rating on this criterion for Alternative HC-4 is high.

6.14.4.7 Short-Term Effectiveness

DPT application of chemical oxidants does not involve significant surface disturbance; however, the density of the sand and gravel could present a challenge to a large scale DPT program, which may necessitate the use of a hollow stem auger rig for installation of injection points. For FS cost estimating purposes, use of a hollow stem auger rig is assumed. Also, due to the short lifespan of most chemical oxidants and the high levels of residual contamination within the proposed remediation target zones, multiple injections would be necessary to achieve RAOs and PRGs.

The equipment is mobile and easily moved between injection locations. The full benefit of ISCO treatment would not be realized immediately because multiple injection events may be required to address the contaminants present at the Site. The potential risks to the public posed by chemical oxidants would be reduced through standard health and safety practices. Formation of undesirable treatment residuals may result with some chemical oxidants. In addition, a chemical oxidant which achieves the remediation target zone PRGs for subsurface soil and high concentration groundwater without excessive heat release and risk to nearby structures and underground utilities would be the most suitable for this site. ISCO is expected to be completed within 1 year at 79 injection locations. However, as noted, multiple injection events over many years would be required to sustain contaminant reductions in groundwater and prevent rebound due to high levels of residual soil contamination. The risks to workers performing remedial and monitoring activities would be mitigated through the use of PPE, traffic control, and standard health and safety practices. Long-term groundwater monitoring would continue for 30 years, and 5-year reviews would be conducted at the site to determine if chemical-specific ARARs have been achieved or the alternative is incorporated into a site-wide final remedy. The overall rating on this criterion for Alternative HC-4 is moderate to high.

Efficiency in energy and natural resource consumption can be achieved through BMPs that optimize initial design of an in-situ chemical oxidation system. Fuel consumption and air emission related to drilling operations can be reduced by retrofitting engines to accommodate diesel emission controls or replacing obsolete engines. Air emissions also could be reduced by employing BMPs, such as using cleaner fuels (e.g., ultra-low sulfur diesel or biodiesel) to power equipment and limiting onsite vehicle speeds. Impacts on land and ecosystems can be lessened by establishing minimally intrusive traffic patterns for onsite activities and limiting noise that may disturb sensitive species. Material consumption and waste can be reduced by considering product life cycles during purchasing; giving preference to products, packing material, and disposable equipment with reuse or recycling potential; and considering products with recycled or bio-based content rather than petroleum-based contents.

6.14.4.7 Implementability

ISCO is technically and administratively feasible as chemical oxidation technology is well established and could be implemented at the HRIA. Multiple injection events would be required due to the inferred presence of DNAPL although the presence of significant silty zones within the shallow aquifer could significantly limit delivery of treatment fluids. Chemical oxidants would be delivered to the subsurface with standard, readily available DPT equipment. Application of chemical oxidants underneath buildings or roads may require similar equipment capable of directional boring. Application of chemical oxidants with DPT equipment is relatively straightforward. Approximately 79 injection locations would be required within this remediation target zone. Bench-scale tests would be required to determine the dose of chemical oxidant required to achieve contaminant destruction. A pilot scale test may also be necessary prior to full scale implementation. The density of the sand and gravel could present a challenge to a large scale DPT program, which may necessitate the use of a hollow stem auger rig for installation of injection points. For FS cost estimating purposes, use of a hollow stem auger rig is assumed. However, even with hollow stem auger, conditions within the remediation target zones (density of the aquifer and drill locations beneath overhead power lines and beside Berwick Creek) may still present challenges to the large-scale drilling program required for installation of injection points. These difficulties can be overcome using a tracked drilling rig and by using more aggressive drilling techniques, such as air rotary or sonic drilling. Periodic groundwater monitoring would be easily implementable using readily available services and materials. The overall rating on this criterion for Alternative HC-4 is moderate to high.

6.14.4.8 Cost

The capital costs associated with Alternative HC-4 are estimated to be $8.3 million. The annual O&M cost is estimated to be $209,000. The 30-year present worth cost associated with this alternative is approximately $9.5 million. Detailed cost estimates for this alternative are included in **Appendix D**.

6.14.5 Alternative HC-5: In-Situ Enhanced Bioremediation and Institutional Controls with Monitoring

6.14.5.1 Remedial Alternative Component Descriptions and Sequencing

A description of the remedial components of Alternative HC-5 is provided in Section 5.3.2.5. The following is a summary of the remedial components of this alternative.

Alternative HC-5, In-Situ Enhanced Anaerobic Bioremediation (EAB), uses injections of amendments to stimulate the anaerobic biotic and/or abiotic degradation processes coupled with ICs and long-term groundwater monitoring. Amendment types include injectable carbon, zero valent iron, or reduced iron minerals and/or abiotic reductants. For cost estimating purposes, it was assumed that EVO would be used at the site; however, a different amendment or amendments could be selected during the design phase based on the results of treatability and pilot testing. EVO would be injected via approximately 79 injection locations spaced approximately 25 feet apart throughout the remediation target zone (based on the expected radius of influence). In addition, each injection location would consist of three injection points installed to allow EVO injection at three different 10-foot depth intervals. In addition, it is assumed that bioaugmentation injections will occur approximately 3 months after the EVO injections. The costing for this alternative assumes that an additional full-scale injection event would take place approximately 18 months after the first injection. Monitoring of CVOCs, ethylene, ethane, methane, sulfate, iron, alkalinity, total organic carbon, and water quality parameters (DO, conductivity, temperature, oxidation reduction potential, and pH) would be performed for 30 years following injections. Quarterly sampling is assumed through a full year after completion of the second (i.e., final) injection event, with the frequency reduced to twice a year thereafter. Monitoring also would be conducted to assess whether the remedial alternative exacerbates potential for vapor intrusion so appropriate mitigation procedures could be employed if vapor intrusions issues are found as a result of the remedial alternative.

6.14.5.2 Remedial Action Objectives

Alternative HC-5 could achieve the groundwater reduction of mass discharge PRG. Alternative HC-5 would also achieve the PRG for subsurface soil (removal of PCE DNAPL) although, similar to ISCO, biodegradation reactions only degrade contaminants once they are dissolved in groundwater. Therefore, treatment of DNAPLs is often rate limited to the dissolution rate of contaminants into groundwater. However, enhanced mass transfer of residual DNAPL mass to groundwater has been documented, which indirectly accelerates removal rates by a factor of 4 to 16. Therefore, bioremediation does accelerate residual DNAPL treatment although the timeframes are generally on the order of several years to decades, depending on the initial residual DNAPL mass.

By achieving the groundwater and (eventually) the subsurface soil PRGs, Alternative HC-5 would also achieve the RAOs for the HRIA, i.e., preventing human and ecological exposure to high concentrations of PCE contamination, reducing DNAPL contaminant mass within the HRIA to reduce the overall longevity of the HRIA "residual source area," and reducing contaminant mass discharge to downgradient groundwater.

6.14.5.3 Overall Protection of Human Health and the Environment

Alternative HC-5 would result in the biodegradation via reductive dechlorination of VOCs in subsurface soil and groundwater, which would be protective of human health and the environment. This alternative is a safe treatment alternative that uses food-grade additives to enhance bioremediation; however, the delivery of a considerable amount of food-grade amendment into the groundwater can have transient negative impacts on water quality parameters due to generation of volatile fatty acids, methane, and in some instances, dissolution of metals. However, these effects are only observed during treatment, and water quality is anticipated to quickly recover post-treatment. In addition, the potential for biofouling will need to be addressed. Biological transformation of contamination in subsurface soil would reduce the potential for contaminants to migrate to the groundwater aquifer. ICs would protect human health by restricting the use of and access to contaminated groundwater. The overall rating on this criterion for Alternative HC-5 is "Yes."

6.14.5.4 Compliance with ARARs

Remedial action activities for this alternative would be designed to comply with all action-specific and location-specific ARARs. Permit equivalencies would be addressed. ARARs evaluated for this alternative are presented in **Appendix B** and include WAC 173-340-720 and 40 CFR 141.11-.16 for groundwater cleanup and WAC 173-340-740 for soil cleanup. However, because Alternative HC-5 would constitute an interim measure to contain contaminant migration in subsurface soil and groundwater, it is anticipated that pursuant to (CERCLA §121(d)(4)(A)), the interim measures ARARs waiver would be applied. Therefore, the overall rating on this criterion for Alternative HC -5 is "Yes, with waivers."

6.14.5.5 Long-Term Effectiveness and Permanence

This alternative provides long-term effectiveness and permanence by destroying chlorinated VOC contaminants via anaerobic reductive processes and reducing contaminant concentrations in the subsurface soil and groundwater over time. However, treatment of subsurface soil contamination and DNAPL is much slower and would require long treatment timeframes (on the order of decades for DNAPL). In permeable zones that are hydraulically connected to wells, EAB would not likely be an effective technology for DNAPL occurring in pools but could be applicable to DNAPL distributed as residuals and in low permeability zones (EPA 2003). The key design factor is delivering sufficient amendments to the source zone to encourage microbial growth as close as possible to the DNAPL. Potential options for improving the effectiveness of EAB in treating DNAPLs are completing additional injections of substrate, evaluating and using food substrates than can either partition into the DNAPL or enhance dissolution, enhancing microbial degradation near the DNAPL/water interface, and/or initiating combined depletion technologies (e.g., abiotic ZVI plus bioremediation amendments or thermal plus EAB) (EPA 2003).

The existence of relatively low permeability silt zones and clay seams would not reduce the effectiveness of in-situ EAB as much as for chemical oxidation since the dechlorination conditions and bacteria would stay in the subsurface for a longer timeframe. Establishing a high biomass with active dechlorinators can often self-sustain for several years, especially if long-lived amendments such as EVO are used. Therefore, any contaminants diffused out of the low permeable zones would also be treated. In addition, the concentration reductions of contaminants in the groundwater could increase the rates of mass transfer for contaminants out of the low permeability zones. It has been observed that rebound is far less prevalent at sites implementing in-situ EAB compared to chemical oxidation (McDade 2005, McGuire 2006).

Biodegradation of contaminants will ensure that contamination does not remain, and confirmation subsurface soil and groundwater sampling will verify that subsurface soil and groundwater PRGs and overall HRIA RAOs have been achieved. However, inadequate distribution of substrate injected into the subsurface may lead to areas where complete detoxification is not achieved. The potential for future exposure of contaminated groundwater to receptors would be minimized through implementation of ICs, such as well drilling and groundwater use restrictions in the HRIA plume area. Long-term groundwater monitoring would continue for 30 years, and 5-year reviews would be conducted at the site to determine chemical-specific ARARs have been achieved or the alternative is incorporated into a site-wide final remedy. The overall rating on this criterion for Alternative HC-5 is moderate to high.

6.14.5.6 Reduction of Toxicity, Mobility, or Volume through Treatment

In-situ EAB would reduce the toxicity and volume of contamination. Chlorinated VOCs would be transformed to non-toxic end products, such as ethylene. The intermediate product, vinyl chloride, is more toxic than PCE and TCE, but accumulation of vinyl chloride is unlikely because of its ability to degrade under aerobic conditions, which are prevalent downgradient and outside of the proposed remediation zone. In addition, use of abiotic amendments (e.g., ZVI) in addition to biotic ones, facilitates degradation through beta-elimination, which converts PCE and TCE directly to ethylene and ethane, with no intermediate formation. Intermediates, such as DCEs and vinyl chloride, would be closely monitored. The overall rating on this criterion for Alternative HC-5 is moderate to high.

6.14.5.7 Short-Term Effectiveness

Although a fairly significant amount of site work would be required for this alternative, this type of construction is routine. Installation of EAB amendment injection systems are relatively common, and the work would be performed without significant risk to the community. Site workers would wear appropriate PPE to minimize exposure to contamination and as protection from physical hazards. The risks to workers performing remedial and monitoring activities would also be mitigated through traffic control and standard health and safety practices.

This alternative would have short-term impacts to the community during construction due to the large number of injection wells that would be installed. Some traffic control would be required. There would be noise during drilling and nutrient injections. Injection requires a large amount of water that would need to be taken from a hydrant.

Initially, installation of injection wells and the amendment injection system would be completed in 6 months. One site-wide amendment injection would be performed at 79 wells within 3 months and again after approximately 18 months.

Long-term groundwater monitoring would continue for 30 years, and 5-year reviews would be conducted at the site to determine chemical-specific ARARs have been achieved or the alternative is incorporated into a site-wide final remedy. The overall rating on this criterion for Alternative HC-5 is moderate to high.

Efficiency in energy and natural resource consumption can be achieved through BMPs that optimize initial design of a bioremediation system. It may be possible to identify processes that accelerate in-situ degradation processes in certain areas without significantly increasing the project footprint. Fuel consumption and air emission related to drilling operations can be reduced by retrofitting engines to accommodate diesel emission controls or replacing obsolete engines. Air emissions also could be reduced by employing BMPs, such as using cleaner fuels (e.g., ultra-low sulfur diesel or biodiesel) to power equipment and limiting onsite vehicle speeds. Impacts on land and ecosystems can be lessened by establishing minimally intrusive traffic patterns for onsite activities and limiting noise that may disturb sensitive species. Material consumption and waste can be reduced by considering product life cycles during purchasing; giving preference to products, packing material, and disposable equipment with reuse or recycling potential; and considering products with recycled or bio-based content rather than petroleum-based contents. Finally, to improve efficiency, a determination of the need to implement supplemental technologies to destroy contaminants in hotspots or areas anticipated to involve lengthy periods of microbial acclimation can be made.

6.14.5.8 Implementability

In-situ EAB is technically and administratively feasible and would be constructed and implemented using conventional construction methods and equipment. The processes that govern degradation reactions are well understood, and technical feasibility of EAB has been established at numerous sites. In general, no significant technical difficulties are anticipated; however, treatability and/or pilot scale testing may be required prior to implementation. No difficulty in obtaining a permit for the injection of bioremediation amendments into groundwater is anticipated. Approximately 79 injection wells would be required within this remediation target zone. A hollow stem auger rig would be used for installation of injection wells; however, conditions at the site (density of the aquifer and drill locations beneath overhead power lines and beside Berwick Creek) may still present challenges to the large-scale drilling program required for installation of injection points. These difficulties can be overcome using a tracked drilling rig and by using more aggressive drilling techniques, such as air rotary or sonic drilling.

Services and materials for implementation of this alternative are readily available. Competitive bids can be obtained from a number of equipment vendors and remediation contractors. No problems are anticipated for the implementation and enforcement of the ICs. Periodic groundwater monitoring would be easily implementable using readily available services and materials. The overall rating on this criterion for Alternative HC-5 is moderate to high.

6.14.5.9 Cost

The capital costs associated with Alternative HC-5 are estimated to be $7.9 million. The annual O&M cost is estimated to be $176,000. The 30-year present worth cost associated with this alternative is approximately $9.1 million. Detailed cost estimates for this alternative are included in **Appendix D.**

6.15 State (Support Agency) Acceptance

State (support agency) acceptance is a modifying criterion under the NCP. EPA has requested comments from the state on the RI/FS and will request comments on the draft interim proposed plan prior to releasing it for public comment. Final assessment of state concerns will be completed after comments on the FS and the interim proposed plan have been received by EPA and are addressed in the interim ROD. Thus, the state acceptance criterion is not considered in the detailed evaluation of alternatives presented in this FS.

6.16 Community Acceptance

Community acceptance is also a modifying criterion under the NCP. Assessment of community acceptance will include responses to questions that any interested person in the community may have regarding any component of the remedial alternatives presented in the final FS report. This assessment will be completed after EPA receives public comments on the interim proposed plan during the public commenting period. Thus, community acceptance is not considered in the detailed analysis of alternatives presented in the FS.

6.17 Comparative Analysis of Alternatives

This FS evaluated the remedial alternatives discussed in this section against the two threshold criteria and five balancing criteria. The results of the detailed analysis for each remedial alterative are presented in **Exhibit 6-5** to allow a comparative analysis of the alternatives and identify the key tradeoffs between them.

Using the rankings presented in **Exhibit 6-6**, comparative analysis for the remedial alternatives using the threshold and balancing criteria has been put into narrative form in the following subsections.

6.17.1 Creek Bed Sediment/Bank Surface Soil Remediation Target Zone

The contaminated creek bed sediment/bank surface soil remediation target zone (>0.468 mg/kg PCE) is approximately 7,400 square feet and includes an estimated 1,400 cy of contaminated creek bed sediment/bank surface soil in an approximately 40-ft wide by 200-ft long stretch of Berwick Creek at the HRIA as shown in **Figure 3-1**. The alternatives for this remediation target zone are:

- Alternative SD-1 No Action
- Alternative SD-2 Removal, Offsite Treatment and Disposal, and Re-Routing of Stream
- Alternative SD-3a Removal, Ex-situ Chemical Oxidation, Onsite Disposal, and Re-Routing of Stream
- Alternative SD-3b Removal, Ex-situ Bioremediation, Onsite Disposal, and Re-Routing of Stream

6.17.1.1 Remedial Action Objectives

Alternative SD-1 No Action would not achieve the PRGs established for the creek bed sediment/ bank surface soil remediation target zone and would therefore not contribute to achievement of the HRIA RAOs. That is, human and ecological exposure would not be prevented and contaminant mass would not be reduced. Alternatives SD-2, SD-3a and SD-3b all would achieve the PRGs established for the creek bed sediment/bank surface soil remediation target zone by removing sediment and soil with PCE concentrations greater than 10 mg/kg and restoring the creek bed to PCE concentrations below 0.468 mg/kg. Alternatives SD-2, 3a, and 3b also contribute to achieving the RAOs for the HRIA of reducing contaminant mass discharge of VOCs from the HRIA "residual source area" to downgradient groundwater and reducing the longevity of the HRIA "residual source area" by removing sediment and surface soil with elevated concentrations of PCE."

6.17.1.2 Overall Protection of Human Health and the Environment

Alternative SD-1 would provide no protection against exposure to contaminated creek bed sediment/bank surface soil, including DNAPL, which is a principal threat waste, nor would it provide protection of groundwater or surface water from migration of contaminants contained in the creek bed sediment/bank surface soil. The potential for exposure to this material is high since it is near the surface, and data suggest the contamination continues to serve as a source of contamination to groundwater. Thus, this alternative was given a rating of none.

Alternative SD-2 would provide a high degree of protection. This alternative would be protective by removing the volume of contaminated creek bed sediment/bank surface soil that exceeds 0.468 mg/kg and treating and disposing of it offsite at a Subtitle C facility. The direct contact pathway would be removed, and the shallow contaminants would not be present to provide a source of contamination to surface water and groundwater.

Alternatives SD-3a and SD-3b would provide a high degree of protection by removing the DNAPL and high concentration contaminated creek bed sediment/bank surface soil to an estimated depth of 5-feet bgs. The direct contact pathway would be removed, and the shallow contaminants would no longer be present to provide a continuing source of contamination to surface water and groundwater.

6.17.1.3 Compliance with ARARs

The No Action Alternative (Alternative SD-1) would not comply with ARARs that require the removal or remediation of contaminants released to the environment, the protection of future human health and the environment, and restoration of contaminated aquifers, including the chemical-specific ARAR for freshwater sediment (WAC 173-204-570) or soil (WAC 173-340-740). The overall rating for this criterion for Alternatives SD-1 is "No."

By removing and disposing (SD-2) or removing and treating (SD-3a and b) creek bed sediments/bank surface soils with PCE concentrations above a conservative EPA RSL of 0.468 mg/kg PCE, it is anticipated that remaining PCE levels would be below the concentration level to be established per WAC 173-204-570 and also would achieve soil ARARs (WAC 173-340-740) established for the remediation target zone. Therefore, the overall rating for this criterion for Alternatives SD-2, 3a, and 3b is "Yes."

6.17.1.4 Long-Term Effectiveness and Permanence

Alternative SD-1 would not provide long-term effectiveness and permanence since no action is taken. Contaminants would persist and continue to migrate into the environment. No controls would be implemented to prevent future exposure. Thus, this alternative was given a rating of none.

Alternatives SD-2 and SD-3a would provide a high degree of long-term effectiveness and permanence by removing contaminated creek bed sediment/bank surface soil. Alternative SD-2 would dispose of contaminated material offsite while Alternative SD-3a would treat the contaminated material and dispose of it onsite. Little to no residual risk would remain in the area where the contaminated material was excavated. In addition, removal of contaminated creek bed sediment/bank surface soil would significantly reduce a continuing source of groundwater contamination.

Alternative SD-3b would provide a moderate to high degree of long-term effectiveness and permanence by removing contaminated creek bed sediment/bank surface soil, treating the material, and disposing of it onsite. Little to no residual risk would remain in the area where the contaminated material was excavated. In addition, removal of contaminated creek bed sediment/bank surface soil would eliminate a continuing source of groundwater contamination. This treatment process is expected to take longer to achieve PRGs established for the creek bed sediment/bank surface soil remediation target zone than Alternatives SD-2 and SD-3a would, and the attainment of PRGs is less certain due to the complexities involved with the treatment process.

6.17.1.5 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative SD-1 would fail to provide a reduction of toxicity, mobility, or volume through treatment since treatment is not a component of this alternative. Alternative SD-1 was given a rating of none.

Alternative SD-2 would provide a high reduction in toxicity, mobility, or volume through treatment. Excavated material would be treated at a Subtitle C facility prior to disposal in order to comply with

LDRs. Treatment at the Subtitle C facility would provide a reduction in toxicity. Additionally, removal of contaminated creek bed sediment/bank surface soil and offsite disposal would cause a reduction in mobility and volume.

Alternatives SD-3a and SD-3b would provide a high level of reduction in toxicity, mobility, or volume through treatment. Under Alternative SD-3a, contaminated creek bed sediment/bank surface soil would be removed and treated onsite via ex-situ treatment. Alternative SD-3a would result in destruction of contaminants through chemical oxidation. Under Alternative SD-3b, contaminated creek bed sediment/bank surface soil would be removed and treated onsite via ex-situ bioremediation. Alternative SD-3b would result in destruction of contaminants through biotransformation.

6.17.1.6 Short-Term Effectiveness

Alternative SD-1 would minimize greenhouse gas emissions, air pollutants, energy consumption, and water use since no action would be taken. This alternative was given a rating of high.

Alternatives SD-2 and SD-3a involve construction activities that would pose moderately high risks during the excavation due to volatilization of contaminants. The open excavation could also pose a physical risk. The volatilized contaminants could impact nearby residents and workers at adjacent properties. Controls, such as minimizing the exposed work area and working in cooler weather, and standard construction practices, such as dust suppression, would be used to minimize risk to workers and the community and would also serve to minimize air pollutants. Additional short-term issues include capturing vapors during excavation activities and noise levels, which would be mitigated through safety measures and engineering controls. For alternative SD-2, additional short-term impacts due to transportation and disposal of excavated material offsite would be mitigated through conventional traffic controls to minimize potential for accidents.

Energy efficient equipment could be used for these alternatives, minimizing the consumption of energy. Alternative, cleaner fuels could also be used to minimize greenhouse gas emissions. These alternatives were given a rating of moderate to high.

Alternative SD-3b would involve construction activities that would pose moderately high risks to workers performing the excavation due to volatilization of contaminants. The open excavation could also pose a physical risk. The volatilized contaminants could impact nearby residents and workers at adjacent properties. Controls, such as minimizing the exposed work area and working in cooler weather, and standard construction practices, such as dust suppression, would be used to minimize risk to workers and the community and would also serve to minimize air pollutants. Additional short-term issues include capturing vapors during excavation activities and noise levels, which would be mitigated through safety measures and engineering controls. The community would also be impacted by the water demand needed for implementation of this alternative. The potential for vinyl chloride generation prior to conversion to ethylene would be another issue posed by this treatment technology, representing an additional short-term risk. The treatment time for ex-situ bioremediation is expected to be longer than the treatment time for ex-situ chemical oxidation.

EPA introduced six core elements of green remediation for consideration, including energy, air emissions, water requirements, material consumption/waste generation, impact on land and ecosystems, and impacts on long-term stewardship of a site (EPA 2008b). These elements are interconnected, and their respective units of measure are varied and distinct, making development of an aggregate analysis and comparison of different remedies challenging and beyond the focus of this

FS. However, as Alternatives SD-2, SD-3a, and SD-3b all include excavation of sediment, applicable BMPs for excavation and surface restoration can be employed in their implementation, leading to similar potential for reducing the environmental and energy footprint of that component of the alternative. Alternative SD-2 does have the potential for increased fuel consumption and air emissions associated with the transport of excavated sediment offsite; however, those impacts could be mitigated somewhat by selecting the closest waste receiver possible and by identifying opportunities for resource sharing with other waste haulers. The onsite treatment component of Alternatives SD-3a and 3b potentially increases impact to the environment over that caused by Alternative SD-2; however, activities can be employed to mitigate the impact of the treatment processes. For example, establishing and maintaining specific areas for different activities, such as material mixing or sorting, would help avoid cross-contamination. Ground surfaces of work areas could be covered with mulch to minimize soil compaction by onsite equipment.

6.17.1.7 Implementability

Alternative SD-1 would take no actions other than 5-year site reviews, so this alternative would be the easiest to implement. Thus, this alternative was given a rating of high.

Alternative SD-2 would be technically and administratively implementable using readily available conventional construction equipment. Services to re-route the creek, remove contaminated creek bed sediment/bank surface soil, and transport it to an offsite disposal facility would be easily obtainable. Access agreements and coordination would be needed as the excavation area is located within the right-of-ways for Hamilton Road and I-5. In addition, control and temporary diversion of traffic flow on Hamilton Road, which is a major trucking route, and a portion of I-5 will be needed and will require significant planning and coordination with Washington DOT.

This alternative would require the use of clean, impermeable fill in the excavation area to reestablish the silt layer separating the creek bed from subsurface soil and groundwater. This fill is expected to be readily available in the general vicinity of the Site. The regulatory and permitting requirements associated with offsite transportation and disposal would not be considered to be administratively intense. One RCRA Subtitle C landfill is located within the general vicinity of the Site. This alternative was given a rating of high.

The excavation of material under Alternative SD-3a would be very similar to excavation under Alternative SD-2. Services to re-route the creek and remove contaminated creek bed sediment/bank surface soil would be easily obtainable. Access agreements and coordination would be needed as the excavation area is located within the right-of-ways for Hamilton Road and I-5. In addition, control and temporary diversion of traffic flow on Hamilton Road, which is a major trucking route, and a portion of I-5 will be needed and will require significant planning and coordination with Washington DOT.

This alternative would require the use of clean, impermeable fill in the excavation area to reestablish the silt layer separating the creek bed from subsurface soil and groundwater, which is expected to be readily available in the general vicinity of the site.

The treatment of sediment s under Alternative SD-3a would be more difficult than under Alternative SD-2. The difficulties to the technical feasibility of this alternative would lie in finding adequate space for the treatment and staging area necessary for treatment of the excavated material. Additionally, testing, such as bench-scale and treatability tests, would be necessary for Alternative SD-3a prior to implementation of the alternative. Additional implementability issues would arise from the creation of a slurry during the treatment process, which creates material handling issues and a need for dewatering of the material prior to onsite disposal. Water generated during dewatering and vapor generated during excavation and treatment would require treatment prior to discharge. This alternative was given a rating of moderate.

Although the excavation of sediment under Alternative 3b is similar to Alternatives SD-2 and 3a, the treatment of creek bed sediment/bank surface soil under Alternative 3b would be the most difficult to implement. The soil would need to be kept fully saturated for bioremediation to occur, and there are many more factors involved in keeping the treatment process operating as compared to the other alternatives. Bioaugmentation may be necessary to achieve an adequate colony of active microorganisms. Lower permeability soils create difficulties in evenly distributing moisture, air, and nutrients. The treatment time for ex-situ bioremediation is also expected to be longer than Alternative SD-3a. Services to re-route the creek and remove contaminated creek bed sediment/bank surface soil would be easily obtainable. Access agreements and coordination would be needed as the excavation area is located within the right-of-ways for Hamilton Road and I-5. In addition, control and temporary diversion of traffic flow on Hamilton Road, which is a major trucking route, and a portion of I-5 will be needed and will require significant planning and coordination with Washington DOT.

This alternative would require the use of clean, impermeable fill in the excavation area to reestablish the silt layer separating the creek bed from subsurface soil and groundwater. This material is expected to be readily available in the general vicinity of the site. The difficulties to the technical feasibility of this alternative would lie in finding adequate space for the treatment and staging area necessary for treatment of the excavated material. Additionally, testing, such as bench-scale and treatability tests, would be necessary prior to implementation. Additional implementability issues would arise from the creation of a slurry during the treatment process, which creates material handling issues and a need for dewatering of the material prior to onsite disposal. Water generated during dewatering and vapor generated during excavation and treatment would require treatment prior to discharge. This alternative was given a rating of low.

6.17.1.8 Cost

Present worth costs for all alternatives were evaluated over a 1-year period. Alternative SD-1, the No Action Alternative, has no costs associated with it since no remedial activities would be performed.

The capital costs associated with Alternative SD-2 are estimated to be $3.01 million. The annual O&M cost for this alternative is estimated to be $34,000. The 30-year present worth cost associated with this alternative is approximately $3.04 million.

The capital costs associated with Alternative SD-3a are estimated to be $3.1 million. The annual O&M cost is estimated to be $54,000. The 30-year present worth cost associated with this alternative is approximately $3.2 million

The capital costs associated with Alternative SD-3b are estimated to be $3.1 million. The annual O&M cost is estimated to be 54,000. The 30-year present worth cost associated with this alternative is approximately $3.2 million

Detailed cost estimates are included in **Appendix D**.

6.17.2 Subsurface Soil and High Concentration Groundwater Remediation Target Zones

The alternatives that were developed to address the subsurface soil and high concentration remediation target zones are:

- Alternative HC-1 No Action
- Alternative HC-2 Hydraulic Containment and ICs with Monitoring
- Alternative HC-3 In-Situ Thermal Treatment and ICs with Monitoring
- Alternative HC-4 In-Situ Chemical Oxidation and ICs with Monitoring
- Alternative HC-5 Enhanced In-Situ Bioremediation and ICs with Monitoring

6.17.2.1 Remedial Action Objectives

A comparison of whether the remediation alternatives would achieve the PRGs developed for the subsurface soil and high concentration groundwater remediation target zones is included in **Exhibit 6-6** and summarized below.

Alternative HC-1 No Action would not achieve the PRGs established for the subsurface soil and high concentration groundwater remediation target zones. That is, PCE DNAPL mass in subsurface soil would not be reduced nor would there be a reduction of mass discharge of VOC contamination by 90% from the high concentration groundwater to the dissolved phase plume as quickly as technically achievable. In addition, Alternative HC-1 would not contribute to achieving the RAOs for the HRIA; i.e., it would not prevent human or ecological exposure pathways to high concentrations of PCE contamination nor would it achieve the reduction of mass discharge (the measure of contaminant migration) of VOCs from the HRIA to downgradient groundwater.

Alternative HC-2 could achieve the groundwater reduction of mass discharge PRG, and ICs would help contribute to the RAOs for the HRIA of mitigating direct exposure pathways to high concentrations of PCE contamination. However, Alternative HC-2 would not likely achieve the PRG for subsurface soil; i.e., the removal of PCE DNAPL as quickly as technically achievable, thus, leaving a continuing source of contamination in place.

Alternative HC-3 could achieve the groundwater PRG (reduction of mass discharge)and the PRG for subsurface soil (remove PCE DNAPL as quickly as technically achievable) and reduce source material by reducing subsurface soil PCE concentrations to below 10 mg/kg. It would, therefore, also achieve the RAOs for the HRIA, i.e., mitigating any direct exposure pathways to high concentrations of PCE contamination, reducing DNAPL contaminant mass within the HRIA to reduce HRIA source material, and reducing contaminant mass discharge (the measure of contaminant migration) of VOCs from the HRIA to downgradient groundwater.

Alternative HC-4 could achieve the groundwater mass discharge PRG. Alternative HC-4 could also achieve the PRG for subsurface soil by removing PCE DNAPL and reducing PCE concentrations to below 10 mg/kg, but it would not occur as quickly as technically achievable. Chemical oxidation reactions can only occur once DNAPL is dissolved into the aqueous phase. Because of the low solubility of PCE DNAPL, dissolution is very slow, resulting in chemical treatment timeframes on the order of decades for significant PCE DNAPL removal. In addition, the fast reactivity of chemical oxidants result in the need for multiple injections to sustain reactions until the DNAPL mass is depleted to ensure that rebound does not occur.

By achieving the groundwater and (eventually) the subsurface soil RAOs, Alternative HC-4 would achieve the RAOs for the HRIA, i.e., preventing human and ecological exposure to high concentrations of PCE contamination, reducing DNAPL contaminant mass within the HRIA to reduce the overall source material in the HRIA, and reducing contaminant mass discharge to downgradient groundwater.

Alternative HC-5 could achieve the groundwater reduction of mass discharge PRG. Alternative HC-5 would also achieve the PRG for subsurface soil (removal of PCE DNAPL), but it would not occur as quickly as technically achievable. Similar to ISCO, biodegradation only occurs once DNAPL is dissolved in groundwater and so the timeframe would generally be on the order of several years to decades depending on the initial residual DNAPL mass. However, the EAB amendments are longer lived compared to oxidants, and the effects can last several years, as opposed to months, resulting in fewer injections required to sustain biodegradation reactions.

By achieving the groundwater and (eventually) the subsurface soil PRGs, Alternative HC-5 would also achieve the RAOs for the HRIA, i.e., preventing human and ecological exposure to high concentrations of PCE contamination, reducing DNAPL contaminant mass within the HRIA to reduce the overall longevity of the HRIA "residual source area," and reducing contaminant mass discharge to downgradient groundwater.

6.17.2.2 Overall Protection of Human Health and the Environment

Alternative HC-1 would provide no protection against exposure to contaminated groundwater/subsurface soil nor would it provide protection of groundwater from migration of contaminants contained in the subsurface soil. Thus, this alternative was given a rating of "No."

Alternative HC-2 would provide a low to moderate degree of protection. This alternative would be protective by reducing the concentration of dissolved VOCs in groundwater and using a hydraulic barrier through groundwater extraction to contain the source area; however, it would not likely achieve the removal of PCE DNAPL as quickly as technically achievable, thus, leaving a continuing source of contamination in place and therefore was given a rating of "No."

Alternative HC-3 would provide a high degree of protection by reducing the mass of VOC contamination in subsurface soil and groundwater. This reduction in mass would remove DNAPL and significantly reduce soil concentration in the residual source area, achieving both a reduction in contaminant mass discharge to the downgradient contaminant plumes and reduce the source longevity and was therefore given a rating of "Yes."

Alternative HC-4 would provide a moderate to high degree of protection. It would be protective of human health and the environment by reducing contaminant mass discharge through the chemical destruction of VOCs in groundwater. This reduction in mass discharge would reduce the loading to the downgradient contaminant plumes and potentially allow a more rapid remediation of downgradient groundwater. However, multiple injections of oxidants would be required to sustain this reduction in mass discharge since residual DNAPL is present. Chemical oxidants only treat contaminants once dissolved in groundwater, and so treatment of residual DNAPL is determined by the dissolution rate of DNAPL into groundwater. Although ISCO accelerates this dissolution rate, it is still relatively slow and would require relatively long treatment times to significantly reduce residual DNAPL mass in soil. Alternative HC-4 was given a rating of "Yes."

Alternative HC-5 would provide a moderate to high degree of protection and was also given a rating of "Yes" for this criterion. EAB will reduce the contaminant concentrations in the high concentration remediation target zone, resulting in a reduction in the overall mass discharge to the downgradient contaminant plume. In addition, the prevalence of rebound within source zones treated with EAB is much lower than observed for sites treated with ISCO (HC-4 alternative). However, similar to HC-4, biodegradation reactions only occur once contaminants are dissolved in groundwater and, therefore, the treatment timeframe required for treatment of residual DNAPL under HC-5 is much longer compared to HC-3. The amendment used for the biodegradation will be food grade so impact to drinking water wells and the environment are not a concern if the potential for negative secondary water quality impacts and biofouling is mitigated in the design of the remedy.

6.17.2.3 Compliance with ARARs

The No Action Alternative (Alternative HC-1) would not comply with ARARs that require the removal or remediation of contaminants released to the environment, the protection of future human health and the environment, and restoration of contaminated aquifers, including the chemical-specific ARARs for groundwater (40 CFR 141-11-.16 [MCLs] and WAC 173-340-720) and the chemical-specific ARAR for soils (WAC 173–340-740). The overall rating on this criterion for Alternative HC -1 is "No."

Because Alternative HC-2 would constitute an interim measure to contain contaminant migration in subsurface soil and groundwater, it is anticipated that pursuant to (CERCLA §121(d)(4)(A)), the interim measures ARARs waiver would be applied, and groundwater ARARs would be addressed in the final remedy for the HRIA. However, Alternative HC-2 would not likely comply with the ARAR for soil cleanup. Therefore, the overall rating on this criterion for Alternative HC -2 is "No."

Implementation of Alternative HC-3 through HC-5 could achieve the chemical-specific ARARs for subsurface soil and groundwater although the timeframes would be different. Like Alternative HC-2, it is anticipated that pursuant to (CERCLA §121(d)(4)(A)), the interim measures ARARs waiver would be applied to Alternatives HC-3, -4 and -5, and groundwater ARARs would be addressed in the final remedy for the HRIA. Therefore, the overall rating on this criterion for Alternatives HC-3, -4, and -5 is "Yes, with waivers".

6.17.2.4 Long-Term Effectiveness and Permanence

Alternative HC-1 would not provide long-term effectiveness and permanence since no action would be taken. Contaminants would persist and continue to migrate into the environment. No controls would be implemented to prevent future exposure. Thus, this alternative was given a rating of none.

Alternative HC-2 would provide a low to moderate degree of long-term effectiveness and permanence by removing and treating contaminated groundwater. In addition, the creation of a hydraulic barrier around this remediation target zone would reduce contaminant mass discharge from the HRIA source area to downgradient areas. However, neither VOCs sorbed onto subsurface soils nor residual DNAPL would be effectively treated under this alternative, thus, leaving in place a continuing source of contamination to the groundwater. Mass removal under this alternative would be minimal. This alternative would likely take longer than 30 years to achieve the HRIA RAOs. This alternative was given a rating of low.

Alternative HC-3 would provide a high degree of long-term effectiveness and permanence by removing DNAPL and substantially reducing subsurface soil and groundwater contaminant concentrations in the source area, resulting in a reduction in contaminant mass discharge to downgradient groundwater. Difficulty in effectively capturing vapors generated during thermal treatment will be encountered due to the silt and clay layer and the shallow groundwater table at the Site. This alternative was given a rating of high.

Alternative HC-4 would provide a moderate level of long-term effectiveness and permanence by destroying contaminant mass in groundwater and eventually reducing concentration in subsurface soil over time. Since the oxidant would break down within a few months of the injection event, multiple injection events over long treatment timeframes (several years to decades) would likely be required to effectively treat sorbed and residual DNAPL in soils. Inadequate distribution of chemical oxidants in the subsurface could lead to untreated areas of soil contamination that could continue to contribute VOCs to the groundwater. Thus, this alternative was given a rating of moderate.

Alternative HC-5 would provide a high degree of long-term effectiveness and permanence. This alternative would be designed to aggressively reduce VOC concentrations in groundwater within the subsurface soil and high concentration groundwater remediation target zones using the enhanced anaerobic biotic and/or abiotic degradation processes. In addition, byproducts generated during anaerobic fermentation, such as methane, can enhance aerobic natural attenuation processes, such as aerobic cometabolism, in the downgradient dissolved plume. Once a robust microbial community is established, enhanced degradation processes will remain effective over the long term through ongoing in-situ degradation of VOCs by natural and/or augmented bacteria, resulting in a lower prevalence of rebound compared to HC-4. However, several injections of amendments may be required to establish the desired reactions. Similar to HC-4, HC-5 would also address DNAPL in the subsurface soil remediation target zone; however, it would require relatively long treatment timeframes (years to decades) to effectively treat residual DNAPL in soil.

6.17.2.5 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative HC-1 would not provide a reduction of toxicity, mobility, or volume through treatment since treatment would not be a component of this alternative. This alternative was given a rating of none.

Alternative HC-2 would provide a moderate reduction of toxicity, mobility, or volume through treatment. HC-2 does not directly destroy contaminants but instead relies on physical removal processes requiring above ground treatment and disposal of contaminants. Contaminated groundwater would be extracted and treated, which would reduce the toxicity, mobility, and volume of groundwater contamination; however, contamination in subsurface soil would not be addressed. Therefore, there would be no reduction in toxicity, mobility, or volume in the subsurface soil (including DNAPL). Mass removal under this alternative would be minimal. This alternative was given a rating of low.

Alternatives HC-3, HC-4, and HC-5 would provide a high level of reduction in toxicity, mobility, or volume through in-situ treatment of subsurface soils and groundwater. All alternatives would reduce the residual and sorbed contaminant mass in subsurface soils, which would result in a reduction of hazardous substance volume. The timeframes for achieving reductions will vary, with HC-3 providing the fastest removal rates. However, HC-3 does not directly destroy contaminants but instead relies on physical removal processes requiring above ground treatment and disposal of contaminants. HC-4 and HC-5, however, directly degrade contaminants to innocuous byproducts in-situ. All three alternatives are highly effective at reducing contaminant mass discharge from the source area, resulting in a substantial reduction in contaminant mobility. However, HC-4 and HC-5 are much slower at treating residual DNAPL mass in soil compared to HC-3. Toxicity would be decreased by lowering VOC concentrations in the soil and groundwater. All alternatives were given a rating of high.

6.17.2.6 Short-Term Effectiveness

Alternative HC-1 would minimize greenhouse gas emissions, air pollutants, energy consumption, and water use since no action will be taken. No construction activities would be performed under this alternative, so no risks to remediation workers or the community would occur; however, contamination is not addressed. Thus, this alternative was given a rating of moderate.

Alternatives HC-2, HC-3, and HC-4 would provide a moderate to high level of short-term effectiveness. Potential for short-term risks to the community and to site workers would be mitigated through site control and traffic control measures. In addition, air monitoring would be required to reduce risks to workers and the community from fugitive emissions during construction. Remediation workers would not be subject to significant risks associated with direct contact with contaminated materials, and potential risks would be mitigated through the use of PPE and standard health and safety practices. Some contact may be made with the contaminants while installing wells and piping; however, if one of these alternatives is implemented after the creek bed sediment/bank surface soil has been removed (Alternatives SD-2 and SD-3), then the risk would be reduced. For Alternative HC-3, it is estimated that construction and completion of the heating process would occur 12 to 18 months after site mobilization. Under Alternative HC-4, ISCO is estimated to be completed after 12 months although injections would need to continue for years to decades.

Alternative HC-5 would provide a moderate to high level of short-term effectiveness. The installation of this alternative can be completed within 6 months of site mobilization. Amendment injection is anticipated to occur in two rounds, so the same risks (vapors at wells, onsite physical hazards, and traffic) will be incurred twice. (Alternative HC-4, with multiple injections, would have a similar impact.) Potential for short-term risks to the community and to site workers would be mitigated through site control and traffic control measures. In addition, air monitoring would be required to reduce risks to workers and the community from fugitive emissions during construction. Remediation workers would not be subject to significant risks associated with direct contact with contaminated materials, and potential risks would be mitigated through the use of PPE and standard health and safety practices. It is estimated that active bioremediation would take place for 3 years and then the site would switch over to monitored natural attenuation for the remainder of the evaluation period. However, it is likely that without augmentation to address residual DNAPL, the treatment time would be years to decades.

Alternatives HC-2 and HC-3 will require significantly larger amounts of energy than Alternatives HC-4 and HC-5. In addition, a qualitative and quantitative review of four remediation technologies for a site in Portland Oregon where groundwater is contaminated with TCE indicated that thermal treatment and pump and treat technologies would leave carbon footprints that were orders of magnitude larger than those left by the other technologies, more passive technologies that were examined (combined biotic/abiotic treatment using EHC™ and EAB using injection of EVO) (Adventus 2008). Carbon foot prints of less than 1 metric ton of carbon dioxide equivalents (CO_2e) were estimated for the two bioremediation based technologies versus CO_2e estimates of over 7,000 and 8,000 metric tons, respectively, for thermal treatment and pump and treat. Energy efficient equipment could be used for these alternatives to minimize energy consumption, and alternative fuels could be used to minimize greenhouse gas emissions. In addition, renewable energy sources, such as solar panels, could be used for Alternatives HC-2 and HC-3 to help power the treatment or auxiliary systems. Groundwater that has been extracted and treated under Alternative HC-2 could be re-injected into the aquifer rather than discharged to surface water in order to recharge the aquifer at the Site. Targeted re-injection would enhance the hydraulic barrier at the Site or serve to narrow the groundwater plume. In addition, combining technologies to treat the different remediation target zones could also reduce the carbon foot print. An example is to apply a multi-component strategy to only apply very aggressive, energy intensive technology (i.e., thermal) to address DNAPL and subsurface soil contamination coupled to a more green technology (e.g., EAB) to address the high concentration groundwater remediation target zone.

These alternatives were given a rating of moderate to high.

6.17.2.7 Implementability

Alternative HC-1 has no action taken other than 5-year site reviews, so this alternative would be the easiest to implement. Thus, this alternative was given a rating of high.

Alternative HC-2 would be technically and administratively implementable using readily available conventional construction equipment. Pump and treat technology is well established and would be readily implementable in the HRIA. Additional wells, well vaults, and underground piping and electrical lines could be installed using standard drilling and construction equipment. The overall rating for this alternative is moderate to high.

Alternative HC-3 would be technically and administratively implementable; however, very few vendors are able to provide this proprietary technology. This alternative is innovative, but experienced contractors are available to implement the action. Implementation of an effective vapor recovery system would be difficult due to the silt and clay layer and the shallow groundwater table at the Site. Given the shallow/absent vadose zone, soil vapor extraction systems will likely be more expensive due to the need for technologies, such as horizontal recovery or multi-phase extraction and treatment. Permits would need to be obtained for air emissions and the installation of wells, piping, and related remediation system equipment. Construction of the treatment system would be accomplished using conventional construction equipment and services, with contractors that specialize in this innovative technology. Heat retention and transport within and downgradient of the target treatment volume are uncertain. Impacts on heat transfer to Berwick Creek should be considered and evaluated to minimize any undesirable impacts. A pilot test may be necessary prior to full-scale implementation. This alternative was given a rating of moderate.

Alternative HC-4 would be technically and administratively implementable. ISCO technology is well established and can be implemented at the site. Chemical oxidants would be delivered to the subsurface using readily available, conventional construction equipment. Bench-scale tests would be required to determine the dose of chemical oxidant required at the Site. A pilot-scale test may also be necessary prior to full-scale implementation. This alternative was given a rating of moderate to high.

Alternative HC-5 would be technically and administratively implementable. The in-situ EAB technology is relatively standard, and several contractors are available that have experience with their installations. Treatment of VOCs in groundwater with in-situ EAB is a proven technology. However, to facilitate the proper application of the technology, the installation may need to proceed in phases. During the first phase only one line of wells would be used for amendment addition. The results of the first phase would be used to help guide subsequent phases.

For Alternatives HC-4 and HC-5, the fact that the HRIA aquifer is semi-confined to confined will significantly impact the amendment injection design, including feasible injection rates and injection well spacing. Generally, pressurized injections would be required; these must be carefully designed to prevent exceeding the overburden pressure and causing fracturing of the aquifer. This is particularly important because fracturing could compromise the confining unit between the Berwick Creek bed and groundwater, resulting in increased hydraulic communication between the two. This could cause undesirable migration of contamination and/or amendments between the two remediation target zones.

6.17.2.8 Cost

Alternative HC-1, the No Action Alternative, has no costs associated with it since no remedial activities would be performed. Present worth costs for Alternative HC-2 assumes a 30-year treatment and monitoring period. Alternatives HC-3 though HC-5 include treatment that would be completed within 3 years and monitoring for a 30-year period.

The capital costs associated with Alternative HC-2 are estimated to be $1.3 million. The annual O&M cost is estimated to be $411,000. The 30-year present worth cost associated with this alternative is approximately $5.4 million.

The capital costs associated with Alternative HC-3 are estimated to be $7.7 million. The annual O&M cost is estimated to be $3.5 million. The 30-year present worth cost associated with this alternative is approximately $12.8 million.

The capital costs associated with Alternative HC-4 are estimated to be $8.3 million. The annual O&M cost is estimated to be $209,000. The 30-year present worth cost associated with this alternative is approximately $9.5 million

The capital costs associated with Alternative HC-5 are estimated to be $7.9 million. The annual O&M cost is estimated to be $176,000. The 30-year present worth cost associated with this alternative is approximately $9.1 million.

Detailed cost estimates are included in **Appendix D**.

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Exhibit 6-6: Summary of Comparative Analysis of Alternatives

			Threshold Criteria		Balancing Criteria					
								Implementability		
Remedial Alternative	Description	Creek Bed Sediment/ Surface Soil PRGs Achieved?	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-Term Effectiveness	Technical/ Engineering Considerations	Estimated Time for Implementation (years)	Present Worth Cost (Dollars)
Creek Bed Sediment/Bank Surface Soil Remediation Target Zone										
SD-1	No Action	No	No	No	⓿	⓿	❺	❺	<1	$0
SD-2	Removal, Offsite Treatment and Disposal, and Re-routing of Stream	Yes	Yes	Yes	❺	❺	❹	❺	1	$3.04 million
SD-3a	Removal, Ex-situ Chemical Oxidation, Onsite Disposal, and Re-routing of Stream	Yes	Yes	Yes	❺	❺	❹	❸	1	$3.2 million
SD-3b	Removal, Ex-situ Bioremediation, Onsite Disposal, and Re-routing of Stream	Yes	Yes	Yes	❹	❺	❸	❶	1-2	$3.2 million

Exhibit 6-6: Summary of Comparative Analysis of Alternatives (cont.)

		Remedial Action Objectives		Threshold Criteria		Balancing Criteria					
									Implementability		
Remedial Alternative	Description	Subsurface Soil PRG Achieved?	High Concentration Groundwater PRG Achieved?	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-Term Effectiveness	Engineering/ Technical Considerations	Estimated Time for Implemen-tation (years)	Present Worth Cost (Dollars)
High Concentration Groundwater and Subsurface Soil Remediation Target Zones											
HC-1	No Action	No	No	No	No	⓿	⓿	❸	❺	<1	$0
HC-2	Hydraulic Containment and Institutional Controls with Monitoring	No	Yes	No	No	❶	❶	❹	❹	30	$5.4 million
HC-3	In-Situ Thermal Treatment and Institutional Controls with Monitoring	Yes	Yes	Yes	Yes, with waiver	❺	❺	❹	❸	1	$12.8 million
HC-4	In-Situ Chemical Oxidation and Institutional Controls with Monitoring	Yes, but long treatment timeframe	Yes	Yes	Yes, with waiver	❸	❺	❹	❹	10	$9.5 million
HC-5	In-Situ Enhanced Bioremediation and Institutional Controls with Monitoring	Yes, but long treatment timeframe	Yes	Yes	Yes, with waiver	❹	❺	❹	❹	10	$9.1 million

Threshold and Balancing Criteria

⓿	None	❸	Moderate
❶	Low	❹	Moderate to High
❷	Low to Moderate	❺	High

6.18 Alternatives Retained for Development of Comprehensive Technology Scenarios

The detailed and comparative analyses of the individual technology-specific remedial alternatives indicate that while the different technology-specific remediation alternatives can address the HRIA contamination, their effectiveness in doing so as stand-alone technologies is highly variable. For example, while Alternative HC-2 (Hydraulic Containment) could achieve the PRG established for the high concentration groundwater remediation target zone, it would not achieve the PRG established for the subsurface soil remediation target zone. In addition, while Alternatives HC-3 (Thermal), HC-4 (Chemical Oxidation), and HC-5 (Enhanced Bioremediation) all could achieve the PRG for the subsurface soil zone, Alternatives HC-4 and HC-5 would require substantially longer durations than would Alternative HC-3 to reach this PRG. Conversely, while Alternatives HC-3, -4 and -5 all would achieve the groundwater PRG in approximately the same duration, Alternatives HC-4 and -5 could accomplish it at a lower cost.

In order to most effectively address source strength reduction, the technology-specific alternatives and/or components of the alternatives evaluated in Section 6, with the exception of Alternative HC-2 [7] will be combined into comprehensive technology scenarios (CTS) in Section 7 to effectively target the various impacted media. The CTS alternatives will first be evaluated on their compliance with the RAOs stated in Section 3 and then will be evaluated against seven of EPA's nine evaluation criteria: overall protection of human health and the environment; compliance with ARARs;, long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. The remaining two EPA evaluation criteria, support agency and community acceptance, will be addressed in future cleanup decision documents.

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[7] Alternative HC-2 is not considered for inclusion in a comprehensive technology scenario because it would not achieve the subsurface soil PRG.

Section 7

Development and Analysis of Comprehensive Technology Scenario Alternatives

The detailed analysis of the individual technology-specific remedial alternatives presented in Section 6 indicates that employing an individual technology across all remediation zones would not effectively meet all the RAOs established for the HRIA and/or there are more efficient approaches to achieve the RAOs and PRGs. While the different technology-specific remediation alternatives can address contaminated media, their effectiveness in doing so is highly variable. In order to effectively address source strength reduction, a combination of technologies is required to effectively target the various impacted media (i.e., sorbed DNAPL vs. high concentration groundwater) and achieve RAOs and PRGs.

To target the various impacted media, the individual remedial technology alternatives evaluated in Section 6.17 have been developed into a limited number of CTSs to incorporate best engineering practices for site-specific consideration. That is, the combinations of individual alternatives were developed with the intent to achieve the PRGs for each of the remediation target zones and the overall RAOs for the HRIA in a cost-effective and sustainable way. Employing a combination of technologies allows for a multi-component approach that couples aggressive mass removal in the creek bed sediment/bank surface soil and subsurface soil remediation target zones with more green and sustainable treatment in the high concentration groundwater remediation target zone. In addition, synergies between the technologies can be maximized such that the beneficial impacts of aggressive treatment (e.g., in-situ thermal remediation [ISTR] treatment) can be taken advantage of to augment or enhance treatment effectiveness of the less aggressive technologies (e.g., EAB). The CTSs developed to address contamination across the impacted sediment, soils, and groundwater media in the HRIA are described below.

7.1 Description of CTS Alternatives

7.1.1 Common Elements Across CTS Alternatives

With the exception of CTS-1 (No Action), several common elements are included within each of the CTS alternatives. The common elements include the following:

7.1.1.1 Re-route Berwick Creek

Berwick Creek would be diverted around the areas of contamination prior to starting remedial actions in the HRIA. This diversion may be temporary or permanent.

A temporary diversion would consist of routing the creek through a 48-inch diameter HDPE pipe around the remediation target zones and back into Berwick Creek downstream of these zones. Upon completion of the remedial action, the original creek channel would be reconstructed and habitat restored and the temporary diversion removed. A permanent diversion of the creek would involve creation of a new creek channel and habitat prior to remedial actions in the HRIA. Habitat considerations include the planting of native vegetation and installation of fish habitat, such as spawning gravel.

Whether reconstructing the current creek channel after remedial actions are completed or constructing a new creek channel prior to initiating remedial actions, requirements that are protective of aquatic receptors would need to be met, e.g., 0.468 mg/kg PCE based on EPA's RSLs for protection of benthic and freshwater organisms living in Berwick Creek sediments. The design specifications for the creek diversion, creek channel construction, and habitat restoration would be completed in consultation with the appropriate natural resource agencies. Diversion of Berwick Creek would be conducted during a seasonally dry period within Washington state's in-stream work window.[8]

7.1.1.2 Pre-Remedial Action Sediment and Soil Sampling

Sampling of surface soils outside of the current creek channel would be conducted prior to diverting the creek to confirm the extent of contamination that is greater than 10 mg/kg PCE.

After re-routing Berwick Creek, sampling would be conducted within the bed and banks of the current Berwick Creek channel to confirm the extent of contamination that is greater than 10 mg/kg, the thickness and continuity of the silt "cap" below the creek, and the depth of the groundwater table. This sampling would be needed in part because heavy flooding over the past 5 years may have swept away some of the original contaminated material. In locations where flooding has occurred, sediment and surface soil within the bed and banks of the current creek channel may now be clean, thereby reducing the volume of materials that require treatment, excavation, and/or restoration.

Sampling to determine if there are any subsurface soils with PCE concentrations greater than 10 mg/kg under North Hamilton Road could be conducted either prior to or after re-routing Berwick Creek.

7.1.1.3 Institutional Controls

A variety of ICs would be implemented during and after the interim action at the HRIA. The objectives of the ICs for the HRIA include preventing use of HRIA groundwater for drinking water, requiring appropriate worker protection controls and materials handling during implementation of the interim remedial action, and preventing or restricting construction of houses or commercial buildings over residual contamination to prevent vapor intrusion and inhalation exposures. The types of ICs that would be employed include activity and use restrictions through proprietary (e.g., easements, covenants) and/or governmental (e.g., zoning requirements, building codes, and/or restrictions on well drilling) controls. Other ICs that could be added to the above if warranted include information device ICs (e.g., warning signs, advisories, additional public education, deed notices, Notices of Environmental Contamination) to inform people of the presence of any residual contamination and the risks such contamination may pose. Implementation, monitoring, and enforcement of the ICs would be the responsibility of some combination of property owners, local government, Ecology, and/or EPA.

7.1.2 Monitoring

Monitoring (consisting of surface water, soil, groundwater, and air sampling) will be performed during and after remediation in order to ensure protection of humans and the environment and evaluate the need for any future additional action for remaining contamination. Future cleanup decisions within the HRIA will also take into account results from future OU2 investigations in order to support a Site-wide, groundwater plume management strategy.

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[8] The State of Washington limits construction actions within and near fresh water fish-bearing streams from July 1 through September 30 when stream water levels are the lowest.

7.1.2.1 RAO Performance Monitoring Points

Confirmation sampling would be conducted in sediment and soil after treatment to evaluate compliance with the 10 mg/kg PCE PRG and to guide any additional actions (more treatment and/or excavation and offsite disposal) needed to meet the PRG throughout the HRIA.

To evaluate the mass discharge in groundwater PRG, performance monitoring wells would be established**. Figure 3-2** shows the proposed mass discharge measurement plane and the wells that may be used to measure discharge relative to the remediation target zones and the PCE contaminant plume. The location of the proposed plane has been chosen to incorporate the following considerations:

- Near the downgradient edge of the high concentration groundwater remediation target zone.
- Screened in the upper and lower zones of the shallow aquifer where groundwater contamination is located.

Exact placement and screened intervals of the mass discharge wells may be changed once additional data are collected during the remedial design to characterize the vertical and lateral hydraulic system more fully. It is also important to note that groundwater samples would be collected in wells that correspond to the mass discharge analysis and analyzed for contaminant concentrations using standard analytical procedures. These data would be used to compare standard analytical contaminant concentration changes as another line of evidence for mass discharge reductions that are observed. In addition, groundwater analytical results would be used to determine when to conduct a mass discharge assessment. For instance, if a 90% reduction in contaminant concentrations is observed at the discharge wells, an assessment of mass discharge may be conducted to verify corresponding reductions.

7.1.3 Five-Year Reviews

If hazardous substances remain onsite above levels that allow for unrestricted use and unlimited exposure after remedial action (as expected), 5-year site reviews would be performed as required by statute to evaluate whether the remedy is or will be protective of human health and the environment. Since this interim remedial action leaves hazardous substances in place above levels that allow for unlimited use and unrestricted exposure, a 5-year review will be conducted 5 years from the start of the interim action.

7.1.4 ARARs Waiver

The alternatives considered for the HRIA will be an interim remedial action. Consequently, none of the alternatives evaluated are expected to be able to fully attain all of the ARARs for the HRIA. The ARARs that will be attained and those that will be waived will be specified in the interim ROD, which is expected to include the interim action waiver provided for in Section 121(d)(4)(A) of CERCLA. The interim ROD will be followed by a final ROD for the HRIA or Site that will fully address compliance with all ARARs, consistent with CERCLA, including any waivers.

7.2 Unique Feature of CTS Alternatives

This subsection summarizes the unique features of each of the evaluated alternatives. Please note that a specific implementation sequence of each component within CTS-2 and CTS-3 is not proposed at this time in order to allow flexibility to consider and adapt to new information during the design phase. For example, it may be decided to initiate treatment in the high concentration groundwater remediation target zone before the other two remediation target zones because of vendor availability or the high costs associated with implementing an ISTR technology.

7.2.1 CTS-1

CTS-1 complies with Section 300.430(e)(6) of the NCP for the development of a No Action alternative. A "no action" alternative is required by the NCP to provide an environmental baseline against which impacts of the various remedial alternatives can be compared.

Under this CTS, no action would be taken to remedy the shallow contaminated creek bed sediment/ bank surface soil or high concentration groundwater and subsurface soils or to monitor VOC concentrations to address the associated risks to human health or the environment.

Five-year site reviews would be performed as required by the NCP to evaluate whether adequate protection of human health and the environment is provided. Monitoring (consisting solely of visual inspections) would be performed as necessary to complete the 5-year site reviews.

7.2.2 CTS-2

The conceptual remediation configuration for CTS-2 is illustrated in **Figure 7-1**. CTS-2 consists of the following unique components:

- In-situ thermal treatment of contaminated sediments and soils with PCE concentrations greater than 10 mg/kg
- Excavation and offsite disposal of any remaining contaminated sediment and surface soil with PCE concentrations greater than 10 mg/kg after ISTR
- Enhanced in-situ bioremediation of any remaining contaminated subsurface soil with PCE concentrations greater 10 mg/kg after ISTR
- Enhanced in-situ bioremediation of groundwater with PCE concentrations greater than 4,000 μg/L

In-Situ Thermal Treatment of Sediments and Soils

Under CTS-2, in-situ thermal treatment would be used on contaminated creek bed sediment and bank surface soil within the current creek channel and on other surface soil and subsurface soil within the HRIA. ISTR treatment is expected to reduce PCE concentrations to 10 mg/kg or less to ensure removal of DNAPL. Substantial reductions in PCE DNAPL in sediment and soil would also decrease PCE concentrations in groundwater within and downgradient of the HRIA.

A full suite of thermal technologies (e.g., steam injection, steam extraction, electrical heating) would be considered as part of the remedial design. ISTR treatment methods work by heating contaminated sediment, soil, and groundwater. The heat volatilizes chemicals, which are extracted using multi-phase (liquid and vapor) and/or vapor collection wells. In addition, certain ISTR technologies may also degrade contaminants directly in the subsurface through hydrous pyrolysis oxidation, hydrolysis at lower temperatures, oxidation or pyrolysis at higher temperatures, and/or by stimulating the growth of microbes that biodegrade contaminants. Collection wells capture the harmful chemicals in liquids and/or gases and pipe them to the ground surface for treatment.

Construction of the ISTR treatment system would be accomplished using conventional construction equipment and services, with contractors that specialize in this innovative technology. During operation, temperature, groundwater quality, vapor emissions, and condensate/discharge will be monitored. A description of the ISTR treatment conceptual design is included under the description of

Alternative HC-3 in Section 5. The total ISTR time estimated to achieve reductions of PCE concentrations to 10 mg/kg or less is 18 months, including design, construction, startup, and operation of the treatment system.

Post-Thermal Treatment of Remaining Contaminated Creek Bed Sediments, Surface Soil, and/or Subsurface Soil

If Site geology and/or hydraulic conditions result in target heat distribution and/or design treatment temperatures not being achieved, or if Site conditions result in inefficient liquid/vapor collection, there may be portions of the remediation target zone where ISTR does not reduce PCE levels to 10 mg/kg or less. In other locations, starting PCE concentrations may be so high that even a 99% reduction in concentration still leaves > 10 mg/kg in the soil. Finally, results of additional site characterization may indicate isolated hotspots of elevated PCE levels that would be inefficient to address by extending the ISTR treatment grid. To address these potential situations, under CTS-2, if after ISTR treatment there are creek bed sediments and surface soils with PCE concentrations greater than 10 mg/kg, these would be removed (excavated) and consolidated within the HRIA prior to disposal. Excavated soils would be placed on an impermeable liner and the stockpile covered to minimize the risk of contaminants leaking into the underlying soil until waste characterization testing can be completed and the material is transported offsite to an approved disposal facility.

If further treatment is required prior to offsite disposal (based on landfill restrictions), a chemical would be injected or mixed into the contaminated materials to help destroy or "oxidize" the PCE. Oxidizing chemicals help change harmful chemicals into harmless ones, like water, carbon dioxide, and diluted hydrochloric acid. Typical chemical oxidants include hydrogen peroxide (H_2O_2), sodium persulfate ($Na_2S_2O_8$), and potassium permanganate ($KMnO_4$). Soil sampling and testing would be required to determine the best chemical oxidant and dosage needed to effectively reduce contaminants in the excavated material. The excavated sediment and surface soil, whether treated on or offsite, would be loaded into dump trucks and transported to a licensed disposal facility. For CTS-2, it was assumed that 90% of the estimated 1,400 cy of contaminated creek bed sediment/bank surface soil would be treated onsite via ISTR or other remedial technology (i.e., ex-situ chemical oxidation). An estimated 140 cy of soil was assumed to be disposed at a licensed disposal facility.

It is anticipated that ISTR will achieve PCE levels of 10 mg/kg or less in the subsurface soil remediation target zone; however, if PCE concentrations above 10 mg/kg remain in the subsurface soil zone, a polishing technology, such as in-situ bioremediation, would be employed to further reduce concentrations.

In-Situ Enhanced Bioremediation of High Concentration Groundwater

Under CTS-2, in-situ biological treatment using EAB would be used on groundwater with PCE concentrations greater than 4,000 μg/L. Biological treatment is expected to reduce the discharge of PCE from the high concentration zone DNAPL to the dissolved-phase PCE groundwater downgradient areas by 90%. Residual contamination in subsurface soils would also be reduced. Biological treatment could be conducted either before or after ISTR.

In-situ enhanced bioremediation using EAB is a technology that uses microorganisms to reduce the concentration or toxicity of a hazardous substance to non-toxic end products. EAB has been shown to be highly effective for chlorinated solvents because under conditions where oxygen is absent (termed anoxic), microbes use chlorinated ethylenes as alternative electron acceptors (analogous to how people use oxygen during respiration). This process is termed reductive dechlorination or halorespiration. During this process, chlorine atoms are removed from chlorinated ethylenes sequentially resulting in the ultimate formation of ethylene, a non-hazardous byproduct. In order for EAB to be efficient, conditions must be strongly reducing as indicated by the absence of oxygen, depletion of sulfate, and formation of ferrous iron and methane. Therefore, electron donors (e.g., emulsified vegetable oil or cellulose) are added to deplete oxygen and create sufficiently reducing conditions to drive halorespiration.

In order to boost or enhance this natural process, certain amendments can be injected into the soil and groundwater. Examples of amendments include whey, lactate, EVO, and suspensions of zero-valent iron. Testing will be done during remedial design to determine the best amendment or combination of amendments to use and to determine where injection wells are to be placed. This testing area would be located in the area of highest PCE concentrations along the most downgradient boundary of the 4,000 μg/L PCE remediation target zone. A description of the bioremediation conceptual design can be found in Section 5 under the description of Alternative HC-5. For CTS-2, fewer bioremediation injection wells were assumed than in Alternative HC-5 because thermal treatment would reduce the area proposed for EAB. Of the 79 injection wells assumed in Alternative HC-5, it was estimated that only 65 injection locations would be needed to treat the high concentration groundwater remediation area beyond the thermal treatment zone. It was also assumed that selected existing wells may be utilized for injection of amendments such that a total of 55 bioremediation injection wells would need to be installed.

Estimated Timeframe for CTS-2:

- Diversion of Berwick Creek: Up to 6 months.
- Design, Construct, Operate ISTR System, and Achieve Sediment and Soil PRG: 18 months.
- Design, Pilot Test, Construct, and Operate Enhanced In-Situ Bioremediation and Achieve High Concentration Groundwater PRG: 4 years.
- Total estimated timeframe to achieve PRGs is 5 years assuming overlap of ISTR and enhanced in-situ bioremediation implementation.
- Total estimated time frame also assumes that ISTR will achieve the 10 mg/kg PCE or less PRG. If the additional remedial components described above are needed to achieve the 10 mg/kg PCE PRG, the total estimated timeframe may be different.

Costs:

- Capital Cost: $8.6 million
- Annual Operation and Maintenance Cost: $209,000
- Total Present Worth Cost: $9.8 million

The estimated timeframe for Alternative CTS-2 is substantially shorter than the time frames estimated for the EAB-(HC-5) and ISCO- only (HC-4) alternatives (up to 10 years). Overall remediation costs for the HRIA also would be lower because while CTS-2 addresses the creek bed sediment/bank surface soil, Alternatives HC-4 and HC-5 do not. A separate creek bed sediment/bank surface soil alternative would need to be implemented along with the selected HC alternative and therefore result in a higher overall remediation cost for the HRIA (up to approximately $12 million). The timeframe for Alternative HC-3 is comparable to the timeframe for Alternative CTS-2, but the overall costs for the HRIA would be substantially higher if ISTR is used for both the subsurface soil and high concentration groundwater zones (up to approximately $16 million, including implementation of a separate sediment/bank soil alternative).

7.2.3 CTS-3

The conceptual approach for CTS-3 is illustrated in **Figure 7-2**. CTS-3 consists of the following unique components:

- In-situ thermal treatment of sediment and soils with PCE concentrations greater than 10 mg/kg
- Excavation and disposal of remaining sediment and surface soil with PCE concentrations greater than 10 mg/kg after ISTR
- In-situ chemical oxidation of any contaminated subsurface soil with PCE concentrations greater than 10 mg/kg remaining after ISTR
- In-situ chemical oxidation of groundwater with PCE concentrations greater than 4,000 µg/L

In-Situ Thermal Treatment of Sediment and Soils

This is the same as described under CTS-2.

Post-Thermal Treatment of Remaining Contaminated Creek Bed Sediments ,Surface Soil, and/or Subsurface Soil

This is the same as described under CTS-2 except that chemical oxidation would be used instead of in-situ bioremediation as the polishing technology for remaining contamination in subsurface soil.

In-Situ Treatment of High Concentration Groundwater with Chemicals

Under CTS-3, contaminated groundwater greater than 4,000 µg/L would be treated by injection of chemical oxidants via wells into the subsurface soil and groundwater within the high concentration groundwater remediation target zone. As stated under CTS-2, oxidizing chemicals help change harmful chemicals into harmless ones, like water, carbon dioxide, and diluted hydrochloric acid. Chemical treatment is expected to reduce the discharge of PCE from the high concentration zone to the dissolved-phase PCE groundwater downgradient areas by 90%. A description of the conceptual design is provided under Alternative HC-4 in Section 5.

Estimated Timeframe for CTS-3:

- Diversion of Berwick Creek: Up to 6 months.
- Design, Construct, Operate ISTR System, and Achieve Sediment and Soil PRG: 18 months.
- Design, Pilot Test, Construct and Conduct In-situ Chemical Oxidation Treatment, and Achieve High Concentration Groundwater PRG: 4 years.
- Total estimated timeframe to achieve PRGs is 5 years assuming overlap in ISTR and in-situ chemical oxidation treatment implementation.
- Total estimated time frame also assumes that ISTR will achieve the 10 mg/kg PCE or less PRG. If the additional remedial components described above are needed to achieve the 10 mg/kg PCE PRG, the total estimated timeframe may be different.

Costs:

- Capital Cost: $10. 5 million
- Annual Operation and Maintenance Cost: $209,000
- Total Present Worth Cost: $11.7 million

7.3 Detailed Analysis of CTS Alternatives

The detailed and comparative analyses of the component alternatives presented in Sections 6.13, 6.14, and 6.17 were used to complete the detailed analysis of the assembled CTSs presented in this section.

7.3.1 Alternative CTS-1

Alternative CTS-1, the No Action Alternative, is required by the NCP as a baseline for comparison against other remedial alternatives. Under this alternative, no action would be taken to remedy the contaminated groundwater/ subsurface soil or to monitor VOC concentrations to address the associated risks to human health or the environment. The only other actions that would be implemented would be 5-year site reviews as required by the NCP.

7.3.1.1 Remedial Action Objectives

CTS-1 would not achieve the PRGs established for any of the remediation target zones nor would it achieve the RAOs for the HRIA. That is, it does not prevent ecological exposure to COPCs in HRIA sediment and surface soil above levels that are protective of ecological receptors nor does it prevent human exposure to COPCs in HRIA sediments, surface soil, and subsurface soil above levels that are protective of recreational users and construction/utility (trench) workers. CTS-1 also does not reduce the DNAPL contaminant mass within the HRIA, minimize further migration of COPCs from the HRIA to downgradient groundwater, or prevent human exposure to groundwater in the HRIA containing COPCs above levels protective for drinking water.

7.3.1.2 Overall Protection of Human Health and the Environment

CTS-1 would not achieve the criterion of overall protection of human health and the environment. CTS-1 does not remove or substantially reduce the amount of contaminant mass, including DNAPL, nor does it implement ICs to prevent use of HRIA groundwater for drinking. The No Action Alternative fails to meet this threshold criterion of protectiveness. The overall rating on this criterion for Alternative HC-1 is No.

7.3.1.3 Compliance with ARARs

ARARs evaluated for this alternative are included in **Appendix B**. The No Action alternative (CTS-1) will not achieve this criterion; therefore, it was given a rating of No.

7.3.1.4 Long-Term Effectiveness and Permanence

Since the No Action Alternative does not address treatment of contaminated sediment, soil and groundwater, the contamination left in place in soil would continue to provide a source to groundwater contamination, and the status of the groundwater contamination would remain unchanged. Thus, this alternative has no long-term effectiveness and permanence. The overall rating on this criterion for Alternative CTS-1 is none.

7.3.1.6 Reduction of Toxicity, Mobility, or Volume through Treatment

No remedial action would be taken under the No Action Alternative; thus, there would be no reduction in toxicity, mobility, or volume of contaminated sediment, soil, and groundwater. The overall rating on this criterion for Alternative CTS-1 is none.

7.3.1.7 Short-Term Effectiveness

No construction activities are required for the No Action Alternative; thus, there are no short-term impacts to workers and the community from implementation. However, since the contaminated sediment and soil is left in place, continued release to groundwater will occur and protection is not achieved. This alternative minimizes greenhouse gas emissions, air pollutants, energy consumption, and water use since no action will be taken. The overall rating on this criterion for CTS -1 is moderate.

7.3.1.8 Implementability

No remedial action would be taken under this alternative; thus, no implementation is required. The overall implementability rating on this criterion for Alternative CTS-1 is high.

7.3.1.9 Cost

There are no costs associated with the no action alternative since no remedial activities would be performed.

7.3.2 Alternative CTS-2

7.3.2.1 Remedial Action Objectives

CTS-2 would achieve the PRGs established for the remediation target zones as well as the RAOs for the HRIA. That is, it would prevent ecological exposure to COPCs in HRIA sediment and surface soil above levels that are protective of ecological receptors and prevent human exposure to COPCs in HRIA sediments, surface soil, and subsurface soil above levels that are protective of recreational users and construction/utility (trench) workers. CTS-2 also would reduce the DNAPL contaminant mass within the HRIA, minimize further migration of COPCs from the HRIA to downgradient groundwater, and prevent human exposure to groundwater in the HRIA containing COPCs above levels protective for drinking water.

7.3.2.2 Overall Protection of Human Health and the Environment

Alternative CTS-2 would achieve the criterion of overall protection of human health and the environment within the scope of the interim action by removing or substantially reducing the amount of contaminant mass, including DNAPL, and through implementation of ICs to prevent the use of HRIA groundwater for drinking. The soil PRG of 10 mg/kg PCE under both alternatives was selected to ensure protection of terrestrial ecological receptors, e.g., short-tailed shrew, from ingestion and inhalation of surface soil in burrow air, and equates to a risk level that is even more protective than the 1×10^{-6} level required for protection of human direct contact exposure with PCE-contaminated soil assuming residential use (22 mg/kg). To further ensure protectiveness, these alternatives include a requirement that when the impacted creek channel is relocated or reconstructed, the maximum allowable concentration of PCE cannot exceed EPA's RSL of 0.468 mg/kg PCE for protection of benthic and freshwater organisms in creek bed sediment and bank surface soil. Current maximum soil TCE levels are already below the 10 mg/kg TCE PRG established for protection of ecological receptors.

A reduction in contaminant mass would also result in a reduction of source material and contaminant migration to areas downgradient of the HRIA, thereby increasing the likelihood of achieving this criterion across more areas of the Hamilton/Labree Site. Based on this evaluation, CTS-2 was given a "Yes" rating under this criterion.

7.3.2.3 Compliance with ARARs

The remedial alternative under CTS-2 would comply with most of the ARARs that pertain to the HRIA interim action. In particular, this alternative would comply with the MTCA Method B requirement for cleanups to attain the 1×10^{-6} risk level for protection of human direct contact exposure with PCE-contaminated soil. The PCE concentration, which equates to a 1×10^{-6} risk from direct contact, is 22 mg/kg assuming residential use, 110 mg/kg assuming industrial/commercial and construction/utility (trench worker) use, and 924 mg/kg assuming recreational use within the HRIA Berwick Creek bed sediment and bank surface soil. The PCE soil PRG is 10 mg/kg PCE, which is more protective than the $1x10^{-6}$ protection level.

Because a comprehensive, Site-wide groundwater cleanup is beyond the scope of the interim action, CTS-2 is not expected to fully attain MCLs or the Ground Water Cleanup Standards in MTCA Section 720 (WAC 173-340-720). These requirements are relevant and appropriate to Site-wide groundwater (including OU1) for which the beneficial use is a source of drinking water. Another section of MTCA that is considered an ARAR is WAC 173-340-747 (Deriving soil concentrations for groundwater protection), which requires soil cleanups to achieve levels that will not cause an exceedance of groundwater cleanup levels and will not result in the accumulation of non-aqueous phase liquid on or in groundwater. The PCE PRG of 10 mg/kg is well above PCE soil concentrations that would be protective of groundwater, so attaining this soil ARAR is also beyond the scope of this interim action.

The remedial alternatives under CTS-2 would address the significant sources of groundwater contamination located within OU1 to the maximum extent practicable for the selected remedy but are not expected to fully attain these ARARs. Therefore, the selected remedy is an interim remedy and invokes the waiver provided for in CERCLA Section 121(d).Given the above considerations, CTS-2 will have two ratings for meeting this criterion: "Yes with a Waiver" for sediment and soil and "Yes with a Waiver" for groundwater.

7.3.2.4 Long-Term Effectiveness and Permanence

The remedial alternatives under CTS-2 would provide a high degree of long-term effectiveness and permanence by substantially reducing sediment, soil, and groundwater contaminant concentrations and mass, including DNAPL which is a principal threat waste, from the HRIA. This reduction in source material would also reduce contaminant Md to areas downgradient from HRIA over the long term.

The valley in which the Hamilton/Labree Site is located is prone to flooding every few years, which could negatively impact the effectiveness of equipment employed for long-term treatment. The treatment technologies considered under CTS-2, however, would be impacted by these events over the short and long terms.

Given the above consideration, CTS-2 was given a numerical rating of 5 (High) for this criterion.

7.3.2.5 Reduction of Toxicity, Mobility, or Volume through Treatment

The remedial alternatives under CTS-2 would provide a high level of reduction in toxicity, mobility, or volume of contaminated materials and satisfy the statutory preferences for treatment of principal waste threats. The remedial alternatives under CTS-2 would be effective at reducing contaminant mass and discharge and result in a substantial reduction in contaminant mobility, and toxicity would be decreased by lowering PCE concentrations in the sediment, soil, and groundwater.

Given the above evaluation, CTS-2 was given a numerical rating of 5 (High) for this criterion.

7.3.2.6 Short-Term Effectiveness

CTS-2 will achieve the following major milestones:

- Diversion of Berwick Creek: Up to 6 months.
- Design, construct, and operate in-situ thermal treatment system and achieve sediment and soil PRG: 18 months.

- Design, pilot test, construct and operate enhanced in-situ bioremediation treatment, and achieve high concentration groundwater performance measure: 4 years.
- Total estimated timeframe to achieve both the sediment and soil PRG and the high concentration groundwater performance measure: 5 years. This assumes there will be an overlap of thermal and enhanced bioremediation treatments and that thermal treatment will achieve the 10 mg/kg PCE or less PRG. If the additional remedial components described for the selected remedy (i.e., additional excavation, treatment, and offsite disposal of sediment/surface soil and/or bioremediation polish in subsurface soils not meeting the PRG following thermal treatment) are needed to achieve the 10 mg/kg PCE PRG in sediment and soil, the total estimated timeframe may be different.

Many issues can impact the timeline, the most significant impact on the timeline is if diversion of Berwick Creek, a remedy component under both CTS-2 and CTS-3, is delayed. This remedy component must be scheduled in compliance with the State of Washington's in-stream work window. In-stream work windows have been established for all waters of the State of Washington. These are in place to protect fish species at critical life stages. For Berwick Creek, the in-stream work window is July 1 to September 30. It may be possible, however, to obtain a waiver from the state in order to perform activities outside of the fish work window. If the work window is missed and a waiver cannot be obtained, the project will be delayed since Berwick Creek needs to be relocated prior to initiating remediation.

Implementation of the remedial alternatives under CTS-2 should not subject members of the community that reside or work near OU1 to significant risks. Potential risks during remediation can be mitigated by preventing the use of OU1 groundwater for drinking, implementing dust control measures during excavation and requiring trucks leaving OU1 to cover their loads to minimize inhalation risk, using conventional traffic controls to minimize car/truck accidents, and controlling access by fencing off the construction and treatment areas and posting warning signs to prevent swimming in Berwick Creek. In addition to risks, there are no anticipated adverse socio-economic impacts from implementing CTS-2 as efforts will be made during implementation to not hinder transportation and commerce.

Remedial alternatives implemented under CTS-2 could pose moderately high risks to onsite remediation workers. Treatment involves placement of delivery systems for injection of thermal, or biological substances into soil and groundwater and collection of vapors. This poses physical risks as well as direct contact and inhalation risks from contaminants. Digging and working in a trench, such as when relocating or reconstructing the Berwick Creek channel or installing horizontal soil vapor extraction wells for in-situ thermal treatment, poses an increased inhalation risk from volatilization of contaminants from the soil and shallow groundwater table. Additional short-term issues associated with these activities include increased noise levels and fugitive dust emissions associated with the use of heavy equipment for excavation and/or disposal of materials. Controls, such as requiring cleanup workers to wear PPE to include air monitoring devices; minimizing the exposed work area; working in cooler weather; using standard construction practices, such as dust suppression with water, foam, or a vacuum manifold to capture emissions; covering truck loads that are transported off the Site; using conventional traffic controls to minimize accidents; and effectively capturing vapors created during treatment, would be used to minimize air pollutants and risks to cleanup workers.

Short-term impacts to the environment also exist with excavation and temporary stockpiling of contaminated sediment and soils under CTS-2. To minimize the impacts to the environment, excavated soils will be placed on an impermeable liner and the stockpile covered to minimize the risk of contaminants leaking into the underlying soil and groundwater until waste characterization testing can be completed and the material is transported offsite to an approved disposal facility.

There could also be short-term energy impacts associated with in-situ thermal treatment of contaminated sediment soil under both CTS-2. Thermal technologies require significantly large amounts of energy as compared to other treatment technologies. Of particular concern is if the existing power grid cannot accommodate the power needs at the Site. However, other thermal technologies are available that use alternative sources of energy, such as natural gas or propane, as the energy source. Thermal treatment is particularly effective on DNAPLs. By using a thermal treatment technology, DNAPL mass is substantially reduced within a relatively short time period. A secondary benefit to thermal technology is that the warmed sediment and soil can enhance bioremediation in groundwater proposed under CTS-2. To combat thermal energy impacts, the thermal treatment area can be minimized to focus only on DNAPL-impacted sediment and soil, energy efficient equipment can be used to minimize energy consumption, and alternative fuels could be used to minimize greenhouse gas emissions. In addition, renewable energy sources, such as solar panels, could be used to help power onsite auxiliary systems.

Short-term impacts must be considered depending on which technology is used in treating the high concentration groundwater. Enhanced bioremediation under CTS-2 proposes the use of food-grade amendments, such as EVO, minimizing the negative impacts to drinking water wells and the environment. However, injection of carbon can affect secondary water quality by increasing the carbon demand in the system and generating volatile fatty acids through fermentation. In addition, byproducts, such as sulfides and methane, which impact water quality, may also be generated. However, conditions will return to pre-treatment conditions once the bioremediation operations are complete. Given the above considerations, CTS-2 was given a numerical rating of 4 (Moderate to High) for this criterion.

7.3.2.7 Implementability

As stated above, the use of ISTR to treat contaminated sediment and soils is proposed in the CTS-2 alternative. Using a thermal technology would be technically and administratively implementable; however, relatively few vendors are able to provide the proprietary technology needed for this type of treatment. On the other hand, those that are available are very experienced at using this innovative technology to effectively reduce contaminants, including DNAPL. Using an ISTR treatment technology would potentially increase the volatilization of contaminants; therefore, installing an effective vapor recovery system is essential. Installing and implementing such a system, however, may be challenging due to the impermeable silt “cap” below Berwick Creek and the shallow groundwater table across the HRIA. This may necessitate the installation of a series of trenches containing horizontal soil vapor extraction wells, which are more expensive to install than the more common vertical wells. The regulatory and substantive permitting requirements associated with installation of electrode or soil vapor extraction wells, laying piping, constructing the treatment system, and securing approval for air emissions are considered to be moderately intensive. Heat retention and transport within and downgradient of the target treatment volume are uncertain. Impacts on heat transfer to Berwick Creek should be considered and evaluated to minimize any undesirable impacts. A pilot test may be necessary prior to full-scale implementation of ISTR to mitigate these issues.

In regards to the high concentration groundwater remediation zone, the enhanced in-situ bioremediation included in CTS-2 is relatively standard and several contractors are available that have experience with their installations. Treatment of volatile contaminants like PCE in groundwater using enhanced bioremediation is a proven technology. However, to facilitate the proper application of the technology, the installation may need to proceed in phases in order to obtain key engineering design parameters (e.g., feasible injection rates, preferential pathways, area of influence from an injection point, optimal boundaries between target zones). The results of the first phase would be used to help guide subsequent phases.

Offsite disposal at a licensed disposal facility of treated or non-treated residual contaminated sediment and soil is considered under CTS-2 as a contingency. Delays in the project and increased costs could be realized if there is not an appropriate disposal facility relatively close to the site.

Given the above analysis, CTS-2 was given a numerical rating of 4 (Moderate to High) for this criterion.

7.3.2.8 Cost

CTS-2 includes treatment that would be completed within 5 years and monitoring for a 30-year period. The net present worth cost for CTS-2 is estimated at $9.8 million. The capital cost for CTS-2 is $8.6 million, and the annual O&M cost is $209,000.

7.3.3 Alternative CTS-3

7.3.3.1 Remedial Action Objectives

CTS-3 would achieve the PRGs established for the remediation target zones as well as the RAOs for the HRIA. That is, it would prevent ecological exposure to COPCs in the HRIA sediment and surface soil above levels that are protective of ecological receptors and prevent human exposure to COPCs in HRIA sediments, surface soil, and subsurface soil above levels that are protective of recreational users and construction/utility (trench) workers. CTS-3 also would reduce the DNAPL contaminant mass within the HRIA, minimize further migration of COPCs from the HRIA to downgradient groundwater, and prevent human exposure to groundwater in the HRIA containing COPCs above levels protective for drinking water.

7.3.3.2 Overall Protection of Human Health and the Environment

Alternative CTS-3 would achieve the criterion of overall protection of human health and the environment within the scope of the interim action by removing or substantially reducing the amount of contaminant mass, including DNAPL, and through implementation of ICs to prevent the use of HRIA groundwater for drinking. The soil PRG of 10 mg/kg PCE was selected to ensure protection of terrestrial ecological receptors, e.g., short-tailed shrew, from ingestion and inhalation of surface soil in burrow air, and equates to a risk level that is even more protective than the 1×10^{-6} level required for protection of human direct contact exposure with PCE-contaminated soil assuming residential use (22 mg/kg). To further ensure protectiveness, this alternative includes a requirement that when the impacted creek channel is relocated or reconstructed, the maximum allowable concentration of PCE cannot exceed EPA's RSL of 0.468 mg/kg PCE for protection of benthic and freshwater organisms in creek bed sediment and bank surface soil. Current maximum soil TCE levels are already below the 10 mg/kg TCE PRG established for protection of ecological receptors.

A reduction in contaminant mass would also result in a reduction of source material and contaminant migration to areas downgradient of the HRIA, thereby increasing the likelihood of achieving this criterion across more areas of the Hamilton/Labree Site. Based on this evaluation, CTS-3 was given a "Yes" rating under this criterion.

7.3.3.3 Compliance with ARARs

The remedial alternatives under CTS-3 would comply with most of the ARARs that pertain to the HRIA interim action. In particular, this alternative would comply with the MTCA Method B requirement for cleanups to attain the 1 x 10^{-6} risk level for protection of human direct contact exposure with PCE-contaminated soil. The PCE concentration, which equates to a 1x10^{-6} risk from direct contact, is 22 mg/kg assuming residential use, 110 mg/kg assuming industrial/commercial and construction/utility (trench worker) use, and 924 mg/kg assuming recreational use within the HRIA Berwick Creek bed sediment and bank surface soil. The PCE soil PRG is 10 mg/kg PCE, which is more protective than the 1 x 10^{-6} protection level.

Because a comprehensive, Site-wide groundwater cleanup is beyond the scope of the interim remedy, CTS-3 is not expected to fully attain MCLs or the Ground Water Cleanup Standards in MTCA Section 720 (WAC 173-340-720). These requirements are relevant and appropriate to Site-wide groundwater (including OU1) for which the beneficial use is a source of drinking water. Another section of MTCA that is considered an ARAR is WAC 173-340-747 (Deriving soil concentrations for groundwater protection), which requires soil cleanups to achieve levels that will not cause an exceedance of groundwater cleanup levels and will not result in the accumulation of non-aqueous phase liquid on or in groundwater. The PCE PRG of 10 mg/kg is well above PCE soil concentrations that would be protective of groundwater, so attaining this soil ARAR is also beyond the scope of this interim action.

The remedial alternatives under CTS-3 would address the significant sources of groundwater contamination located within OU1 to the maximum extent practicable for the selected remedy but are not expected to fully attain these ARARs. Therefore, the selected remedy is an interim remedy and invokes the waiver provided for in CERCLA Section 121(d).

Given the above considerations, CTS-3 will have two ratings for meeting this criterion: “Yes with a Waiver” for sediment and soil and “Yes with a Waiver” for groundwater.

7.3.3.4 Long-Term Effectiveness and Permanence

The remedial alternatives under CTS-3 would provide a high degree of long-term effectiveness and permanence by substantially reducing sediment, soil, and groundwater contaminant concentrations and mass, including DNAPL which is a principal threat waste, from the HRIA. This would result in a reduction in source longevity and contaminant mass discharge to areas downgradient from the HRIA over the long term. The remedial alternatives under CTS-3 are the same as for CTS-2 discussed in Section 7.3.2.4 and are not repeated here.

One difference in the effectiveness and permanence for CTS-3 is the use of chemical oxidation for the high concentration groundwater zone. Low permeability silt zones and clay seams in the shallow aquifer will significantly impact the performance of the chemical oxidation and the potential for rebound. Chemical oxidants are preferentially delivered into high conductivity zones and so will likely not be delivered to the low permeability silt zones. Therefore, treatment of contaminants within the silt will rely on diffusion of contaminants out of the silt zones into permeable zones where they can be treated or diffusion of the oxidant into the silt. The relatively short longevity of the oxidant will limit the amount of treatment that can be achieved in the silt.

Given the above consideration, CTS-3 was given a numerical rating of 5 (High) for this criterion.

7.3.3.5 Reduction of Toxicity, Mobility, or Volume through Treatment

CTS-3 would provide a high level of reduction in toxicity, mobility, or volume of contaminated materials and satisfy the statutory preferences for treatment and treatment of principal waste threats. CTS-3 would be effective at reducing contaminant mass and discharge and result in a substantial reduction in contaminant mobility, and toxicity would be decreased by lowering PCE concentrations in the sediment, soil, and groundwater. Under CTS-3, chemical oxidants will be injected. Some chemical oxidizers can create toxic byproducts, which may increase toxicity in the short run; however, the potential for this to happen would be mitigated during the design of this alternative. Different chemical oxidants would be evaluated in bench scale and/or pilot treatability studies to evaluate performance, including creation of toxic byproducts and those products tracked over time. Oxidants would be selected based on the ability to achieve PRGs and minimize formation of undesirable byproducts.

Given the above evaluation, CTS-3 was given a numerical rating of 5 (High) for this criterion.

7.3.3.6 Short-Term Effectiveness

CTS-3 will achieve the following major milestones:

- Diversion of Berwick Creek: Up to 6 months.
- Design, construct and operate in-situ thermal treatment system, and achieve sediment and soil PRG: 18 months.
- Design, pilot test, construct and operate in-situ chemical oxidation treatment, and achieve high concentration groundwater performance measure: 4 years.
- Total estimated timeframe to achieve both the sediment and soil PRG and the high concentration groundwater performance measure: 5 years. This assumes there will be an overlap of thermal and chemical oxidation treatments and that thermal treatment will achieve the 10 mg/kg PCE or less PRG. If the additional remedial components described for the selected remedy (i.e., additional excavation, treatment and offsite disposal of sediment/surface soil, and/or chemical oxidation polish in subsurface soils not meeting the PRG following thermal treatment) are needed to achieve the 10 mg/kg PCE PRG in sediment and soil, the total estimated timeframe may be different.

The short-term effectiveness issues for remedial alternatives under CTS-3, and specifically the ISTR and excavation alternatives, are the same as for CTS-2 (see Section 7.3.2.6 for details) and are not repeated here.

Under CTS-3, chemical treatment within the groundwater remediation target zone is proposed. Injection of certain chemicals may produce unfavorable byproducts, such as manganese oxide which could be harmful to human health and the environment. This may be mitigated, however, if taken into consideration during design. As indicated in Section 7.3.3.5, different chemical oxidants would be evaluated in bench scale and/or pilot treatability studies to evaluate creation of toxic byproducts, and oxidants would be selected based on the ability to achieve PRGs and minimize formation of undesirable byproducts.

Given the above considerations, CTS-3 was given a numerical rating of 3 (Moderate) for this criterion.

7.3.3.7 Implementability

The implementability for remedial alternatives under CTS-3, and specifically the ISTR and excavation alternatives, are the same as for CTS-2 (see Section 7.3.2.7 for details) and are not repeated here. The chemical treatment technology included as part of CTS-3 is well established and can be implemented at the HRIA within the high concentration groundwater remediation target zone. Chemical oxidants would be delivered to the subsurface using readily available, conventional construction equipment. Testing would be required to determine the dose of chemical oxidant required. Testing may also be necessary prior to full scale implementation in order to obtain key engineering design parameters (e.g., feasible injection rates, preferential pathways, area of influence from an injection point, and longevity of oxidant).

Given the above analysis, CTS-3 was given a numerical rating of 4 (Moderate to High) for this criterion.

7.3.2.8 Cost

CTS-3 includes treatment that would be completed within 5 years and monitoring for a 30-year period. The net present worth cost for CTS-3 is estimated at $11.7 million. The capital cost for CTS-3 is $10.5 million, and the annual O&M cost is $209,000. As stated earlier in this section, these cost estimates are expected to be accurate within a range of +50 to - 30%.

7.4 Comparative Analysis of CTS Alternatives

In this section, the three CTSs and their associated remedial alternatives are comparatively evaluated against the two threshold criteria and five balancing criteria. The results of this evaluation are presented in **Exhibit 7-1**.

7.4.1 Remedial Action Objectives

CTS-1 would not achieve the PRGs established for any of the remediation target zones nor would it achieve the overall RAOs for the HRIA. CTS -2 and CTS-3 would achieve the PRGs established for each of the remediation target zones as well as the RAOs for the HRIA.

7.4.2 Overall Protection of Human Health and the Environment

The CTS-1 alternative (No Action) would not address any risks and therefore is not protective of human health and the environment and does not achieve this criterion. Therefore, it was given a No rating.

The remedial alternatives under both CTS-2 and CTS-3 would achieve the criterion of overall protection of human health and the environment within the scope of the interim action by removing or substantially reducing the amount of contaminant mass, including DNAPL, and through implementation of ICs to prevent the use of HRIA groundwater for drinking. The soil PRG of 10 mg/kg PCE under both alternatives was selected to ensure protection of terrestrial ecological receptors, e.g., short-tailed shrew, from ingestion and inhalation of surface soil in burrow air, and equates to a risk level which is even more protective than the 1 x 10^{-6} level that is required for protection of human direct contact exposure with PCE-contaminated soil assuming residential use (22 mg/kg). To further ensure protectiveness, these alternatives include a requirement that when the impacted creek channel is relocated or reconstructed, the maximum allowable concentration of PCE cannot exceed EPA's RSL of 0.468 mg/kg PCE for protection of benthic and freshwater organisms in creek bed sediment and bank surface soil. Current maximum soil TCE levels are already below the 10 mg/kg TCE PRG established for protection of ecological receptors.

A reduction in contaminant mass would also result in a reduction of source material and contaminant migration to areas downgradient of the HRIA, thereby increasing the likelihood of achieving this criterion across more areas of the Hamilton/Labree Site. Based on this evaluation, both CTS-2 and CTS-3 were given a "Yes" rating under this criterion.

7.4.3 Compliance with ARARs

Compliance with ARARs is the second of the two threshold criteria that each alternative must meet in order to be further evaluated as a potential remedial action, unless one of the ARARs is waived.

The No Action alternative (CTS-1) will not achieve this criterion; therefore, it was given a rating of "No." Because CTS-1 does not meet either of the threshold criteria (overall protection of human health and the environment and compliance with ARARs), it will not be further evaluated as an alternative.

The remedial alternatives under both CTS-2 and CTS-3 would comply with most of the ARARs that pertain to the HRIA interim remedial action. In particular, both alternatives would comply with the MTCA Method B requirement for cleanups to attain the 1×10^{-6} risk level for protection of human direct contact exposure with PCE-contaminated soil. . The PCE concentration, which equates to a 1×10^{-6} risk from direct contact, is 22 mg/kg assuming residential use, 110 mg/kg assuming industrial/commercial and construction/utility (trench worker) use, and 924 mg/kg assuming recreational use within the HRIA Berwick Creek bed sediment and bank surface soil. The PCE soil PRG for both CTS-2 and CTS-3 is 10 mg/kg PCE, which far exceeds the 1×10^{-6} protection level.

Because a comprehensive, Site-wide groundwater cleanup is beyond the scope of the interim remedy, CTS-2 and CTS-3 are not expected to fully attain MCLs or the Ground Water Cleanup Standards in MTCA Section 720 (WAC 173-340-720). These requirements are relevant and appropriate to Site-wide groundwater (including OU1) for which the beneficial use is a source of drinking water. Another section of MTCA that is considered an ARAR is WAC 173-340-747 (Deriving soil concentrations for groundwater protection), which requires soil cleanups to achieve levels that will not cause an exceedance of groundwater cleanup levels and will not result in the accumulation of non-aqueous phase liquid on or in groundwater. The PCE PRG of 10 mg/kg is well above PCE soil concentrations that would be protective of groundwater, so attaining this soil ARAR is also beyond the scope of this interim action.

The remedial alternatives under CTS-2 and CTS-3 would address the significant sources of groundwater contamination located within OU1 to the maximum extent practicable for the selected remedy but are not expected to fully attain these ARARs. Therefore, the selected remedy is an interim remedy and invokes the waiver provided for in CERCLA Section 121(d). Given the above considerations, CTS-2 and CTS-3 will have two ratings for meeting this criterion: "Yes with a Waiver"" for soil and "Yes with a Waiver" for groundwater.

7.4.4 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence is the first of the five balancing criteria, which weigh the tradeoffs between alternatives.

The remedial alternatives under both CTS-2 and CTS-3 would provide a high degree of long-term effectiveness and permanence by substantially reducing sediment, soil, and groundwater contaminant concentrations and mass, including DNAPL which is a principal threat waste, from the HRIA. These alternatives would result in a reduction in source material and contaminant mass discharge to areas downgradient from the HRIA over the long term.

The valley in which the Hamilton/Labree site is located is prone to flooding every few years, which could negatively impact the effectiveness of equipment employed for long-term treatment. The treatment technologies considered for both CTS-2 and CTS-3, however, would be equally impacted by these events over the short and long terms.

One tradeoff to be considered relates to the physical characteristics of the shallow aquifer found across the Site. Low permeability silt zones and clay seams in the shallow aquifer would not reduce the effectiveness of enhanced in-situ bioremediation proposed under CTS-2 as much as it would for chemical oxidation proposed under CTS-3 since dechlorination conditions and bacteria would stay in the subsurface longer than chemical oxidizers. It has also been observed that rebound effects (initial reductions in contamination followed by increases) are far less prevalent at sites implementing enhanced bioremediation compared to chemical oxidation.

Given the above considerations, CTS-2 and CTS-3 were both given a numerical rating of 5 (High) for this criterion.

7.4.5 Reduction of Toxicity, Mobility, or Volume through Treatment

The remedial alternative under CTS-1 would not achieve this criterion. The remedial alternatives under both CTS-2 and CTS-3 would both provide a high level of reduction in toxicity, mobility, or volume of contaminated materials and satisfy the statutory preferences for treatment of principal waste threats. The remedial alternatives under both CTS-2 and CTS-3 would also be effective at reducing contaminant mass and discharge and result in a substantial reduction in contaminant mobility. Toxicity would be decreased by lowering PCE concentrations in the sediment, soil, and groundwater.

One trade-off to be considered is the use of amendments to enhance reduction of contaminants. Under CTS-2, enhanced bioremediation would entail injection of non-toxic food grade materials into the subsurface soil and groundwater. Under CTS-3, chemical oxidants will be injected. Some chemical oxidizers can create toxic byproducts, which may increase toxicity in the short run; however, the potential for this to happen would be mitigated during the design of this alternative. As indicated in Section 7.3.3.5, different chemical oxidants would be evaluated in bench scale and/or pilot treatability studies to evaluate performance, including creation of toxic byproducts, and oxidants would be selected based on the ability to achieve PRGs and minimize formation of undesirable byproducts.

Given the above evaluation, CTS-2 and CTS-3 were both given a numerical rating of 5 (High) for this criterion.

7.4.6 Short-Term Effectiveness

CTS-1 would minimize greenhouse gas emissions, air pollutants, energy consumption, and water use since no action will be taken. No construction activities would be performed under this alternative, so no risks to remediation workers or the community would occur; however, contamination is not addressed. Thus, this alternative was given a rating of moderate.

CTS-2 and CTS-3 have the same timeframes to achieve the following major milestones:

- Diversion of Berwick Creek: Up to 6 months.
- Design, construct, operate in-situ thermal treatment system, and achieve sediment and soil PRG: 18 months.
- Design, pilot test, construct and operate enhanced in-situ bioremediation treatment or in-situ chemical oxidation, and achieve high concentration groundwater PRG: 4 years.
- Total estimated timeframe to achieve both the sediment and soil PRG and the high concentration groundwater PRG: 5 years. This assumes there will be an overlap of thermal and enhanced bioremediation or in-situ chemical oxidation treatments and that thermal treatment will achieve the 10 mg/kg PCE or less PRG. If the additional remedial components described for CTS-2 and CTS-3 (i.e., additional excavation, treatment and offsite disposal of sediment/surface soil, and/or bioremediation or chemical oxidation polish in subsurface soils not meeting the PRG following thermal treatment) are needed to achieve the 10 mg/kg PCE PRG in sediment and soil, the total estimated timeframe may be different.

Many issues can impact the timeline, the most significant impact on the timeline is if diversion of Berwick Creek, a remedy component under both CTS-2 and CTS-3, is delayed. This remedy component must be scheduled in compliance with the State of Washington's in-stream work window. In-stream work windows have been established for all waters of the State of Washington. These are in place to protect fish species at critical life stages. For Berwick Creek, the in-stream work window is July 1 to September 30. It may be possible, however, to obtain a waiver from the state in order to perform activities outside of the fish work window. If the work window is missed and a waiver cannot be obtained, the project will be delayed since Berwick Creek needs to be relocated prior to initiating remediation.

Implementation of the remedial alternatives under CTS-2 and CTS-3 should not subject members of the community that reside or work near OU1 to significant risks. Potential risks during remediation can be mitigated by preventing the use of OU1 groundwater for drinking, implementing dust control measures during excavation and requiring trucks leaving OU1 to cover their loads to minimize inhalation risk, using conventional traffic controls to minimize car/truck accidents, and controlling access by fencing off the construction and treatment areas and posting warning signs to prevent swimming in Berwick Creek. In addition to risks, there are no anticipated adverse socio-economic impacts from implementing CTS-2 or CTS-3 as efforts will be made during implementation to not hinder transportation and commerce.

Remedial alternatives implemented under CTS-2 and CTS-3 could pose moderately high risks to onsite remediation workers. Treatment involves placement of delivery systems for injection of thermal, chemical, or biological substances into soil and groundwater and collection of vapors. This poses physical risks as well as direct contact and inhalation risks from contaminants. Digging and working in a trench, such as when relocating or reconstructing the Berwick Creek channel or installing horizontal soil vapor extraction wells for in-situ thermal treatment, poses an increased inhalation risk from volatilization of contaminants from the soil and shallow groundwater table. Additional short-term issues associated with these activities include increased noise levels and fugitive dust emissions associated with the use of heavy equipment for excavation and/or disposal of materials. Controls, such as requiring cleanup workers to wear PPE to include air monitoring devices; minimizing the exposed work area; working in cooler weather; using standard construction practices, such as dust suppression with water, foam, or a vacuum manifold to capture emissions; covering truck loads that are transported off the Site;

using conventional traffic controls to minimize accidents; and effectively capturing vapors created during treatment, would be used to minimize air pollutants and risks to cleanup workers.

Short-term impacts to the environment also exist with excavation and temporary stockpiling of contaminated sediment and soils under both CTS-2 and CTS-3. To minimize the impacts to the environment, excavated soils will be placed on an impermeable liner and the stockpile covered to minimize the risk of contaminants leaking into the underlying soil and groundwater until waste characterization testing can be completed and the material is transported offsite to an approved disposal facility.

There could also be short-term energy impacts associated with in-situ thermal treatment of contaminated sediment soil under both CTS-2 and CTS-3. Thermal technologies require significantly large amounts of energy as compared to other treatment technologies. Of particular concern is if the existing power grid cannot accommodate the power needs at the Site. Thermal treatment, however, is particularly effective on DNAPLs. By using a thermal treatment technology, DNAPL mass is substantially reduced within a relatively short time period. A secondary benefit to thermal technology is that the warmed sediment and soil can enhance bioremediation in groundwater as is being proposed under CTS-2. To combat thermal energy impacts, the thermal treatment area can be minimized to focus only on DNAPL-impacted sediment and soil, energy efficient equipment can be used to minimize energy consumption, and alternative fuels could be used to minimize greenhouse gas emissions. In addition, renewable energy sources, such as solar panels, could be used to help power onsite auxiliary systems.

Short-term impacts must be considered depending on which technology is used in treating the high concentration groundwater. Enhanced bioremediation under CTS-2 proposes the use of food-grade amendments, such as EVO minimizing the negative impacts to drinking water wells and the environment. In contrast, under CTS-3, treatment by injecting chemicals may produce unfavorable byproducts, such as manganese oxide, which could be harmful to human health and the environment. Given the above considerations, CTS-2 was given a numerical rating of 4 (Moderate to High), and CTS-3 was given a numerical rating of 3 (Moderate) for this criterion.

7.4.7 Implementability

The remedial alternative under CTS-1 has no action taken other than 5-year site reviews so this alternative would be the easiest to implement. Thus, CTS-1 was given a rating of high.

As stated above, the use of an ISTR technology to treat contaminated sediment and soils is proposed under both the CTS-2 and CTS-3 alternatives. Using an ISTR technology would be technically and administratively implementable; however, very few vendors are able to provide the proprietary technology needed for this type of treatment. On the other hand, those that are available are very experienced at using this innovative technology to effectively reduce contaminants, including DNAPL. Using an ISTR treatment technology would potentially increase the volatilization of contaminants; therefore, installing an effective vapor recovery system is essential. Installing and implementing such a system, however, may be challenging due to the impermeable silt "cap" below Berwick Creek and the shallow groundwater table across the HRIA. This may necessitate the installation of a series of trenches containing horizontal soil vapor extraction wells, which are more expensive to install than the more common vertical wells. The regulatory and substantive permitting requirements associated with installation of electrode or soil vapor extraction wells, laying piping, constructing the treatment system, and securing approval for air emissions, are considered to be moderately intensive. Heat retention and transport within and downgradient of the target treatment volume are uncertain. Impacts on heat transfer to Berwick Creek should be considered and evaluated to minimize any undesirable impacts. A pilot test may be necessary prior to full-scale implementation of ISTR to mitigate these issues.

In regards to the high concentration groundwater remediation zone, the enhanced bioremediation included under CTS-2 is relatively standard, and several contractors are available that have experience with their installations. Treatment of volatile contaminants like PCE in groundwater using enhanced bioremediation is a proven technology. However, to facilitate the proper application of the technology, the installation may need to proceed in phases in order to obtain key engineering design parameters (e.g., feasible injection rates, preferential pathways, area of influence from an injection point, optimal boundaries between target zones). The results of the first phase would be used to help guide subsequent phases.

The chemical treatment technology included as part of CTS-3 is well established and can be implemented at the HRIA within the high concentration groundwater remediation target zone. Chemical oxidants would be delivered to the subsurface using readily available, conventional construction equipment. Testing would be required to determine the dose of chemical oxidant required. Testing may also be necessary prior to full scale implementation in order to obtain key engineering design parameters (e.g., feasible injection rates, preferential pathways, area of influence from an injection point, longevity of oxidant).

Given the above analysis, CTS-2 and CTS-3 were both given a numerical rating of 4 (Moderate to High) for this criterion.

7.4.8 Cost

CTS-1 has no costs associated with it since no remedial activities would be performed.

CTS-2 and CTS-3 both include treatment that would be completed within 5 years and monitoring for a 30-year period. The present worth cost for CTS-2 is estimated at $9.8 million. The capital cost for CTS-2 is $8.6 million, and the annual O&M cost is $209,000.

The present worth cost for CTS-3 is estimated at $11.7 million. The capital cost for CTS-3 is $10.5 million, and the annual O&M cost is $209,000.

These cost estimates are expected to be accurate within a range of +50 to - 30%.

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Exhibit 7-1: Summary of Comparative Analysis of Comprehensive Technology Scenarios

		Threshold Criteria			Balancing Criteria				
							Implementability		
CTS	Components	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-Term Effectiveness	Engineering/ Technical Considerations	Estimated Time for Implementation (years)	Net Present Worth Cost (Dollars)
CTS-1	No Action	No	No	⓿	⓿	❸	❺	<1	$0
CTS-2	ISTR of creek bed sediment/ bank surface soil and subsurface soils; in-situ enhanced bioremediation of groundwater	Yes	Sediment/Soil – Yes with waivers Groundwater – Yes with waivers	❺	❺	❹	❹	5	$9.8 Million
CTS-3	ISTR of creek bed sediment/ bank surface soil and subsurface soils; in-situ chemical oxidation of groundwater	Yes	Sediment/Soil – Yes with waivers Groundwater – Yes with waivers	❺	❺	❸	❹	5	$11.7 Million

Threshold and Balancing Criteria

⓿	None	❸	Moderate
❶	Low	❹	Moderate to High
❷	Low to Moderate	❺	High

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Section 8

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Tables

Table 2-1 Surface Water Monitoring Station Data

Surface Water Monitoring Station	Date Monitored	Creek Gauge Elevation (feet)[1]	Creek Height (feet)[2]	Surface Water Elevation (feet)	Estimated Groundwater Elevation[3]	Elevation Head Difference (feet)[4]	Flow Rate (cfm)	Flow Rate (gpm)	Channel Depth (feet)[5]
SW-5	9/5/02	209.08	4.32	204.76	201.00	-3.76	0.0	0	2.46
	11/21/02	209.08	4.50	204.58	202.20	-2.38	1.2	<50	2.22
SW-6	9/5/02	209.88	5.13	204.75	201.11	-3.64	0.0	0	2.40
	11/21/02	209.88	5.19	204.69	202.30	-2.39	0.6-4.2	<50	2.60
SW-7	9/5/02	208.77	3.98	204.79	200.90	-3.89	6.0	<50	4.11
	11/21/02	208.77	4.18	204.59	202.18	-2.41	0.0	0	3.91
SW-8	9/5/02	205.00	6.18	198.82	196.42	-2.40	65.0	500	0.37
	11/22/02	205.00	5.88	199.12	198.00	-1.12	190.0	1,400	0.91
SW-9	9/5/02	204.49	7.46	197.03	195.00	-2.03	116.0	870	0.43
	11/22/02	204.49	7.16	197.33	196.00	-1.33	170.0	1,250	0.70
SW-10	9/5/02	196.14	4.13	192.01	192.00	-0.01	0.0	0	2.09
	11/21/02	196.14	4.04	192.10	193.00	0.90	6.0	<50	2.20

Source: Farallon (2003)

Notes:
1. Surveyed elevation of top of stream gauge to vertical datum NGVD 29, in feet above mean sea level.
2. Height measured in feet from top of stream gauge to water surface.
3. Groundwater elevation estimated from corresponding well or groundwater contour.
4. A head difference is calculated by subtracting the groundwater elevation from the surface water elevation.
5. Channel depth in feet, measured in center of channel from water surface to bottom of channel.

cfm: cubic feet per minute
gpm: gallons per minute

Table 2-2 Mass, Volume, and Surface Area of PCE in HRIA Remediation Target Zones

Remediation Zone Boundary (PCE Concentration)	Mass (kg)	Mass %	Volume (1,000 cy)	Surface Area (acre)
Creek Bed Sediment/Surface Soil (>0.468 mg/kg)	163	NA[1]	1.36	0.17
Subsurface Soil (>10 mg/kg)	186	27%[2]	3.60	0.22
High Concentration Groundwater (>4,000 µg/L)	411	60%[3]	87.8	1.6

Notes:

[1] Due to uncertainties in the sediment creek contaminant mass, the estimates were not included in the total mass calculations using MVS for subsurface soil and groundwater.

[2] Percent of the total MVS-estimated subsurface soil contaminant mass within HRIA.

[3] Numbers represent estimated mass less the soil mass estimated for the Subsurface Soil Remediation Target Zone.

PCE: tetrachloroethene
HRIA: Hamilton Road Impacted Area
MVS: Mining Visualization Systems
cy: cubic yards
kg: kilograms
mg/kg: milligrams per kilogram
µg/L: micrograms per liter
>: greater than

Table 3-1 Preliminary Remedial Goals for HRIA Remedy by Remediation Zone

Remediation Target Zone Boundary (PCE Concentration)	Contaminant	Chemical-Specific ARAR	Proposed PRG	Basis	ARAR Status
Creek Bed Sediment/Surface Soil (greater than 0.468 mg/kg)	PCE	WAC 173-204-560 (sediment) EPA RSL for terrestrial ecological receptor 9.92 mg/kg PCE WAC 173-340-740 (unrestricted soil) WAC 173-340-745 (industrial soil) 22 mg/kg PCE (residential) 110 mg/kg PCE (industrial/commercial) 924 mg/kg PCE (recreational)	10 mg/kg	The 10 mg/kg level was set based on the potential for DNAPL to be present in sediment and surface soil. Using 10 mg/kg PCE would also ensure that creek bed sediment and bank soil within the current Berwick creek channel with PCE concentrations above the MTCA Method B 1×10^{-6} cleanup standards for human direct contact with soil are addressed, e.g., 22 mg/kg for residential use, 110 mg/kg for industrial/commercial use, 924 mg/kg for recreational use. Addresses RAOs 2, 3, and 4.	Note that for freshwater sediment, the state determines on a case by case basis the criteria, methods, and procedures necessary to meet the intent of the ARAR. While not a PRG, requirements that are protective of ecological receptors would need to be met for relocation or reconstruction of the Berwick Creek channel bed and banks, e.g., 0.468 mg/kg PCE based on EPA's RSLs for freshwater sediments. By removing sediments and surface soils with PCE concentrations above 10 mg/kg, the conservative EPA RSL of 0.468 mg/kg PCE, it is anticipated that these ARARs would be met.

CDM Smith

Table 3-1 Preliminary Remedial Goals for HRIA Remedy by Remediation Zone (continued)

Remediation Target Zone Boundary (PCE Concentration)	Contaminant	Chemical-Specific ARAR	Proposed PRG	Basis	ARAR Status
High Concentration Subsurface Soil (greater than 10 mg/kg)	PCE	WAC 173-340-740 (unrestricted soil) WAC 173-340-745 (industrial soil) 22 mg/kg PCE (residential) 110 mg/kg PCE (industrial/commercial) 924 mg/kg PCE (recreational)	10 mg/kg.	Ensure removal of DNAPL and reduce source longevity Addresses RAOs 2 and 4.	Because groundwater remediation would be carried out as an interim measure, it is anticipated that pursuant to (CERCLA §121(d)(4)(A)), the interim measures ARARs waiver would be applied, and subsurface soil and groundwater ARARs would be addressed in the final remedy for OU1.
High Concentration Groundwater (greater than 4,000 µg/L)	PCE	40 CFR 141.11-.16 5 µg/L PCE (MCL) WAC 173-340-720 (groundwater) 5 µg/L PCE	Reduce mass discharge of VOC contamination by 90% from the high concentration groundwater to the dissolved phase plume as quickly as technically achievable.	The mass discharge reduction goal is a groundwater remediation level met in order to document that contaminant migration, and DNAPL migration in particular, has been mitigated. Addresses RAO 4 and contributes to RAO 1.	MCL for PCE is 5 µg/L but reaching this number is beyond the scope of this interim action. Because groundwater remediation would be carried out as an interim measure, it is anticipated that pursuant to (CERCLA §121(d)(4)(A)), the interim measures ARARs waiver would be applied, and groundwater ARARs would be addressed in the final remedy for OU1.

Notes:
mg/kg: milligrams per kilogram
µg/L: micrograms per liter
ARAR: applicable or relevant and appropriate requirement
PCE: tetrachloroethene
PRG: preliminary remedial goal
RAO: remedial action objective
RSL: EPA Regional Screening Level

Table 5-1 Remedial Technologies/Process Options Evaluated for Assembly into Remedial Alternatives
HRIA Creek Bed Sediment/Bank Surface Soil

General Response Actions	Remedial Technology	Process Option	Alternative SD-1: No Action	Alternative SD-2: Removal, Offsite Treatment and Disposal, and Re-Routing of Stream	Alternative SD-3a: Removal, Ex-Situ Chemical Oxidation, Onsite Disposal, and Re-Routing of Stream [a]	Alternative SD-3b: Removal, Ex-Situ Bioremediation, Onsite Disposal, and Re-Routing of Stream [a]	Alternative SD-4: Removal, Ex-Situ SVE, Onsite Disposal, and Re-Routing of Stream [a]
No Action	None	None	✓				
Institutional Controls	Land Use Controls	Governmental and Proprietary Controls		✓	✓	✓	✓
		Informational Devices		✓	✓	✓	✓
	Community Awareness	Information and Education Programs		✓	✓	✓	✓
Monitoring	Sampling and Analysis	Sediment Sampling		✓	✓	✓	✓
Removal	Excavation	Mechanical Excavation & Backfill		✓	✓	✓	✓
Disposal	Disposal	Offsite Disposal		✓			
		Onsite Disposal			✓	✓	✓
Treatment	Biological	Ex-situ Bioremediation				✓	
	Physical	Ex-situ Soil Vapor Extraction					✓
	Chemical Treatment	Ex-situ Chemical Oxidation			✓		

Notes:

[a] Alternative 4 was not retained for the detailed analysis of alternatives because Alternatives 3a and 3b were retained as representative alternatives for the general response action of treatment for the FS.

1. Check mark designations indicate that remedial technology/process option could be evaluated as a potential component of the indicated remedial alternative.

2. Shaded boxes indicate the process options are not considered for the remedial alternative(s) in question.

3. Descriptions of remedial technologies/process options are provided in Section 4 and in Appendix C, Table C-1.

Alternative SD-1: No Action
Alternative SD-2: Removal of Contaminated Creek Bed Sediment/Bank Surface Soil with Offsite Treatment and Disposal, and Re-routing of Stream
Alternative SD-3a: Removal of Contaminated Creek Bed Sediment/Bank Surface Soil with Ex-situ Chemical Oxidation, Onsite Disposal, and Re-routing of Stream
Alternative SD-3b: Removal of Contaminated Creek Bed Sediment/Bank Surface Soil with Ex-situ Bioremediation, Onsite Disposal, and Re-routing of Stream
Alternative SD-4[*]: Removal of Contaminated Creek Bed Sediment/Bank Surface Soil with Ex-situ Soil Vapor Extraction, Onsite Disposal, and Re-routing of Stream

ICs: institutional controls
SVE: soil vapor extraction
SD: Creek Bed Sediment/Bank Surface Soil

Table 5-2 Remedial Technologies/Process Options Evaluated for Assembly into Remedial Alternatives
HRIA High Concentration Groundwater and Subsurface Soil

General Response Actions	Remedial Technology	Process Option	Alternative HC-1: No Action	Alternative HC-2: Hydraulic Containment and ICs with Monitoring	Alternative HC-3: In-Situ Thermal Treatment [a]	Alternative HC-4: In-Situ Chemical Oxidation	Alternative HC-5: Enhanced In-Situ Bioremediation
No Action	None	None	✓				
Institutional Controls	Land Use Controls	Governmental and Proprietary Controls		✓	✓	✓	✓
	Groundwater Use Controls	Governmental and Proprietary Controls		✓	✓	✓	✓
	Community Awareness	Information and Education Programs		✓	✓	✓	✓
Monitoring	Sampling and Analysis	Groundwater and/or Air Sampling		✓	✓	✓	✓
Containment	Hydraulic Containment through Pumping	Extraction Wells		✓	✓		
Disposal	Discharge	Discharge to POTW		✓			
		Discharge to Surface Water Body		✓			
		Re-injection		✓	✓		
Treatment	Thermal (In-situ)	ERH [a]			✓		
	Biotic/Abiotic (In-situ)	In-Situ Bioremediation					✓
	Physical/Chemical (In-situ)	In-situ Chemical Oxidation				✓	
	Physical	Air Stripping		✓			
		GAC		✓	✓		
		Thermal Oxidizer or chemical oxidant (if vinyl chloride present)		✓	✓		

Note:

[a] ERH is presented as the representative alternative for the thermal remediation technology; however, other in-situ thermal treatment options are retained in the technology/process screening and described in Appendix C Tables C-2 and C-3.

1. Check mark designations indicate that remedial technology/process option could be evaluated as a potential component of the indicated remedial alternative.
2. Remediation subarea designations indicate that the remedial technology/process option is evaluated as a potential component of the indicated remedial alternative.
3. Shading indicates that the remedial technology/process option is excluded.
4. Descriptions of remedial technologies/process options are provided in Section 4 and Appendix C.

Alternative HC-1: No Action
Alternative HC-2: Hydraulic Containment and Institutional Controls with Monitoring
Alternative HC-3: In-Situ Thermal Treatment and Institutional Controls with Monitoring
Alternative HC-4: In-Situ Chemical Oxidation and Institutional Controls with Monitoring
Alternative HC-5: Enhanced In-Situ Bioremediation and Institutional Controls with Monitoring

ERH: electrical resistance heating
HC: high concentration groundwater (PCE > 4,000 ug/L)
ICs: institutional controls
GAC: granular activated carbon
POTW: publicly owned treatment works

Table 5-3 Conventional Chemistry Parameters Measured in EE/CA Investigation Wells

Well ID	Sulfate (mg/L)	Chloride (mg/L)	Alkalinity, Total (mg/L)	Nitrate/ Nitrite (mg/L)	Total Sulfides (mg/L)	pH (sU)	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxygen-Reduction Potential (mV)	Iron (mg/L)
MW-600	1	7.5	118	0.8	2 U	6.45	0.209	11.7	0.69	12.59	25	0.2 U
MW-601	1.8	5.9	117	1	2 U	6.74	0.198	96.6	2.35	11.83	-9	0.2 U
MW-602	34	9	72	1	2 U	6.50	0.251	151.0	2.80	11.65	-30	0.2 U
MW-603	3	5.6	100	1	2 U	6.70	0.195	47.2	2.13	12.03	-63	0.2 U
MW-604	1.4	5.4	101	1	2 U	6.63	0.204	48.5	4.02	13.26	64	0.2 U
MW-605	6.2	1.1	150	1	2 U	6.65	0.280	12.3	1.96	13.26	-51	0.2 U
MW-606	13	1	94	2	2 U	6.68	0.199	27.1	2.93	12.83	86	0.2 U
MW-607	7.1	1.3	82	1	2 U	6.64	0.172	35.7	4.06	13.11	140	0.2 U
MW-608	4.6	1.1	88	1	2 U	6.61	0.164	57.1	3.08	12.71	55	0.2 U
Overall Statistics												
Mean Conc.	8.0	4.2	102	1.1	2 U	6.62	0.208	54.1	2.67	12.59	59.4	0.2 U
Standard Dev.	10.4	3.1	23.3	0.3	0.0	0.1	0.0	44.6	1.05	0.6	57.2	0.0
Max Conc.	34	9	150	1.7	2 U	6.74	0.280	151	4.06	13.26	140	0.2 U
Min Conc.	1	1	72	0.5	2 U	6.45	0.164	11.7	0.69	11.65	-63	0.2 U
High Concentration Groundwater Plume Statistics (MW-600 through MW-605)												
Mean Conc.	7.9	5.8	110	0.9	2 U	6.6	0.223	61.2	2.33	12.44	-10.7	0.2 U
Standard Dev.	12.9	2.7	25.8	0.2	0.0	0.1	0.0	53.9	1.1	0.7	48.1	0.0
Max Conc.	34	9	150	1.1	2 U	6.74	0.280	151	4.02	13.26	64	0.2 U
Min Conc.	1	1.1	72	0.5	2 U	6.45	0.195	11.7	0.69	11.65	-63	0.2 U

Notes:
mg/L: milligrams per liter
sU: standard units
mS/cm: millisiemens per centimeter
NTU: nephalometric turbidity units
°C: degrees Celsius
mV: millivolts

Figures

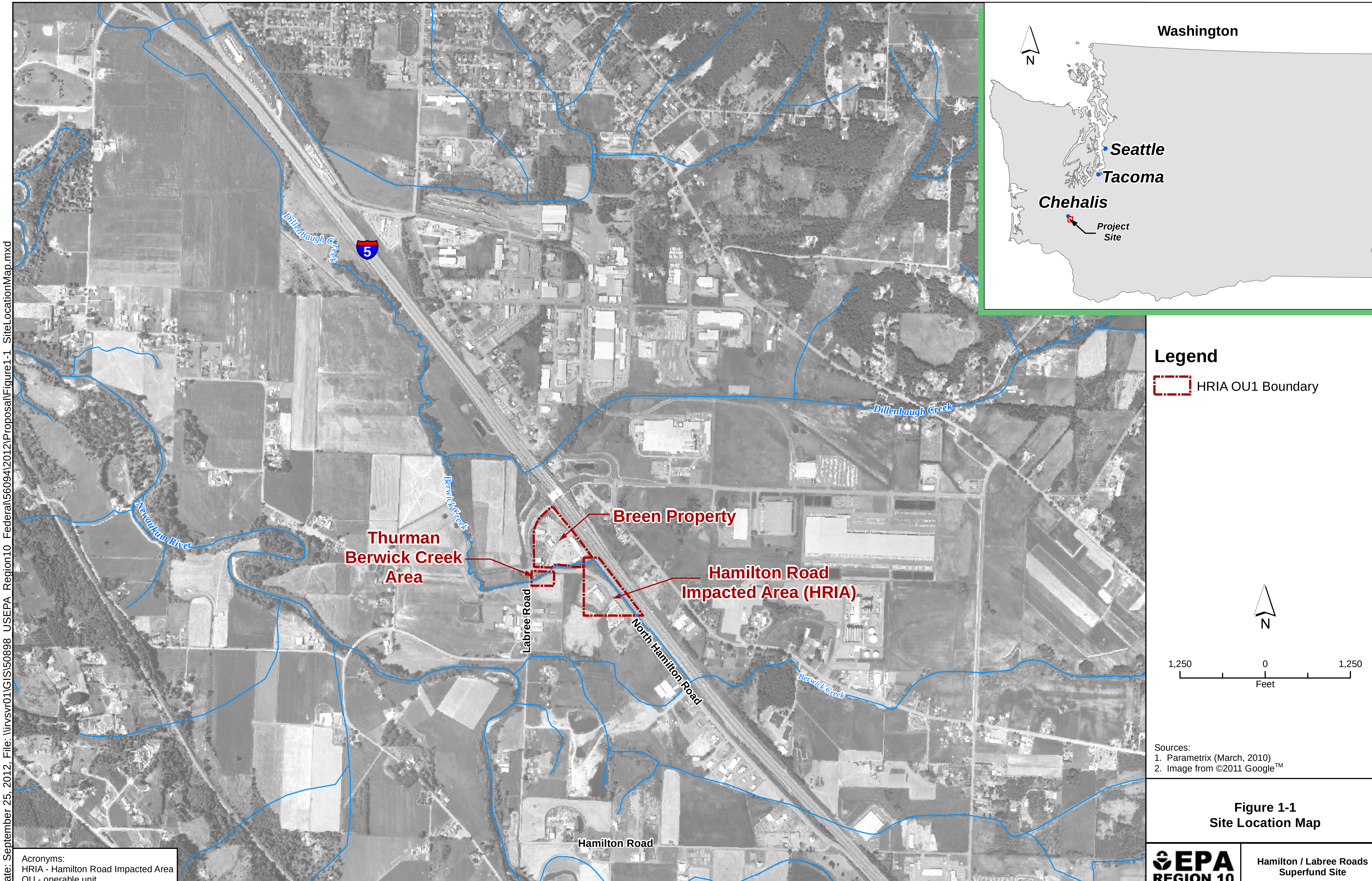
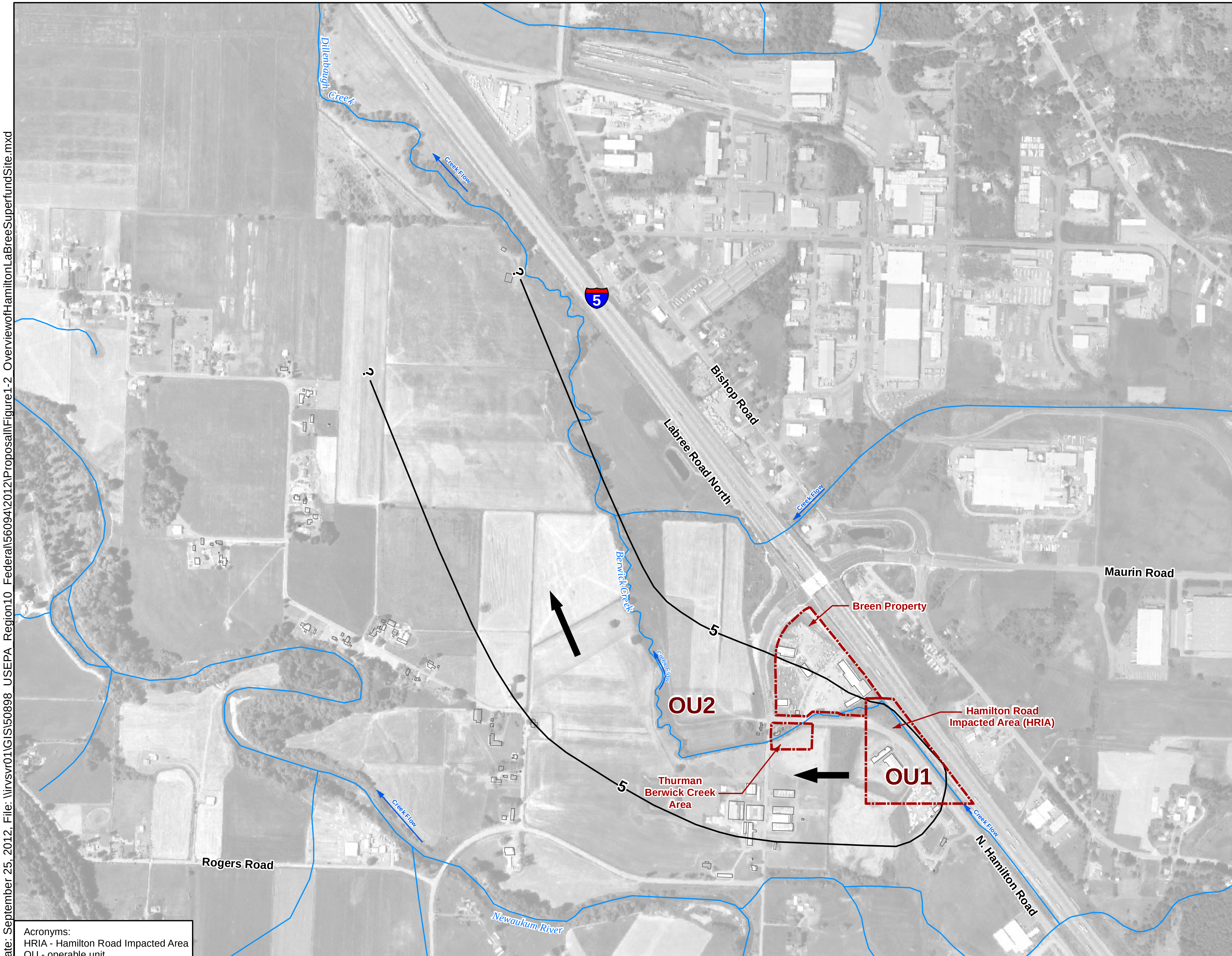


Figure 1-1
Site Location Map

Date: September 25, 2012, File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\Proposal\Figure1-1_SiteLocationMap.mxd

Date: September 25, 2012, File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\Proposal\Figure1-2_OverviewofHamiltonLaBreeSuperfundSite.mxd



Acronyms:
HRIA - Hamilton Road Impacted Area
OU - operable unit

Legend

HRIA OU1 Boundary

Estimated PCE Concentration Boundary (Dashed Where Inferred - Contour Values in ug/L)

Creek Flow Direction

Groundwater Flow Direction

OU1 – HRIA
OU2 - Includes the Breen Property, the Thurman Berwick Creek Area, and the area west and northwest of Labree Road

N

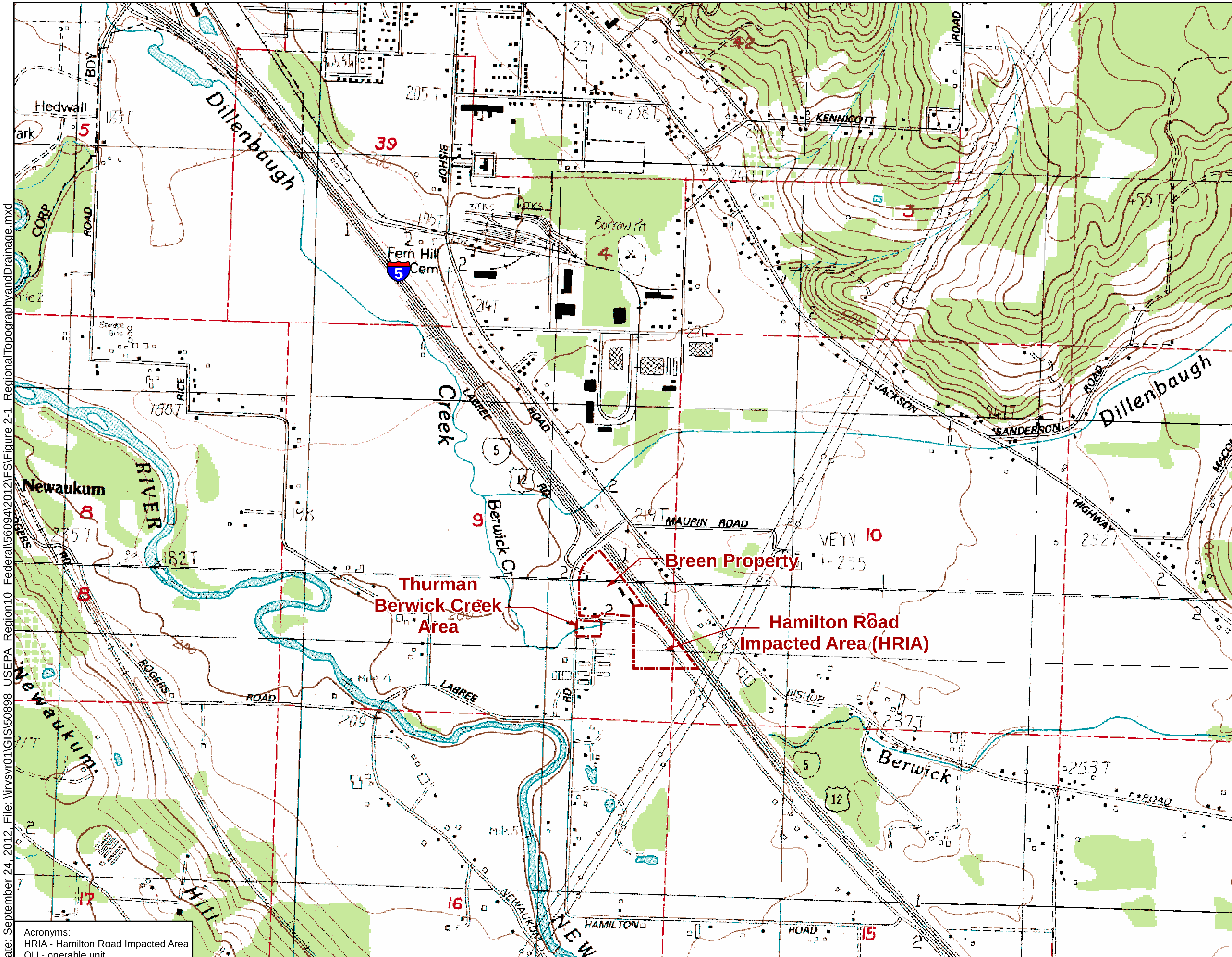
750 0 750
Feet

Sources:
1. Parametrix (March, 2010) [Ecology and Environment, Inc. 2002]
2. Image from ©2011 Google™

Figure 1-2
Overview of Hamilton/Labree Superfund Site

EPA REGION 10

Hamilton / Labree Roads Superfund Site



Acronyms:
HRIA - Hamilton Road Impacted Area
OU - operable unit

Legend

HRIA OU1 Boundary

N

1,250 0 1,250
Feet

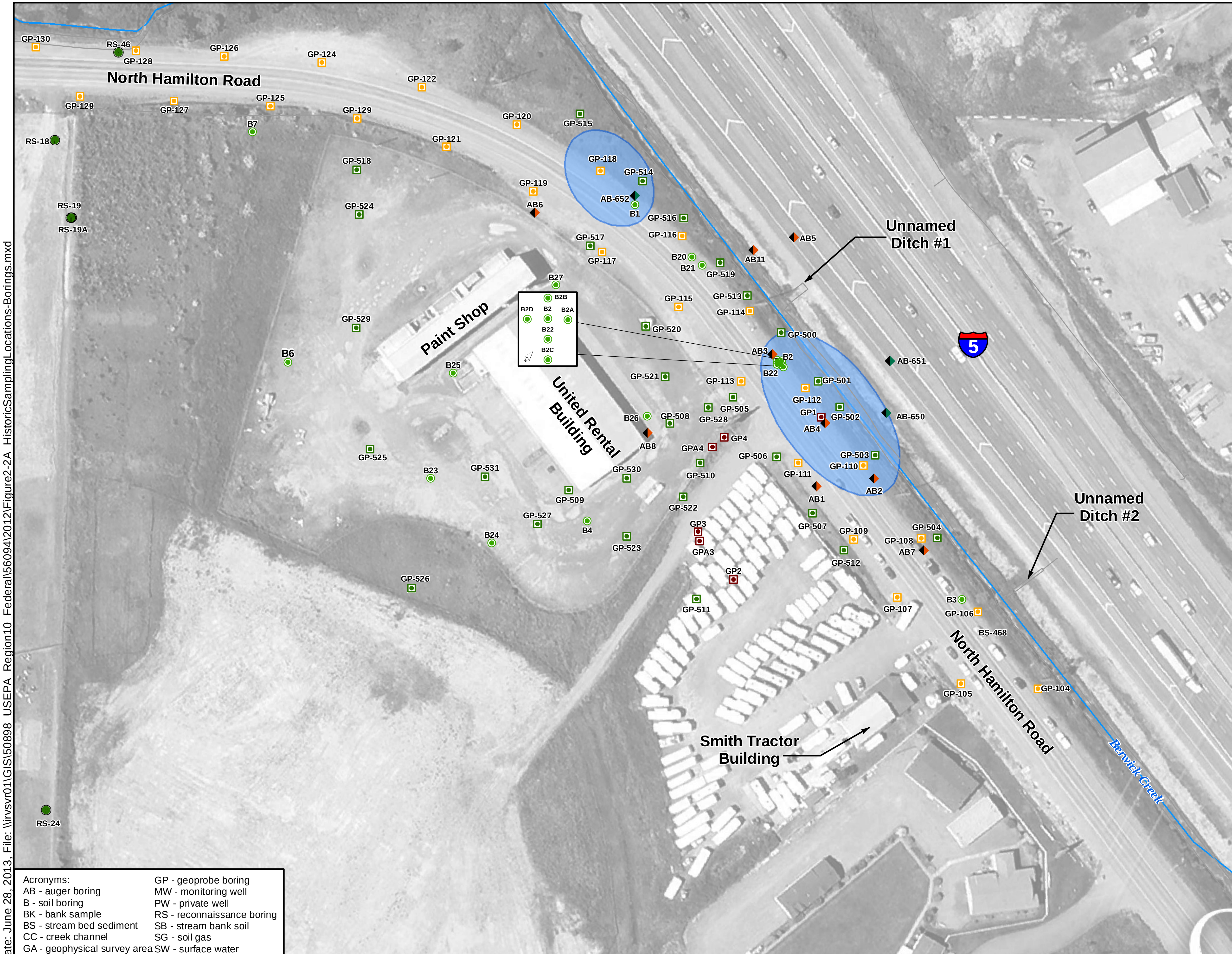
Sources:
1. Parametrix (March, 2010)
2. 7.5' USGS Quadrangle - Centralia, Washington. Dated 1985 and 7.5' USGS Quadrangle - Napavine, Washington. Dated 1985

Figure 2-1
Regional Topography and Drainage

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: September 24, 2012, File: \\irvsvr01\GIS\508898 USEPA Region10 Federal\56094\2012\FS\Figure 2-1 RegionalTopographyandDrainage.mxd



Legend

AB1	◆	Auger Boring (E&E 2000-2001)
AB-650	◆	Auger Boring (URS 2003)
B1	●	Soil Boring
GP1	▣	Geoprobe Boring (E&E 2000-2001; soil and water samples)
GP-104	▣	Geoprobe Boring (E&E 2000-2001; soil samples only)
GP-520	▣	Geoprobe Boring (URS 2003)
RS-18	●	Reconnaissance Boring
	⬭	Hot Spot

Sources:
1. Parametrix (March, 2010) [Ecology and Environment, Inc. 2002]
2. Image from ©2011 Google™

Acronyms:

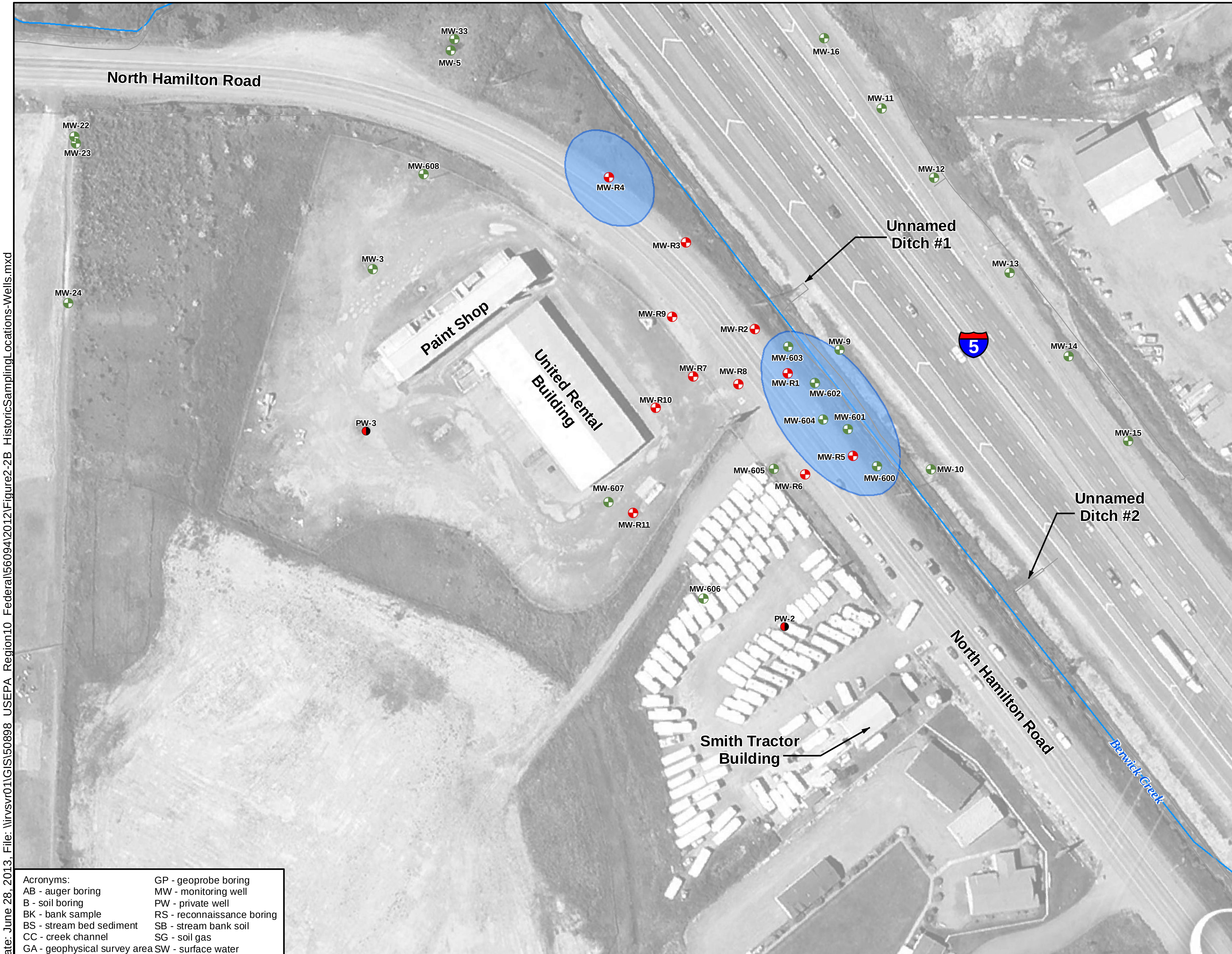
AB - auger boring	GP - geoprobe boring
B - soil boring	MW - monitoring well
BK - bank sample	PW - private well
BS - stream bed sediment	RS - reconnaissance boring
CC - creek channel	SB - stream bank soil
GA - geophysical survey area	SG - soil gas
	SW - surface water

Figure 2-2A
HRIA Historical Sampling Locations - Borings

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: June 28, 2013, File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\Figure2-2A_HistoricSamplingLocations-Borings.mxd



Acronyms:

AB - auger boring	GP - geoprobe boring
B - soil boring	MW - monitoring well
BK - bank sample	PW - private well
BS - stream bed sediment	RS - reconnaissance boring
CC - creek channel	SB - stream bank soil
GA - geophysical survey area	SG - soil gas
	SW - surface water

Legend

- MW-10 Monitoring Well
- MW-R5 Monitoring Well/Recovery Well
- PW-3 Private Well
- Hot Spot

N

100 0 100
Feet

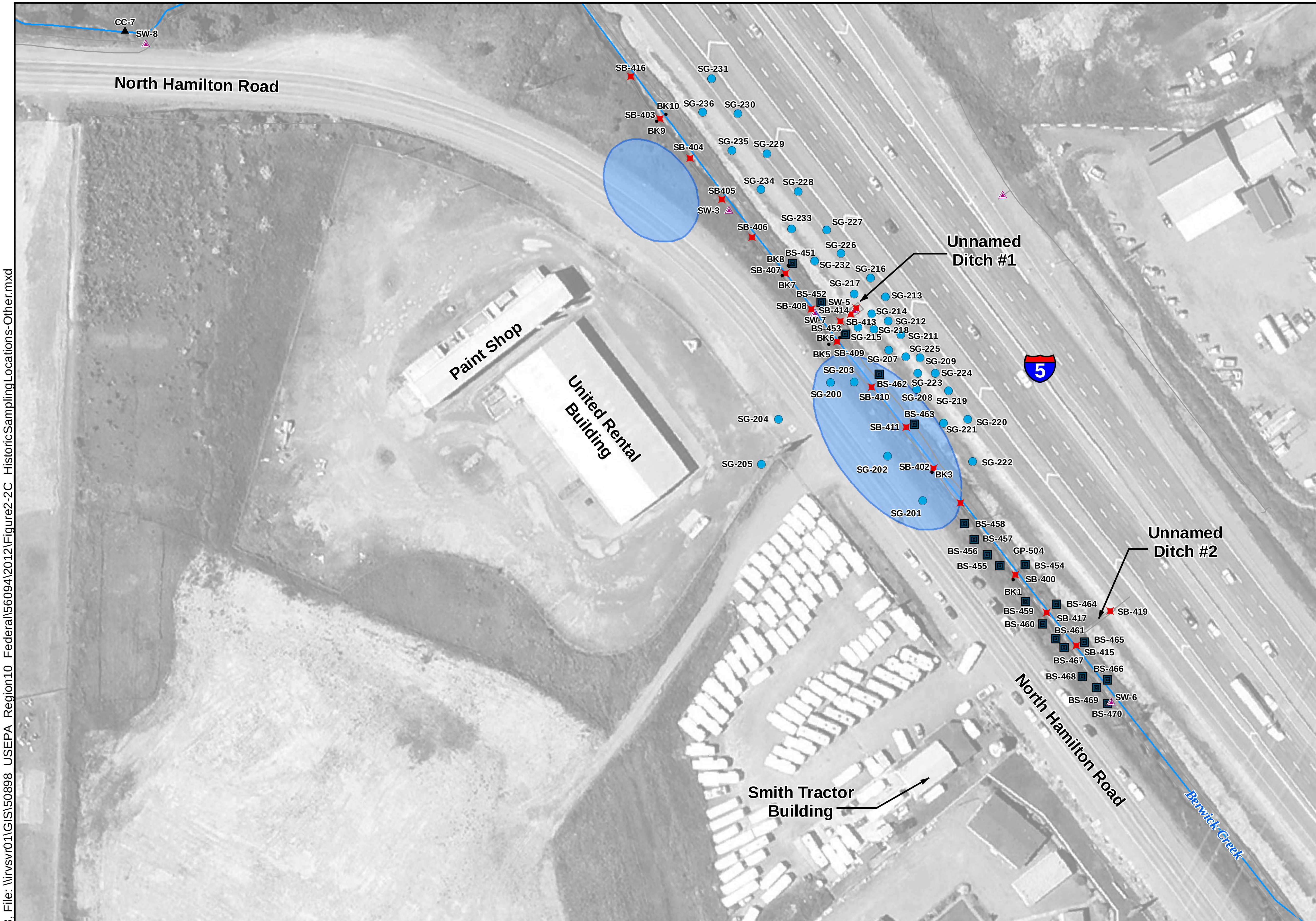
Sources:
1. Parametrix (March, 2010) [Ecology and Environment, Inc. 2002]
2. Image from ©2011 Google™

Figure 2-2B
HRIA Historical Sampling Locations - Wells

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: June 28, 2013, File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\Figure2-2B_HistoricSamplingLocations-Wells.mxd



Legend

BS-451	■	Stream Bed
CC-1	▲	Creek Channel
SB-400	✖	Stream Bank
SG1-20	●	Soil Gas
SG-225	●	Soil Gas
SW-5	△	Surface Water
BK10	•	Bank Sample
	⬭	Hot Spot

N

100 0 100

Feet

Sources:
1. Parametrix (March, 2010) [Ecology and Environment, Inc. 2002]
2. Image from ©2011 Google™

Acronyms:

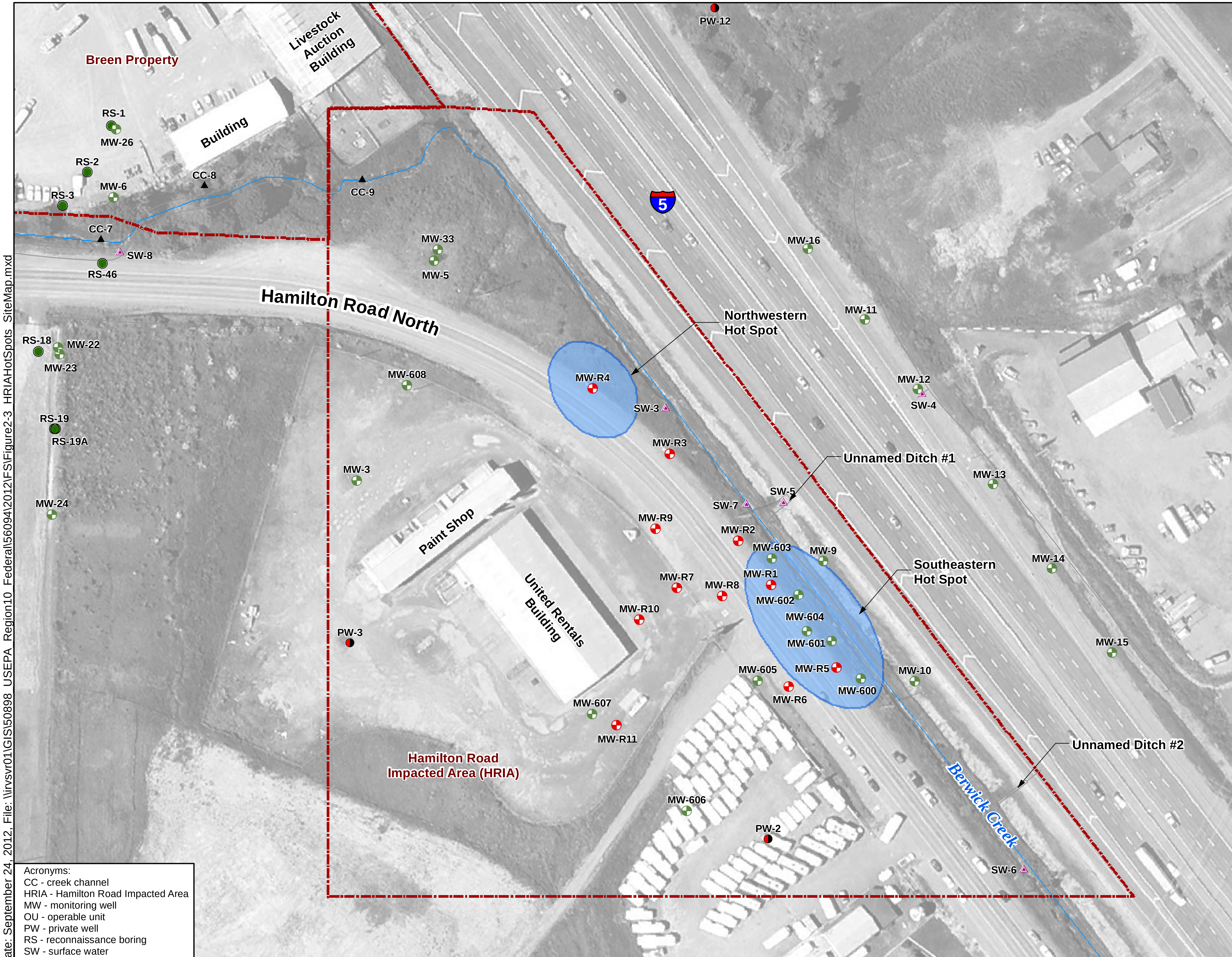
AB - auger boring	GP - geoprobe boring
B - soil boring	MW - monitoring well
BK - bank sample	PW - private well
BS - stream bed sediment	RS - reconnaissance boring
CC - creek channel	SB - stream bank soil
GA - geophysical survey area	SG - soil gas
	SW - surface water

Figure 2-2C
HRIA Historical Sampling Locations - Other

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: June 28, 2013, File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\Figure2-2C_HistoricSamplingLocations-Other.mxd



Date: September 24, 2012, File: \\irvsvr01\GIS\508898_USEPA_Region10_Federal\56094\2012\FS\Figure2-3_HRIAHotSpots_SiteMap.mxd

Legend

- HRIA OU1 Boundary
- Hot Spot
- Creek Channel
- Monitoring Well
- Monitoring Well/Recovery Well
- Private Well
- Reconnaissance Boring
- Surface Water

N

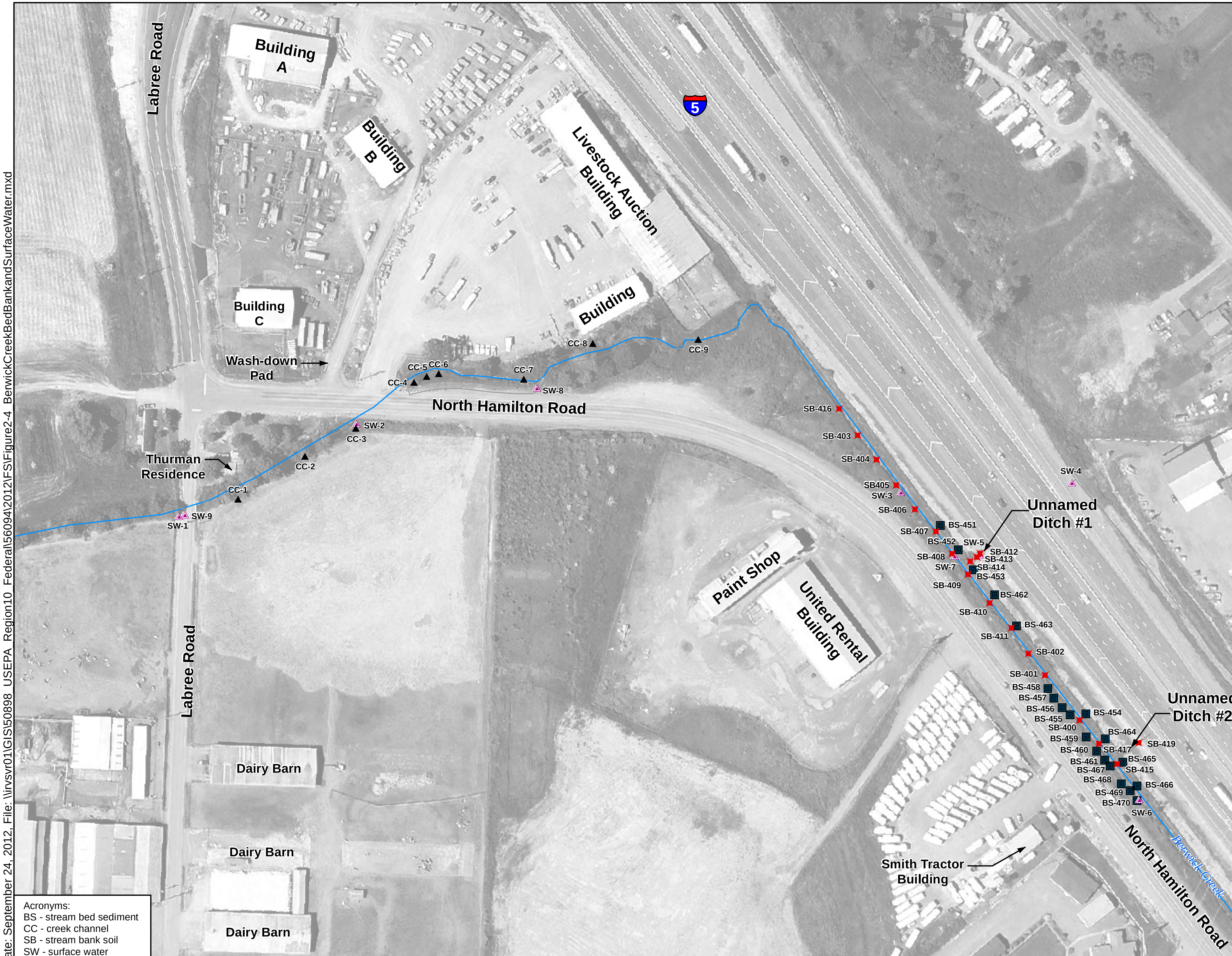
100 0 100
Feet

Sources:
1. Parametrix (March, 2010)
2. Image from ©2011 Google™

Figure 2-3
HRIA Hot Spots
Site Map

EPA REGION 10

Hamilton / Labree Roads Superfund Site



Acronyms:
BS - stream bed sediment
CC - creek channel
SB - stream bank soil
SW - surface water

Legend

BS-451	■	Stream Bed
CC-1	▲	Creek Channel
SB-416	✖	Stream Bank
SW-7	△	Surface Water

N

150 0 150
Feet

Sources:
1. Parametrix (March, 2010) [Ecology and Environment, Inc. 2002]
2. Image from ©2011 Google™

Figure 2-4
Berwick Creek Bed, Bank and Surface Water Sampling Locations

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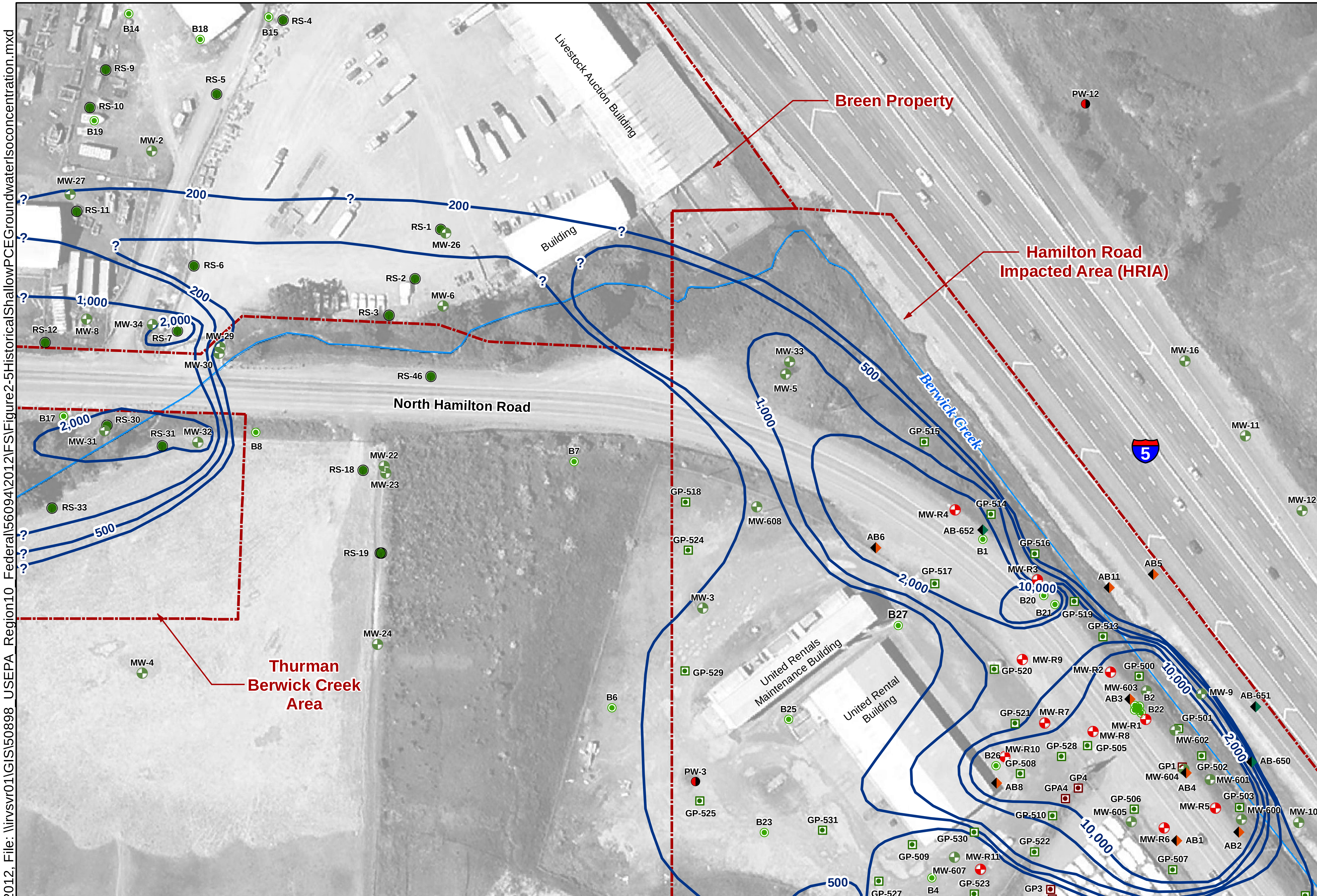
Hamilton / Labree Roads Superfund Site

Date: September 24, 2012, File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\FS\Figure2-4_BerwickCreekBedBankandSurfaceWater.mxd

Date: September 24, 2012, File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\FS\Figure2-5HistoricalShallowPCEGroundwaterIsoconcentration.mxd



Legend

- HRIA OU1 Boundary
- 200 — Historical Groundwater Shallow (<= 25 feet depth) for PCE Isoconcentration in ug/L
- Auger Boring (E&E 2000-2001)
- Auger Boring (URS 2003)
- Soil Boring
- Monitoring Well
- Monitoring Well/Recovery Well
- Private Well
- Reconnaissance Boring
- Shallow Soil Boring
- Geoprobe Boring (E&E 2000-2001; soil and water samples)
- Geoprobe Boring (URS 2003)

N

100 0 100
Feet

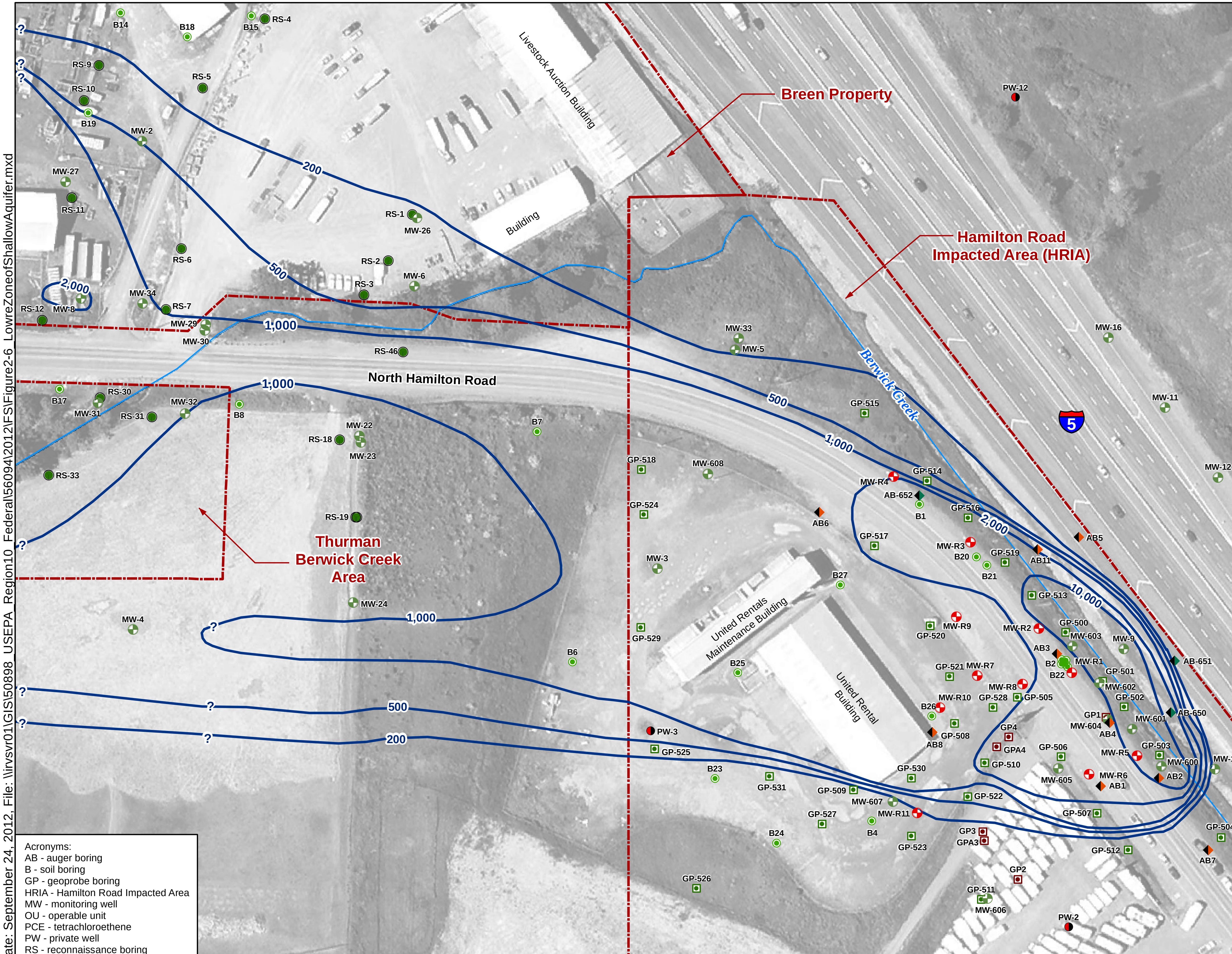
Notes:
1. Contours are based on maximum groundwater concentrations and do not represent a single time-specific sampling event
2. Image from ©2011 Google[TM]

Acronyms:
AB - auger boring
B - soil boring
GP - geoprobe boring
HRIA - Hamilton Road Impacted Area
MW - monitoring well
OU - operable unit
PW - private well
RS - reconnaissance boring

Figure 2-5
Hamilton / Labree
Upper Zone of Shallow Aquifer
PCE Isoconcentration Plot - Historical

EPA REGION 10

Hamilton / Labree Roads Superfund Site



Date: September 24, 2012, File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\FS\Figure2-6_LowreZoneofShallowAquifer.mxd

Acronyms:
AB - auger boring
B - soil boring
GP - geoprobe boring
HRIA - Hamilton Road Impacted Area
MW - monitoring well
OU - operable unit
PCE - tetrachloroethene
PW - private well
RS - reconnaissance boring

Legend

- HRIA OU1 Boundary
- 200 — Historical Groundwater Deep (> 25 feet depth) for PCE Isoconcentration in ug/L
- Auger Boring (E&E 2000-2001)
- Auger Boring (URS 2003)
- Soil Boring
- Monitoring Well
- Monitoring Well/Recovery Well
- Private Well
- Reconnaissance Boring
- Geoprobe Boring (E&E 2000-2001; soil and water samples)
- Geoprobe Boring (URS 2003)

N

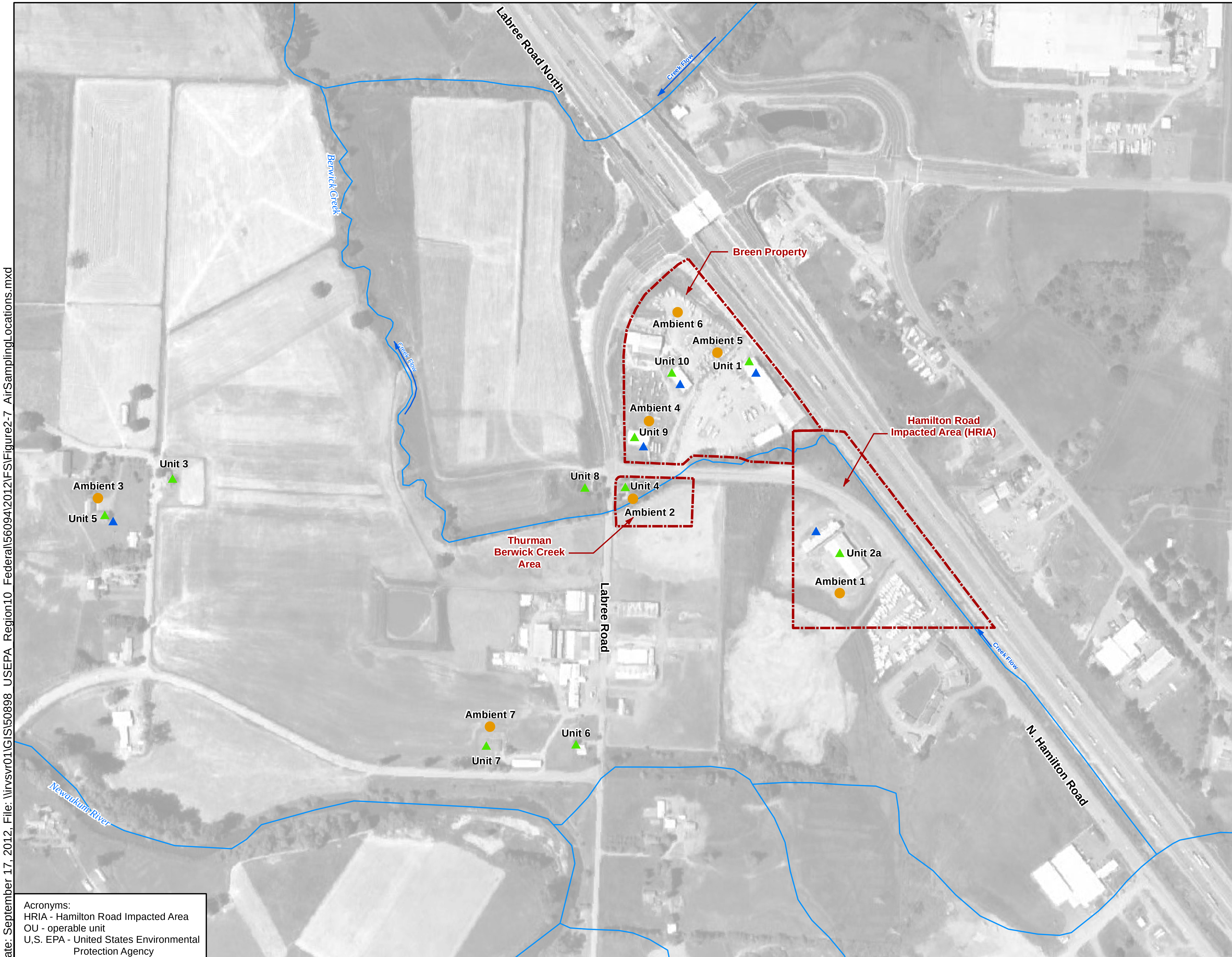
100 0 100
Feet

Notes:
1. PCE concentrations for some wells were ignored due to the sample being located in a transition zone between the shallow and deep zones of the shallow aquifer. It is presumed that these locations underestimate true maximum concentrations in the deep zone, especially downgradient of the United Rentals Building.
2. Contours are based on maximum groundwater concentrations and do not represent a single time-specific sampling event.
3. Image from ©2011 Google™

Figure 2-6
Hamilton / Labree Lower Zone of Shallow Aquifer
PCE Isoconcentration Plot - Historical

EPA REGION 10

Hamilton / Labree Roads Superfund Site



Legend

- HRIA OU1 Boundary
- Sub-Slab Sample
- Indoor Air Sample
- Ambient Air Sample

N

400 0 400
Feet

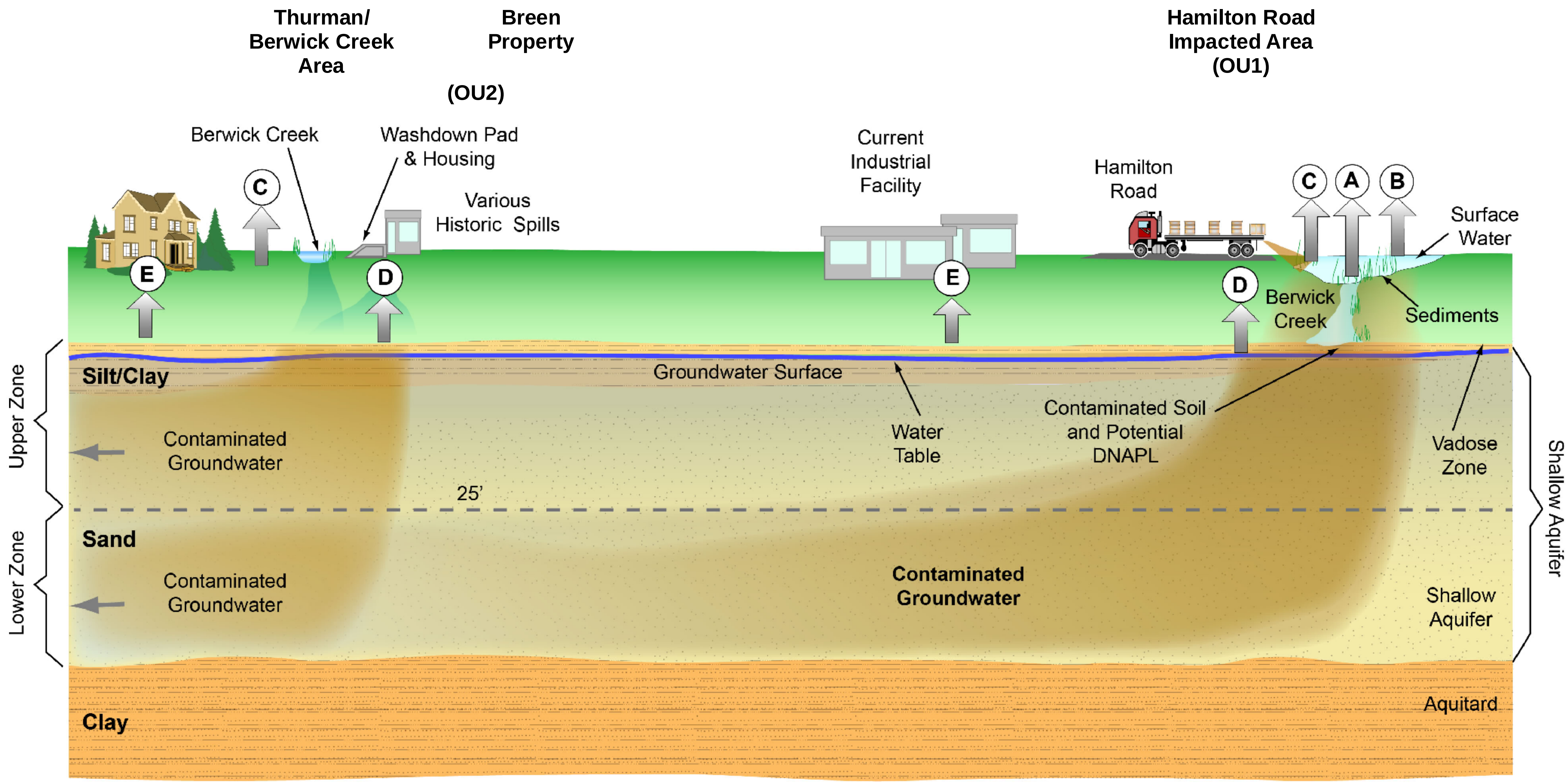
Sources:
1. U.S. EPA Environmental Response Team [EP_C-04-032]
2. Image from ©2011 Google™

Figure 2-7
Ambient Air and
Soil Vapor Sample Locations

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: September 17, 2012, File: \\irvsvr01\GIS\S50898_USEPA_Region10_Federal\56094\2012\FS\Figure2-7_AirSamplingLocations.mxd



Legend

A - Sediment – Ingestion/Direct Contact (Residential, Aquatic, Terrestrial)
B - Surface Water – Ingestion/Direct Contact (Residential, Aquatic, Terrestrial)
C - Outdoor Air – Inhalation (Residential, Terrestrial)
D - **Groundwater –** Ingestion (Occupational, Residential)
E - Indoor Air – Inhalation (Occupational, Residential)

Groundwater flows from right to left, and slightly into the figure (west-northwest).
The two groundwater plumes commingle down gradient of the sources.

North is into page

Not to scale

Acronyms:
OU - operable unit

Figure 2-8
Conceptual Model

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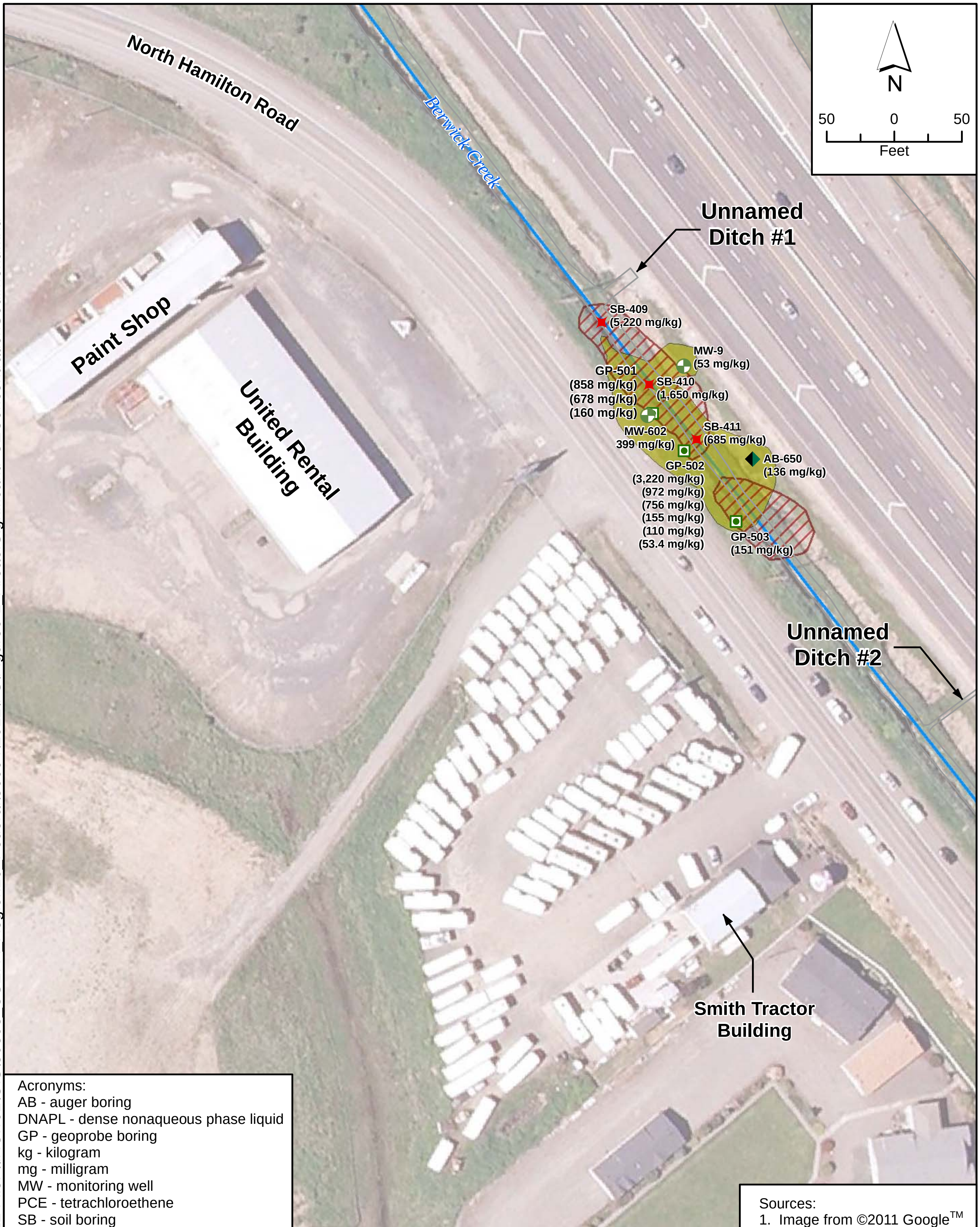
Hamilton / Labree Roads Superfund Site

Date: September 24, 2012, File: \\irvsvr01\GIS\508898_USEPA_Region10_Federal\56094\2012\FS\Figure2-8_ConceptualGroundwater.mxd

Date: September 17, 2012 File: \\irvsvr01\GIS\50898 USEPA Region10 Federal\56094\2012\FS\Figure6-1 AreaofSignificantPCEConcentrationSediment.mxd



Legend

- Subsurface Soil Remediation Zone (PCE greater than 10 mg/kg)
- Creek Bed Sediment/Bank Surface Soil Remediation Zone (PCE greater than 0.468 mg/kg)
- Subsurface Soil Sample Location Containing DNAPL
- Creek Bed Sediment Sample Location Containing DNAPL
- Auger Boring (URS / EPA, 2003)
- Monitoring Well (MW-602: URS / EPA, 2003) and (MW-9: E & E / EPA (Start, 2000 - 2001))

Figure 3-1
Creek Bed Sediment/Bank Soil and Subsurface Soil PCE Target Remediation Zones

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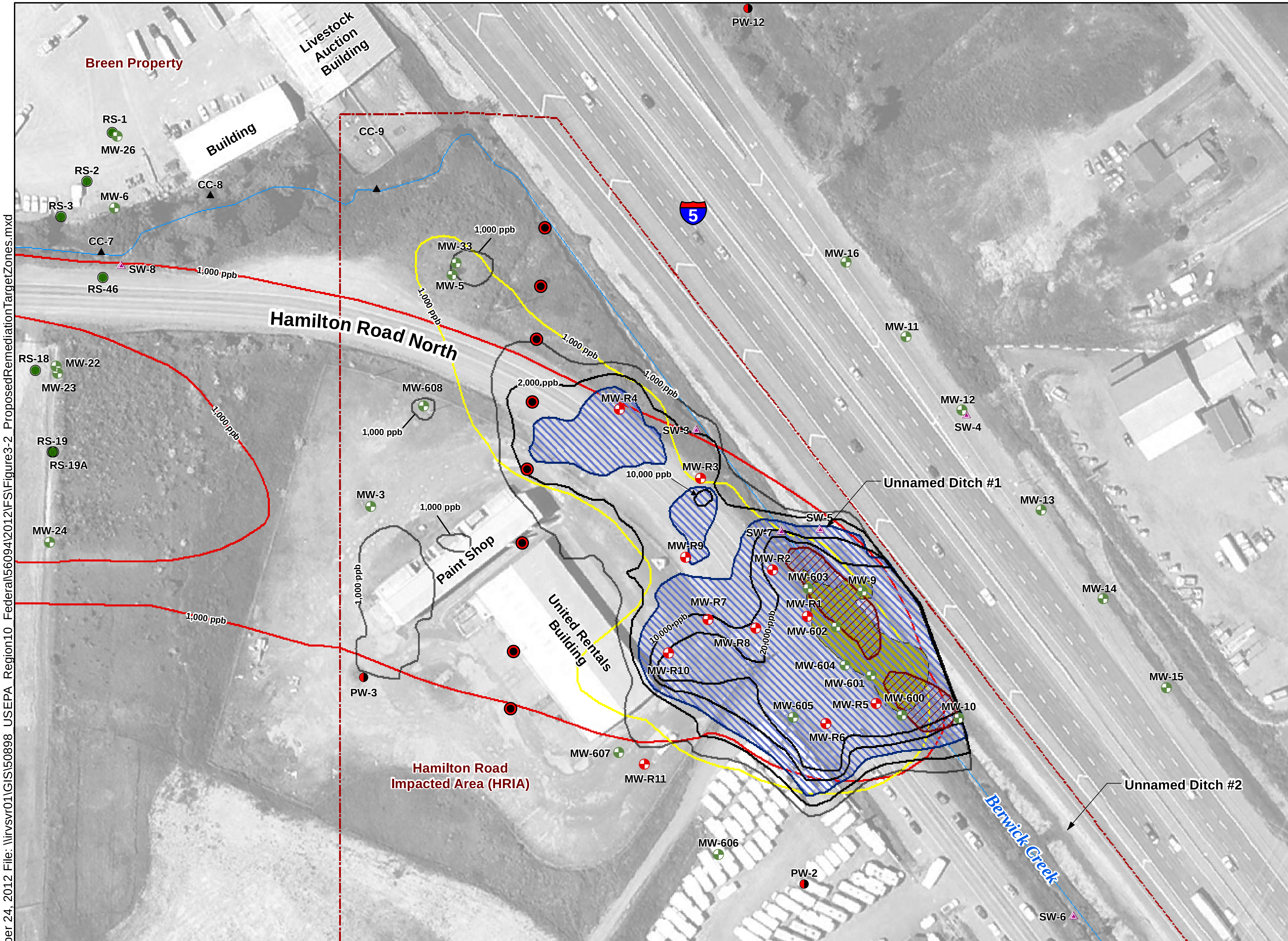

Legend

- HRIA OU1 Boundary
- Creek Bed Sediment/ Bank Surface Soil Remediation Zone (PCE greater than 0.468 mg/kg) (Area: 7,348 sq. ft.)
- Subsurface Soil Remediation Zone (PCE greater than 10 mg/kg) (Area: 9,450 sq. ft.)
- High Concentration Groundwater Remediation Zone (PCE greater than 4,000 ug/L) (Area: 69,438 sq. ft.)
- PCE Isoconcentration Contour in Shallow Groundwater (<=25 feet depth) Using Historical Maximum Values[1]
- PCE Isoconcentration Contour in Deep Groundwater (>25 feet depth) Using Historical Maximum Values[2]
- MVS-Modelled 1,000 ppb PCE Isoconcentration Contour[3] (Area: 158,000 sq. ft.)
- MVS-Modelled 2,000 ppb PCE Isoconcentration Contour[3] (Area: 95,731 sq. ft.)
- MVS-Modelled 10,000 ppb PCE Isoconcentration Contour[3] (Area: 47,421 sq. ft.)
- MVS-Modelled 20,000 ppb PCE Isoconcentration Contour[3] (Area: 36,260 sq. ft.)
- Mass Discharge Performance Monitoring Location
- Creek Channel Soil Sample
- Monitoring Well
- Monitoring Well/Recovery Well
- Private Well
- Reconnaissance Boring
- Surface Water

N

100 0 100

Feet

Sources:
1. Image from ©2011 Google™

Figure 3-2
Proposed Remediation Target Zones

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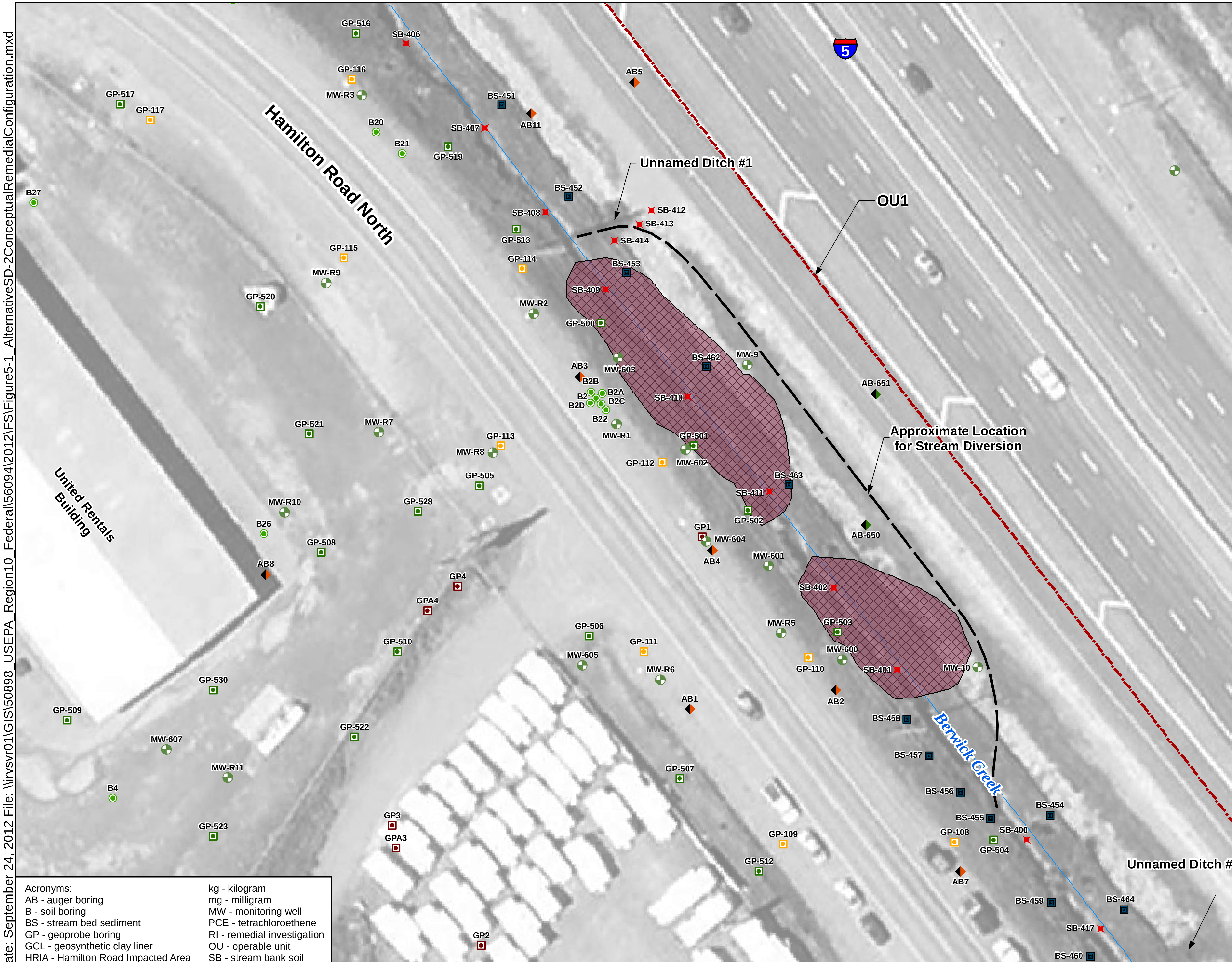
Notes:
1. Shallow aquifer contour from Remedial Investigation (CDM Smith, September 2011) showing maximum historic values.
2. Deep aquifer contour from Remedial Investigation (CDM Smith, September 2011) showing maximum historic values.
3. MVS modeled contours using only the most recent available data from a given locations (Appendix A).

Acronyms:
MVS - mining visualization system
HRIA - Hamilton Labree Impact Area
OU1 - Operable Unit 1
mg - milligram
MW - monitoring well
kg - kilogram
sq - square
ft - feet
ug - microgram
L - liter
PCE - tetrachloroethene
PW - private well
SW - surface water
CC - creek channel
RS - reconnaissance boring

Date: September 24, 2012 File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\FS\Figure3-2_ProposedRemediationTargetZones.mxd



Legend

- HRIA OU1 Boundary
- Area of Creek Bed Sedimentary / Soil Removal Replaced by Stream Habitat Underlain by GCL
- Creek Bed Sediments/Bank Surface Soil Remediation Zone (PCE greater than 0.468 mg/kg)
- Stream Diversion
- AB5 Auger Boring
- AB-651 Auger Boring
- B2 Soil Boring
- BS-462 Stream Bed
- GP3 Geoprobe Boring
- GP-111 Geoprobe Boring
- GP-511 Geoprobe Boring
- MW-13 Monitoring Well
- SB-411 Stream Bank

N

40 0 40
Feet

Notes:
1. Image from ©2011 Google[TM]
2. Developed from CDM Smith RI Report (2011).

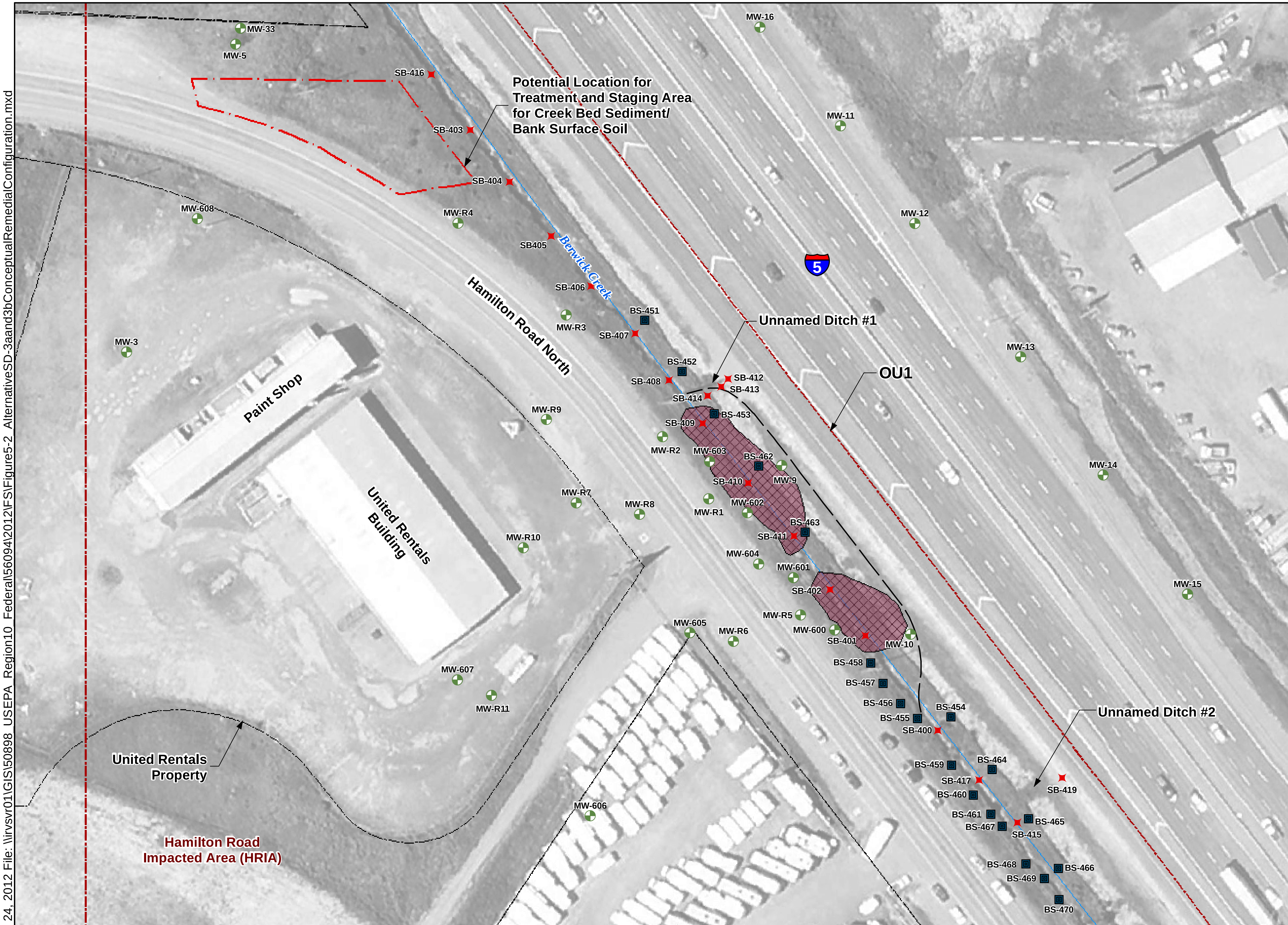
Acronyms:
AB - auger boring
B - soil boring
BS - stream bed sediment
GP - geoprobe boring
GCL - geosynthetic clay liner
HRIA - Hamilton Road Impacted Area
kg - kilogram
mg - milligram
MW - monitoring well
PCE - tetrachloroethene
RI - remedial investigation
OU - operable unit
SB - stream bank soil

Figure 5-1
Alternative SD-2
Conceptual Remedial Configuration

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: September 24, 2012 File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\FS\Figure5-1_AlternativeSD-2ConceptualRemedialConfiguration.mxd



Acronyms:

BS - stream bed sediment
GCL - geosynthetic clay liner
HRIA - Hamilton Road Impacted Area
kg - kilogram
mg - milligram
MW - monitoring well
OU - operable unit
PCE - tetrachloroethene
RI - remedial investigation
SB - stream bank soil

Legend

- HRIA OU1 Boundary
- Area of Creek Bed Sedimentary /Bank Surface Removal Replaced by Stream Habitat Underlain by GCL
- Creek Bed Sediments/Bank Surface Soil Remediation Zone (PCE greater than 0.468 mg/kg)
- Potential Location for Treatment and Staging Area for Creek Bed Sediment/ Bank Surface Soil
- Stream Diversion
- BS-462 Stream Bed
- MW-13 Monitoring Well
- SB-411 Stream Bank

N

50 0 50

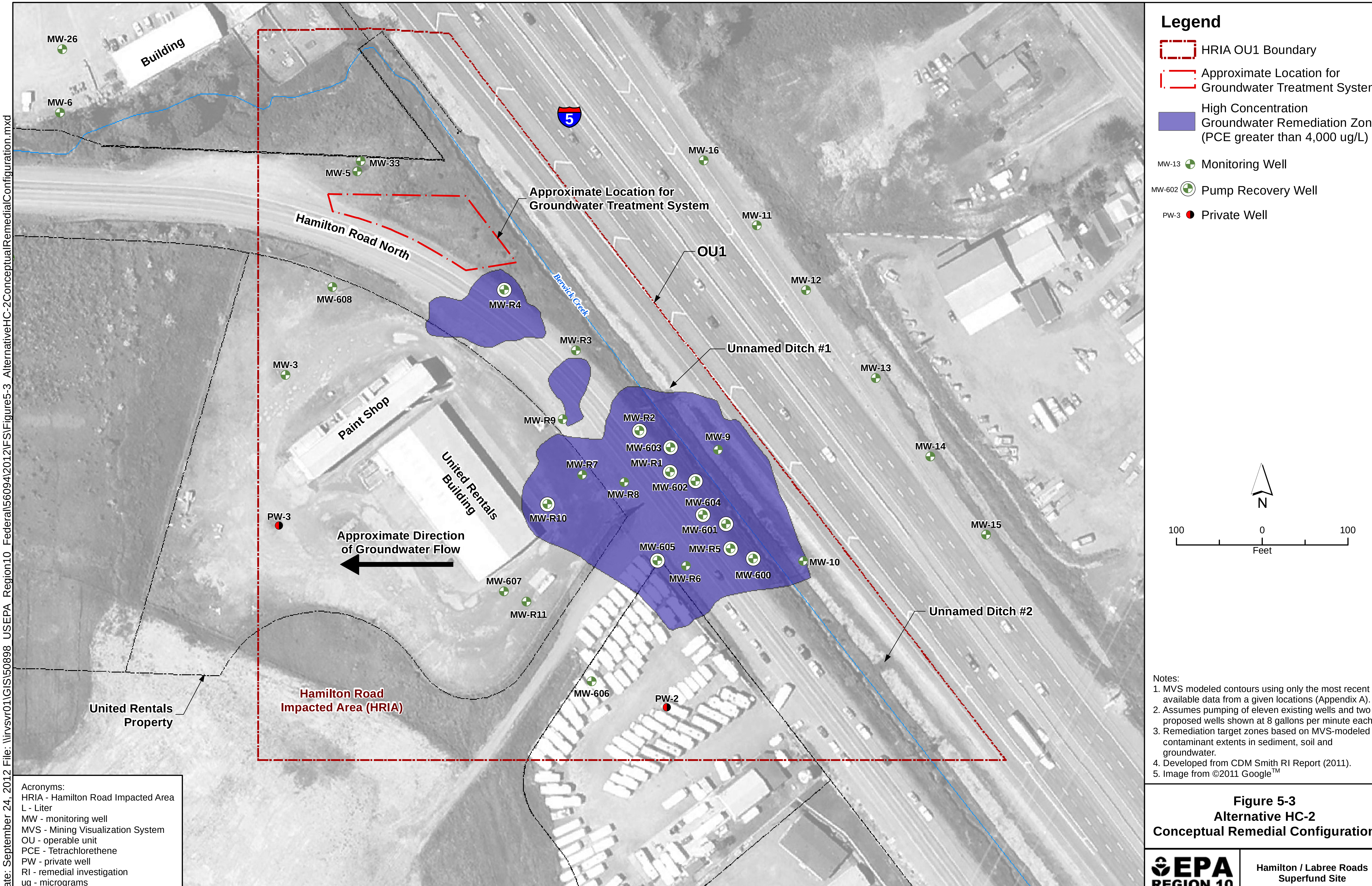
Feet

Notes:
1. Image from ©2011 Google™
2. Developed from CDM Smith RI Report (2011).

Figure 5-2
Alternative SD-3a and SD-3b Conceptual Remedial Configuration

EPA REGION 10

Hamilton / Labree Roads Superfund Site



Notes:
1. MVS modeled contours using only the most recent available data from a given locations (Appendix A).
2. Assumes pumping of eleven existing wells and two proposed wells shown at 8 gallons per minute each.
3. Remediation target zones based on MVS-modeled contaminant extents in sediment, soil and groundwater.
4. Developed from CDM Smith RI Report (2011).
5. Image from ©2011 Google™

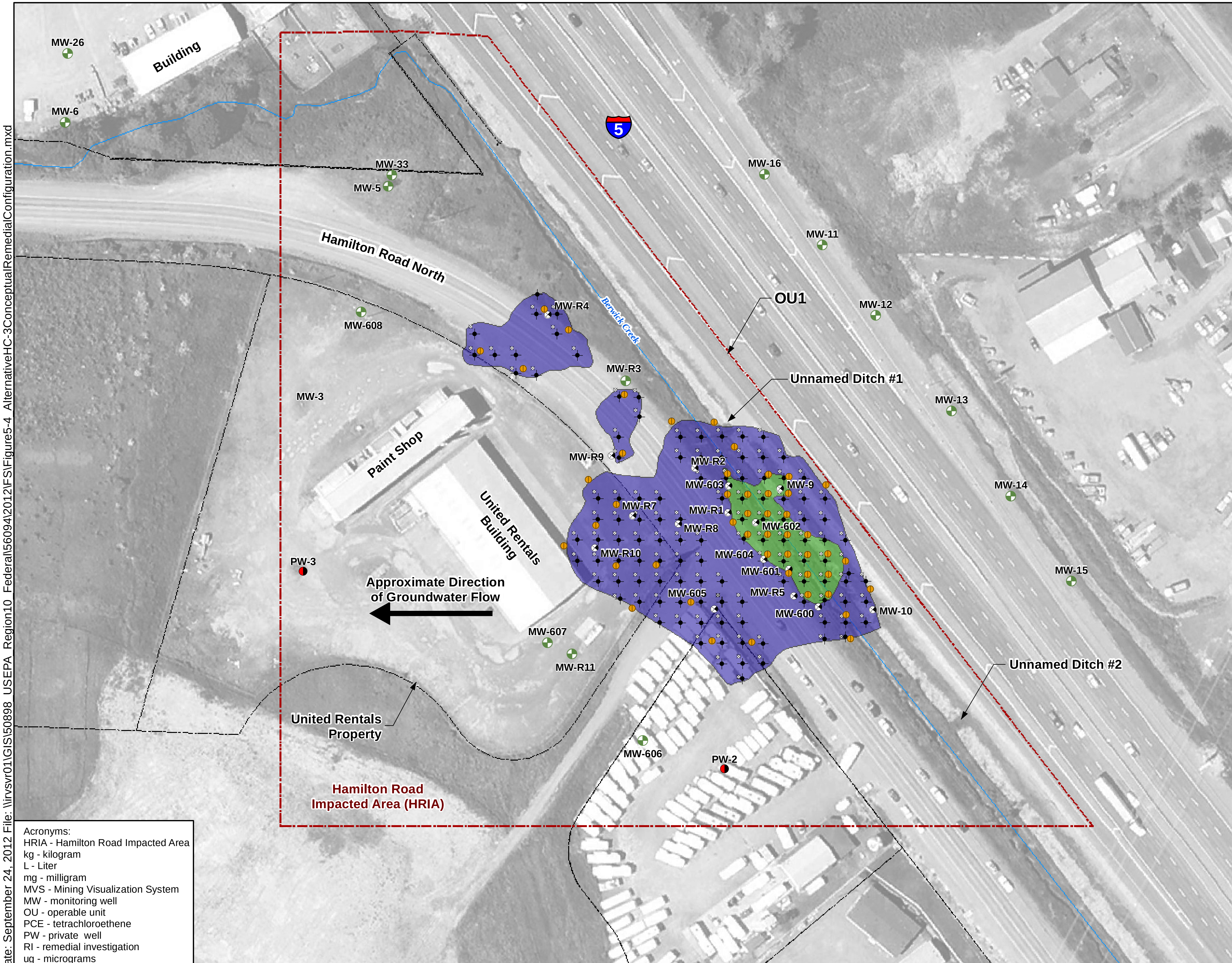
Acronyms:
HRIA - Hamilton Road Impacted Area
L - Liter
MW - monitoring well
MVS - Mining Visualization System
OU - operable unit
PCE - Tetrachlorethene
PW - private well
RI - remedial investigation
ug - micrograms

Figure 5-3
Alternative HC-2
Conceptual Remedial Configuration

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: September 24, 2012 File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\FS\Figure5-3_AlternativeHC-2ConceptualRemedialConfiguration.mxd



Acronyms:
HRIA - Hamilton Road Impacted Area
kg - kilogram
L - Liter
mg - milligram
MVS - Mining Visualization System
MW - monitoring well
OU - operable unit
PCE - tetrachloroethene
PW - private well
RI - remedial investigation
ug - micrograms

Legend

HRIA OU1 Boundary
High Concentration Groundwater Remediation Zone (PCE greater than 4,000 ug/L)
Subsurface Soil Remediation Zone (PCE greater than 10 mg/kg)
MW-13 Monitoring Well
PW-3 Private Well
Abandoned Monitoring Well
Vapor Recovery Well*
Thermal Heating Electrodes*
Temperature Monitoring Point*

N

100 0 100
Feet

Notes:
1. MVS modeled contours using only the most recent available data from a given locations (Appendix A).
2. Monitoring wells and recovery wells located within the plume will be abandoned prior to implementation of ERH.
3. Remediation target zones based on MVS-modeled contaminant extents in sediment, soil and groundwater.
4. * = Locations approximate, exact locations to be determined by contractor.
5. Developed from CDM Smith RI Report (2011).
6. Image from ©2011 Google™

Figure 5-4
Alternative HC-3
Conceptual Remedial Configuration

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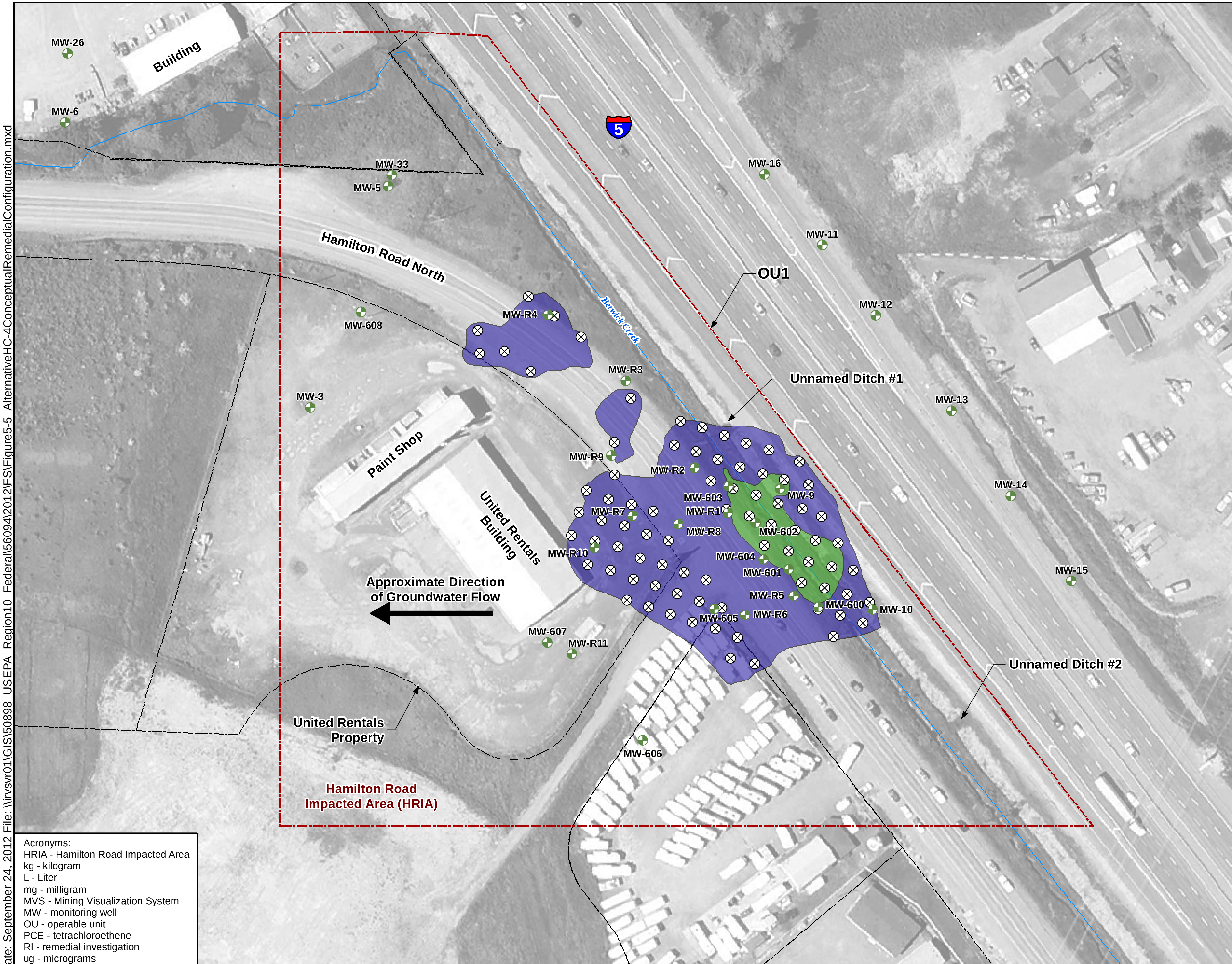
Hamilton / Labree Roads Superfund Site

Date: September 24, 2012 File: \\irvsvr01\GIS\50898 USEPA Region10 Federal\56094\2012\FS\Figure5-4 AlternativeHC-3ConceptualRemedialConfiguration.mxd



Acronyms:
HRIA - Hamilton Road Impacted Area
kg - kilogram
L - Liter
mg - milligram
MVS - Mining Visualization System
MW - monitoring well
OU - operable unit
PCE - tetrachloroethene
RI - remedial investigation
ug - micrograms

Legend

- HRIA OU1 Boundary
- High Concentration Groundwater Remediation Zone (PCE greater than 4,000 ug/L)
- Subsurface Soil Remediation Zone (PCE greater than 10 mg/kg)
- MW-13 Monitoring Well
- Oxidant Injection Locations*

N

100 0 100
Feet

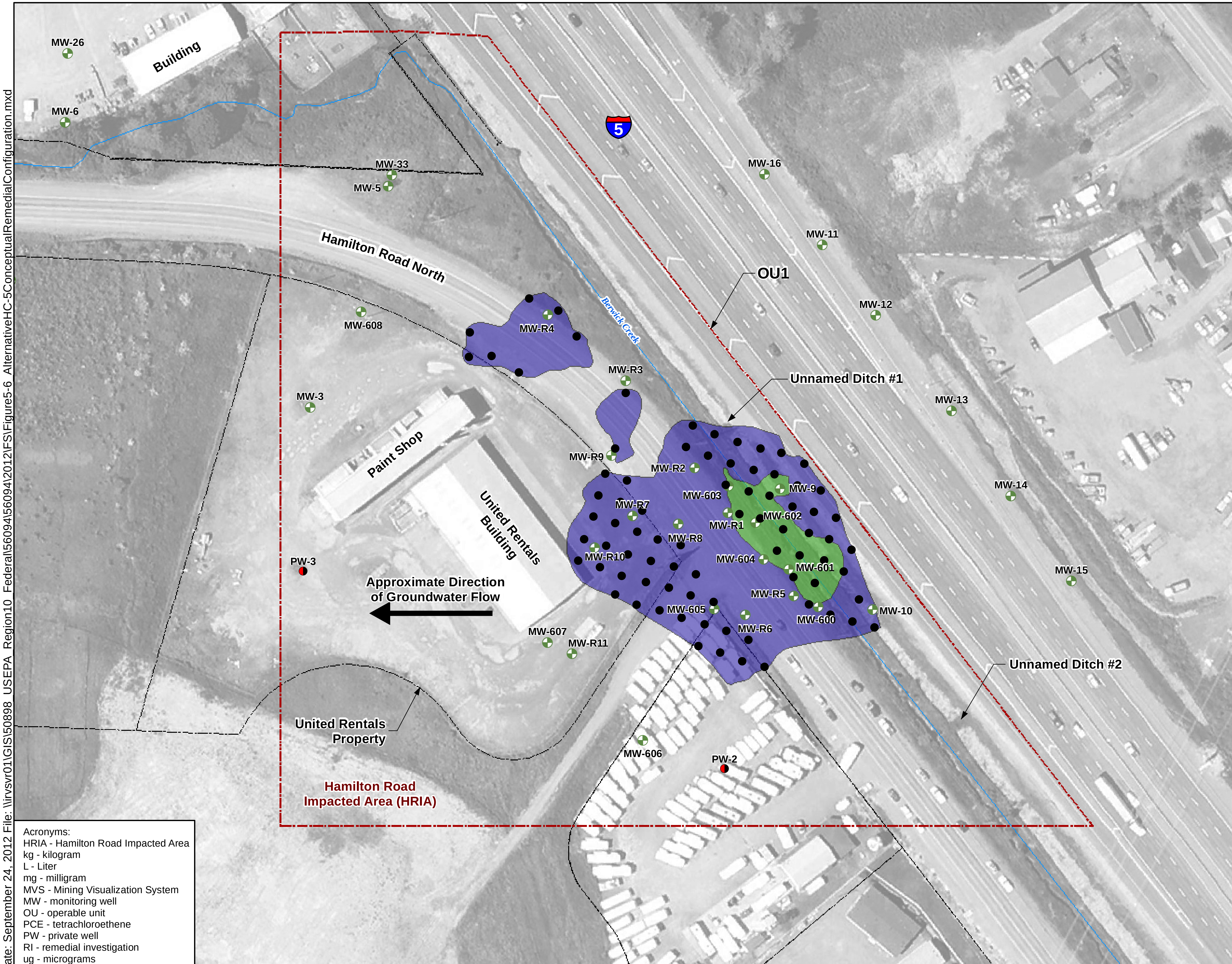
Notes:
1. MVS modeled contours using only the most recent available data from a given locations (Appendix A).
2. * = Locations approximate, exact locations to be determined by contractor.
3. Remediation target zones based on MVS-modeled contaminant extents in sediment, soil and groundwater.
4. Developed from CDM Smith RI Report (2011).
6. Image from ©2011 Google[TM]

Figure 5-5
Alternative HC-4
Conceptual Remedial Configuration

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: September 24, 2012 File: \\irvsvr01\GIS\50898 USEPA Region10 Federal\56094\2012\FS\Figure5-5 AlternativeHC-4ConceptualRemedialConfiguration.mxd



Legend

- HRIA OU1 Boundary
- High Concentration Groundwater Remediation Zone (PCE greater than 4,000 ug/L)
- Subsurface Soil Remediation Zone (PCE greater than 10 mg/kg)
- MW-13 Monitoring Well
- PW-3 Private Well
- Bioremediation Injection Wells*

N

100 0 100
Feet

Notes:
1. MVS modeled contours using only the most recent available data from a given locations (Appendix A).
2. Locations approximate, exact locations to be determined by contractor.
3. Remediation target zones based on MVS-modeled contaminant extents in sediment, soil and groundwater.
4. Developed from CDM Smith RI Report (2011).
5. Image from ©2011 Google[TM]

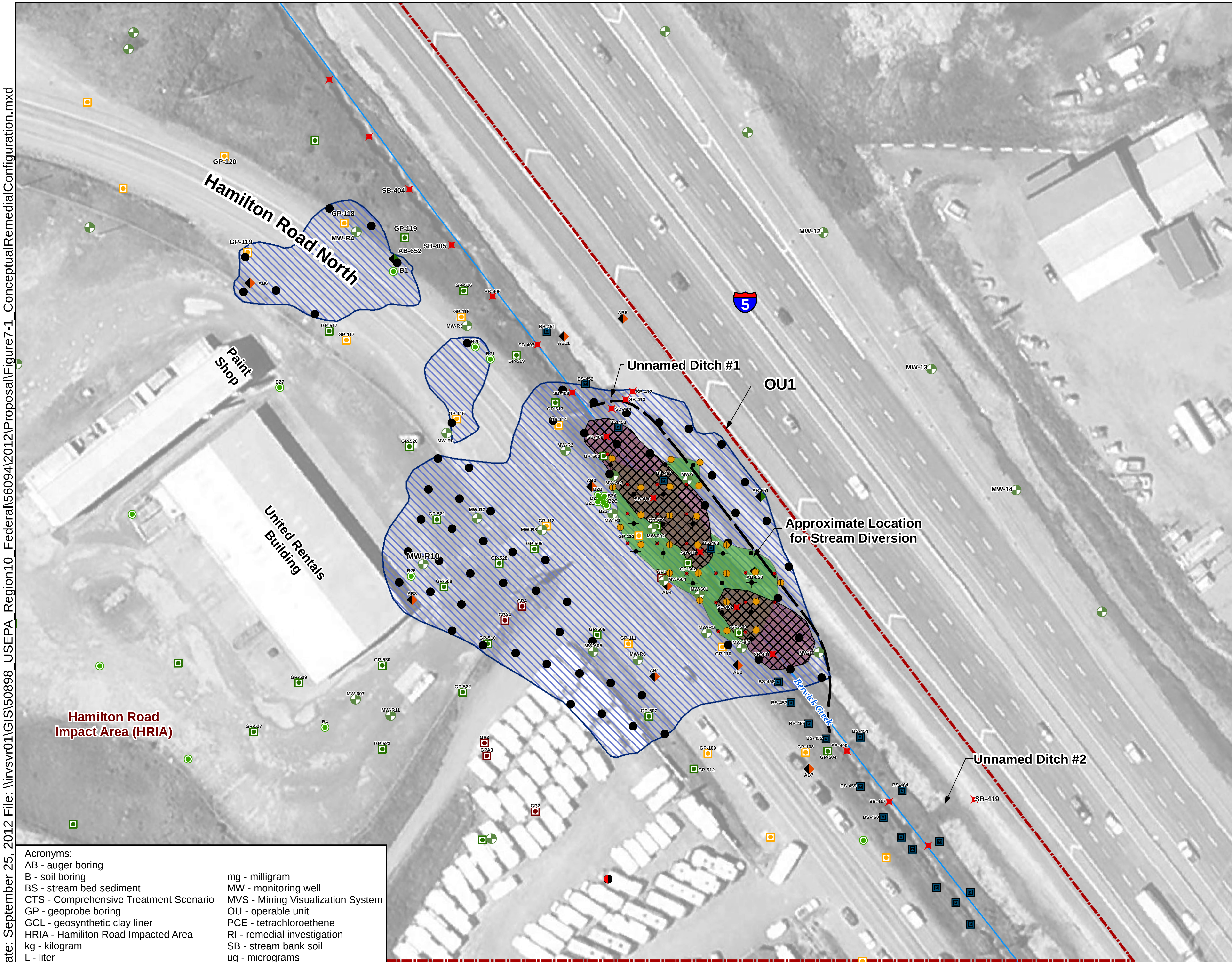
Acronyms:
HRIA - Hamilton Road Impacted Area
kg - kilogram
L - Liter
mg - milligram
MVS - Mining Visualization System
MW - monitoring well
OU - operable unit
PCE - tetrachloroethene
PW - private well
RI - remedial investigation
ug - micrograms

Figure 5-6
Alternative HC-5
Conceptual Remedial Configuration

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: September 24, 2012 File: \\irvsvr01\GIS\50898 USEPA Region10 Federal\56094\2012\FS\Figure5-6 AlternativeHC-5ConceptualRemedialConfiguration.mxd



Legend

- HRIA OU1 Boundary
- Area of Creek Bed Sedimentary / Soil Removal Replaced by Stream Habitat Underlain by Geosynthetic Clay Liner (GCL)
- Creek Bed Sediments/Bank Surface Soil Remediation Zone (PCE greater than 0.468 mg/kg)
- High Concentration Groundwater Remediation Zone (PCE greater than 4,000 ug/L)
- Subsurface Soil Remediation Zone (PCE greater than 10 mg/kg)
- Stream Diversion
- AB5 Auger Boring
- AB-651 Auger Boring
- B2 Soil Boring
- BS-462 Stream Bed
- GP3 Geoprobe Boring
- GP-111 Geoprobe Boring
- GP-511 Geoprobe Boring
- MW-13 Monitoring Well
- SB-411 Stream Bank
- Vapor Recovery Well*
- Thermal Heating Electrodes*
- Temperature Monitoring Point*
- Bioremediation Injection Wells*

40 0 40
Feet

N

Notes:
1. MVS modeled contours using only the most recent available data from a given locations (Appendix A).
2. Monitoring wells and recovery wells located within the plume will be abandoned prior to implementation of ERH.
3. Remediation target zones based on MVS-modeled contaminant extents in sediment, soil and groundwater.
4. * = Locations approximate, exact locations to be determined by contractor.
5. Developed from CDM Smith RI Report (2011).
6. Image from ©2011 Google™

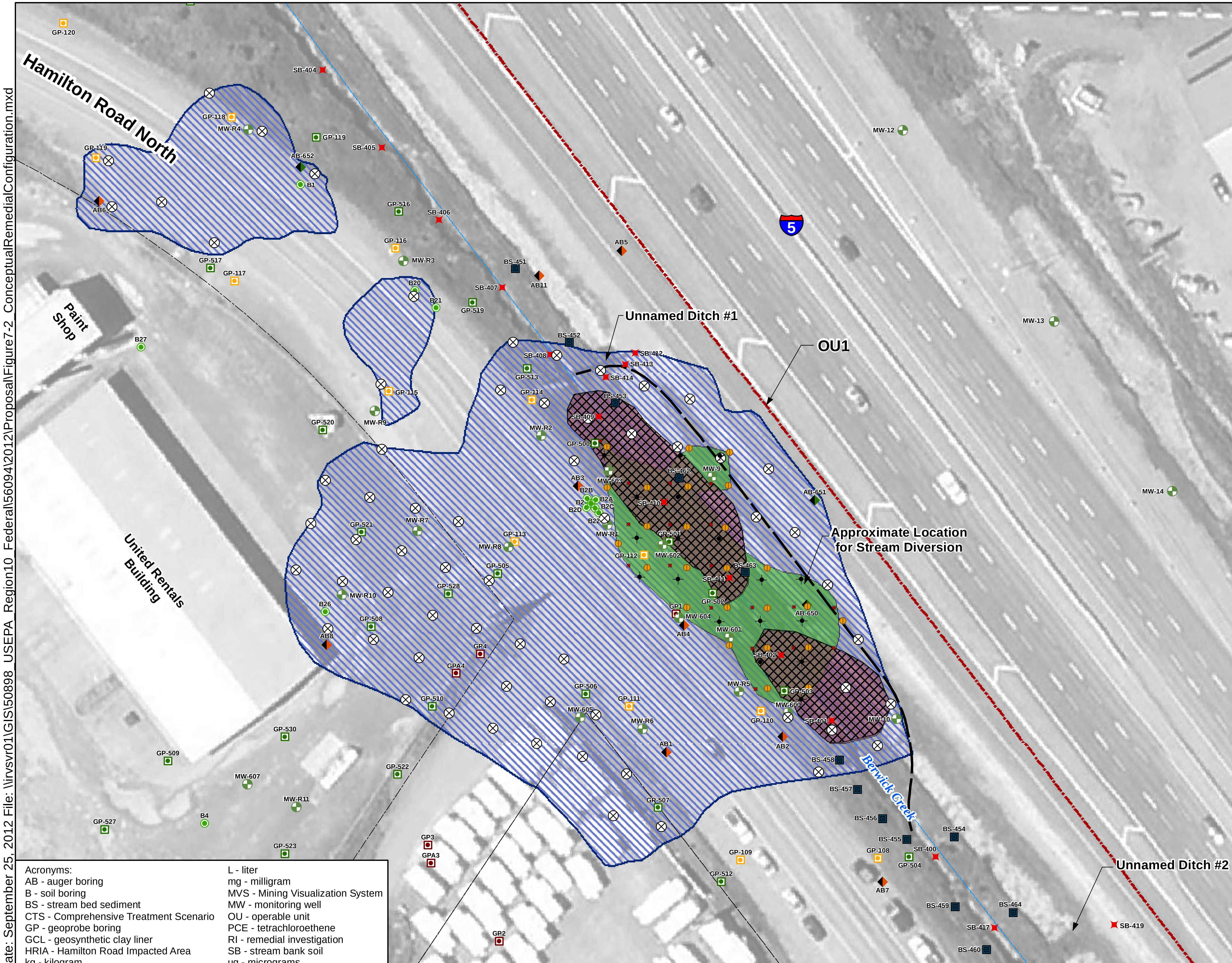
Acronyms:
AB - auger boring
B - soil boring
BS - stream bed sediment
CTS - Comprehensive Treatment Scenario
GP - geoprobe boring
GCL - geosynthetic clay liner
HRIA - Hamilton Road Impacted Area
kg - kilogram
L - liter
mg - milligram
MW - monitoring well
MVS - Mining Visualization System
OU - operable unit
PCE - tetrachloroethene
RI - remedial investigation
SB - stream bank soil
ug - micrograms

Figure 7-1
Comprehensive Treatment Scenario (CTS) 2
Conceptual Remedial Configuration

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: September 25, 2012 File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\Proposal\Figure7-1_ConceptualRemedialConfiguration.mxd



Acronyms:
AB - auger boring
B - soil boring
BS - stream bed sediment
CTS - Comprehensive Treatment Scenario
GP - geoprobe boring
GCL - geosynthetic clay liner
HRIA - Hamilton Road Impacted Area
kg - kilogram
L - liter
mg - milligram
MVS - Mining Visualization System
MW - monitoring well
OU - operable unit
PCE - tetrachloroethene
RI - remedial investigation
SB - stream bank soil
ug - micrograms

Legend

- HRIA OU1 Boundary
- Area of Creek Bed Sedimentary / Soil Removal Replaced by Stream Habitat Underlain by Geosynthetic Clay Liner (GCL)
- Creek Bed Sediments/Bank Surface Soil Remediation Zone (PCE greater than 0.468 mg/kg)
- High Concentration Groundwater Remediation Zone (PCE greater than 4,000 ug/L)
- Subsurface Soil Remediation Zone (PCE greater than 10 mg/kg)
- Stream Diversion
- AB5 Auger Boring
- AB-651 Auger Boring
- B2 Soil Boring
- BS-462 Stream Bed
- GP3 Geoprobe Boring
- GP-111 Geoprobe Boring
- GP-511 Geoprobe Boring
- MW-13 Monitoring Well
- SB-411 Stream Bank
- Oxidant Injection Locations*
- Vapor Recovery Well*
- Thermal Heating Electrodes*
- Temperature Monitoring Point*

40 0 40
Feet
N

Notes:
1. MVS modeled contours using only the most recent available data from a given locations (Appendix A).
2. Monitoring wells and recovery wells located within the plume will be abandoned prior to implementation of ERH.
3. Remediation target zones based on MVS-modeled contaminant extents in sediment, soil and groundwater.
4. * = Locations approximate, exact locations to be determined by contractor.
5. Developed from CDM Smith RI Report (2011).
6. Image from ©2011 Google™

Figure 7-2
Comprehensive Treatment Scenario (CTS) 3
Conceptual Remedial Configuration

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Date: September 25, 2012 File: \\irvsvr01\GIS\50898_USEPA_Region10_Federal\56094\2012\Proposal\Figure7-2_ConceptualRemedialConfiguration.mxd

Appendix A

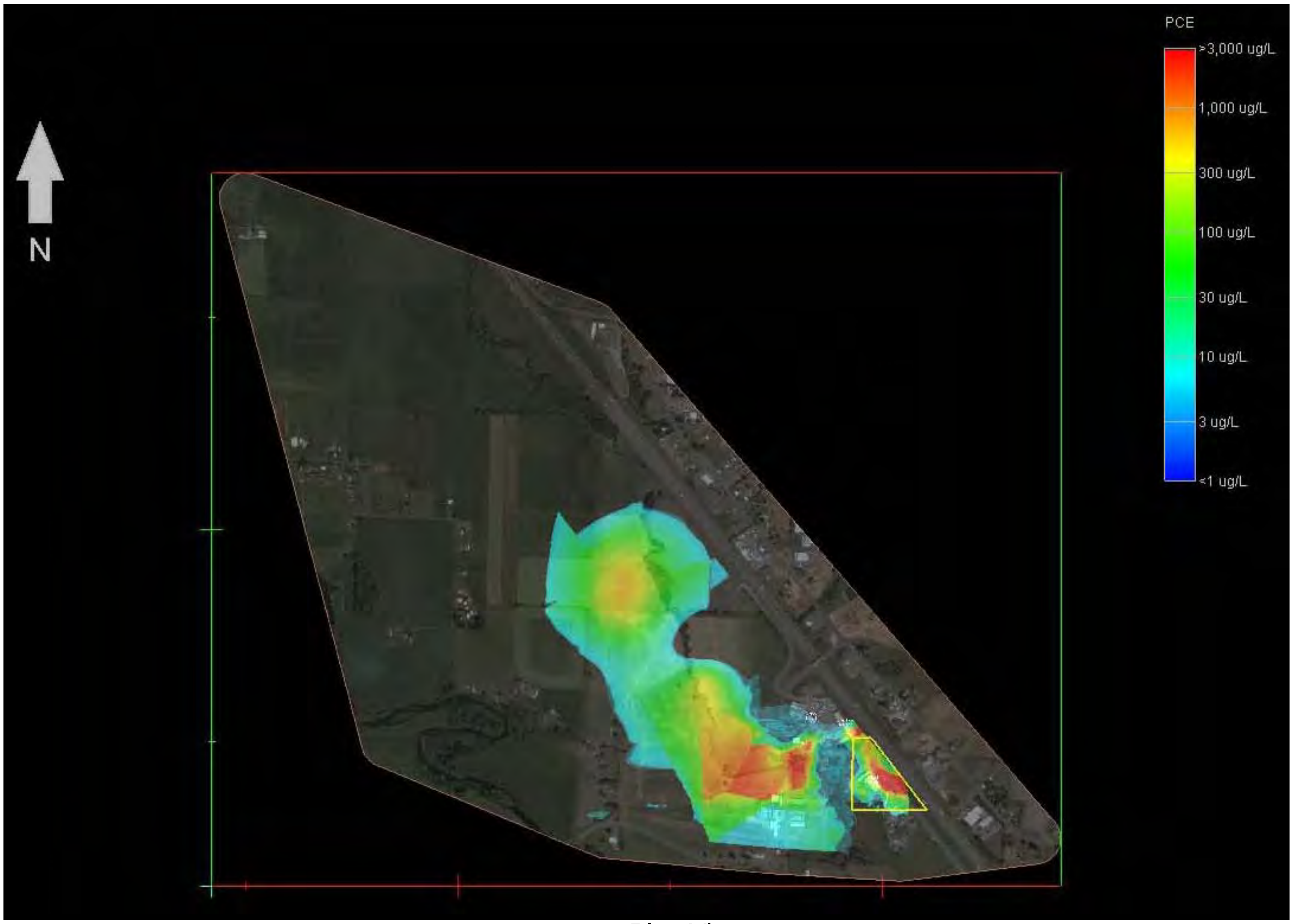
Mining Visualization System (MVS) Software Output

Mining Visualization Software Output

CTech's Mining Visualization Software (MVS) Version 9.13 was used to develop a 3D geostatistical model to help better define the lateral and vertical extent of tetrachloroethylene (PCE) contamination across the Hamilton/Labree Roads Superfund Site, including Hamilton Road Impacted Area (HRIA), also known as Operable Unit (OU)1. The MVS model was used to better delineate the OU1 boundary, refine the conceptual site model (CSM), identify performance monitoring locations, and develop preliminary remediation goals (PRGs) for the HRIA interim action. MVS uses kriging as the primary geostatistical interpolation method, which provides statistical confidence to measure the model accuracy. A convex-hull model domain with a resolution of 360 x 360 x 35 (X, Y, Z) was chosen to provide an appropriate fidelity while minimizing computational time. The most recent PCE data for each sampling location (soil, sediment, and groundwater) were entered into the MVS model.

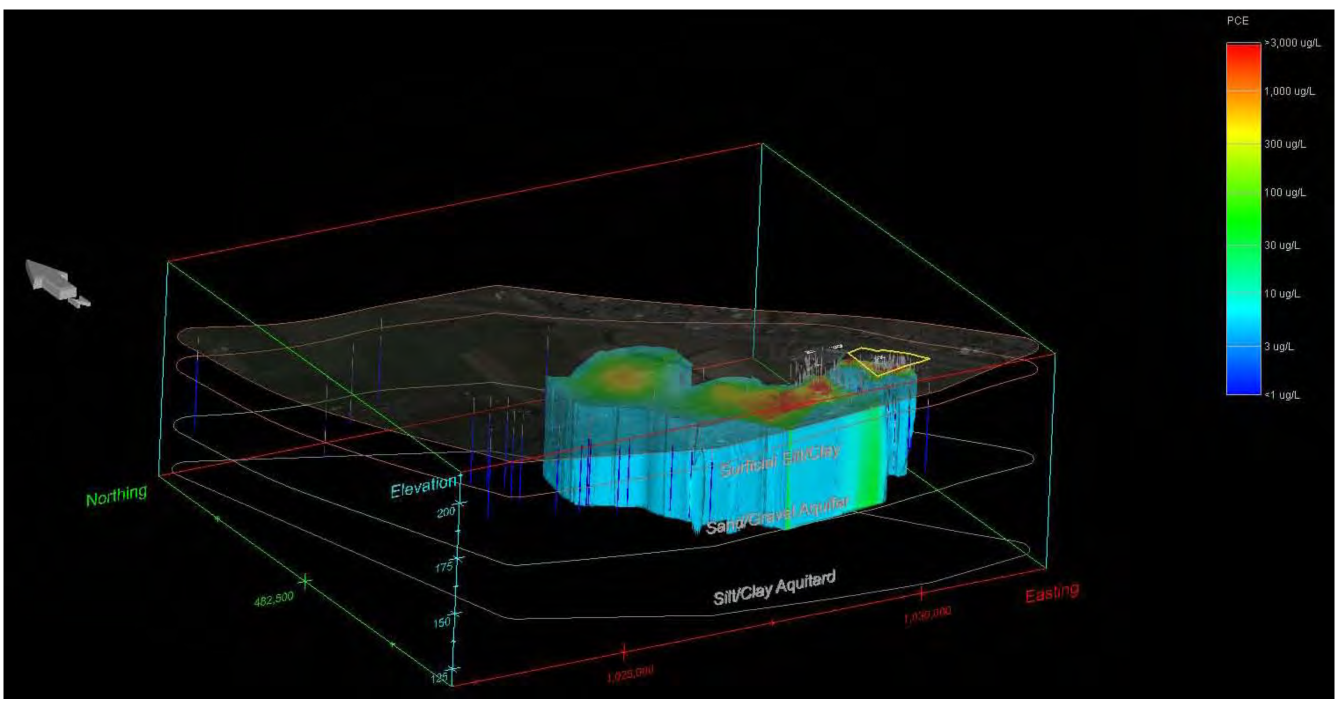
MVS was used to conduct spatial analysis of actual and predicted contaminant concentration distributions in sediment, soil, and groundwater using geostatistics. For the Hamilton/Labree Road MVS model, the following procedures were used (1) input and log transformation of analytical data prior to kriging; (2) use of a grid (360 x 360 x 35 [X, Y, Z]) to evaluate data spatially by interpolation through kriging to "connect" data in three dimensions; and (3) iterative model runs to evaluate contaminant extents, volumes, and masses using variable boundaries to compare how mass distribution varies spatially across the site.

The MVS PCE data were used to prepare a visualization (4D file format) that illustrates the spatial extent of contamination within soil and groundwater. MVS model output was used to delineate (within the limitations of the available data) the lateral and vertical extent of the PCE contamination at HRIA within the various media. The MVS model output provided in this Appendix are a series of screen captures depicting the modeled PCE isoconcentration extents in soil and groundwater. For groundwater, PCE isoconcentration contours above 5, 500; 1,000; 4,000; 10,000; and 50,000 parts per billion PCE were used to compare PCE mass, area, and volume within each of these boundaries. In addition, PCE extents in subsurface soil are also presented using 1 milligram per kilogram (mg/kg), 10 mg/kg, 38 mg/kg, and 777 mg/kg to compare PCE mass, area, and volume within each of these boundaries. Each figure includes a plan and oblique view, and all the figures use the same color concentration scale for ease of comparison. These estimates were used to develop the comparisons discussed in Section 2 and Table 2-2 of the FS and used as the basis for defining remediation target zones for the HRIA interim action.



Plan View

Oblique View



CDM Smith

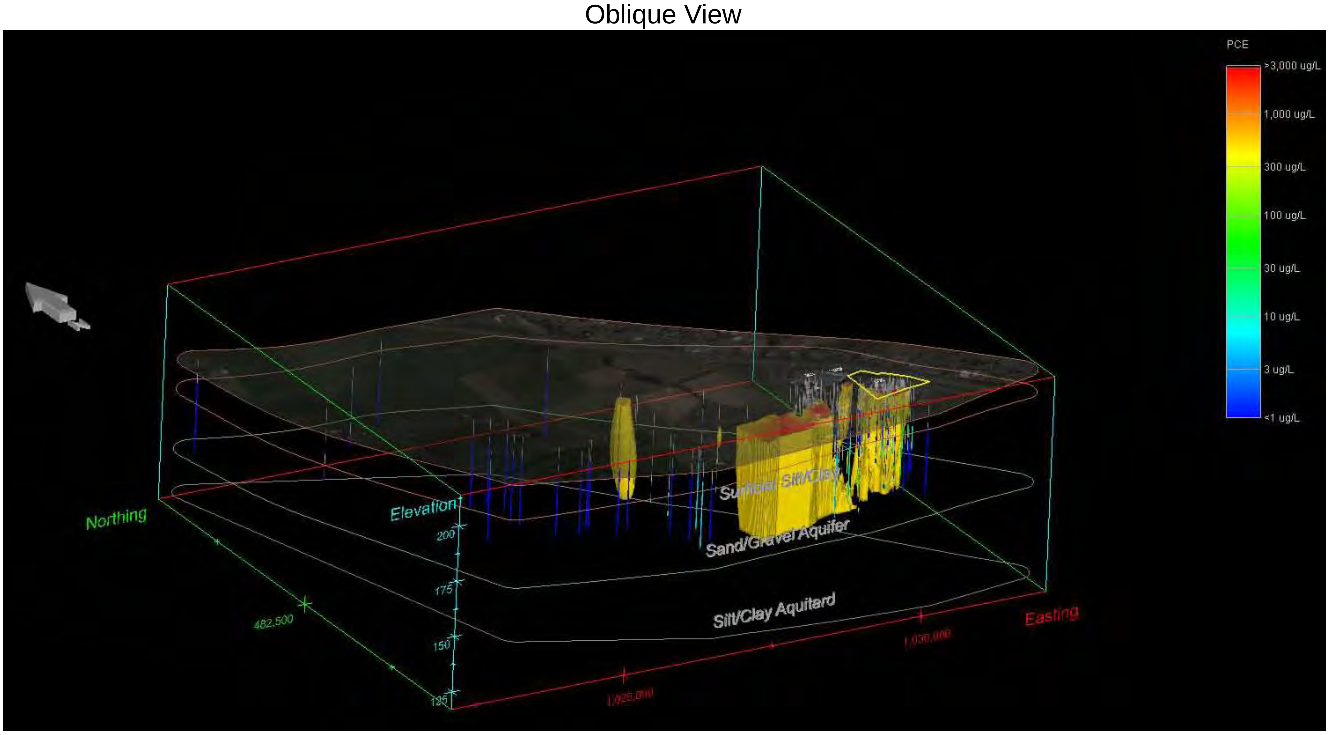
Figure A-1
PCE Greater than 5 ppb
in Groundwater

EPA REGION 10

Hamilton / Labree Roads
Superfund Site

Plan View

Oblique View



CDM Smith

Figure A-2
PCE Greater than 500 ppb
in Groundwater

EPA REGION 10

Hamilton / Labree Roads
Superfund Site

Plan View

Oblique View

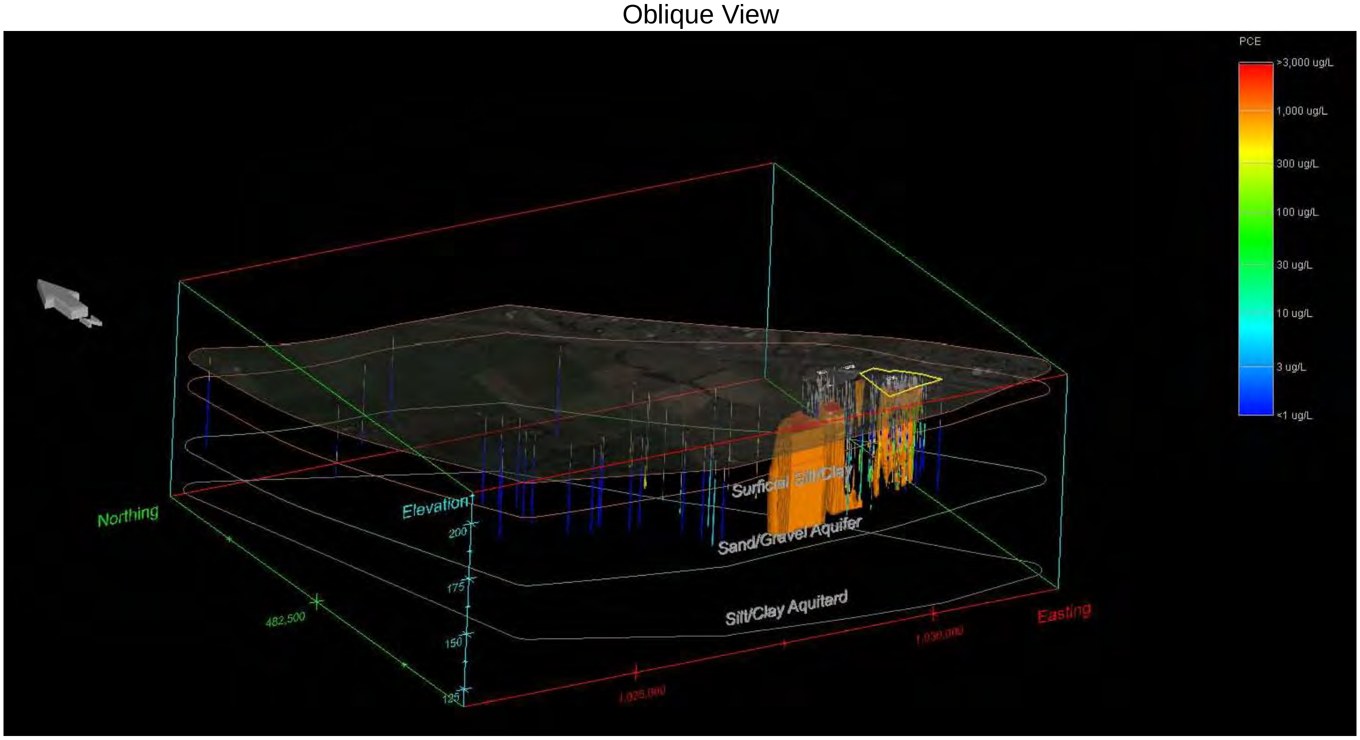


Figure A-3
PCE Greater than 1,000 ppb
in Groundwater

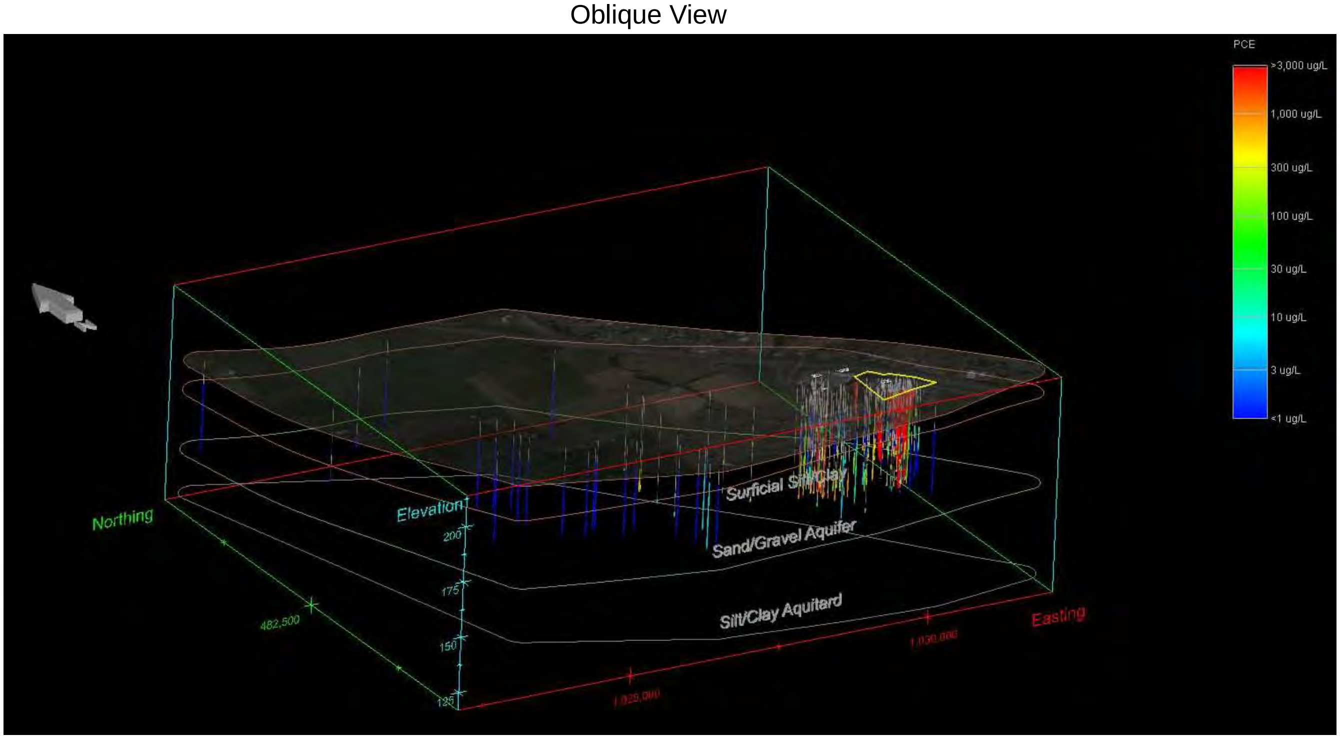
CDM Smith

EPA REGION 10

Hamilton / Labree Roads
Superfund Site

Plan View

Oblique View



CDM Smith

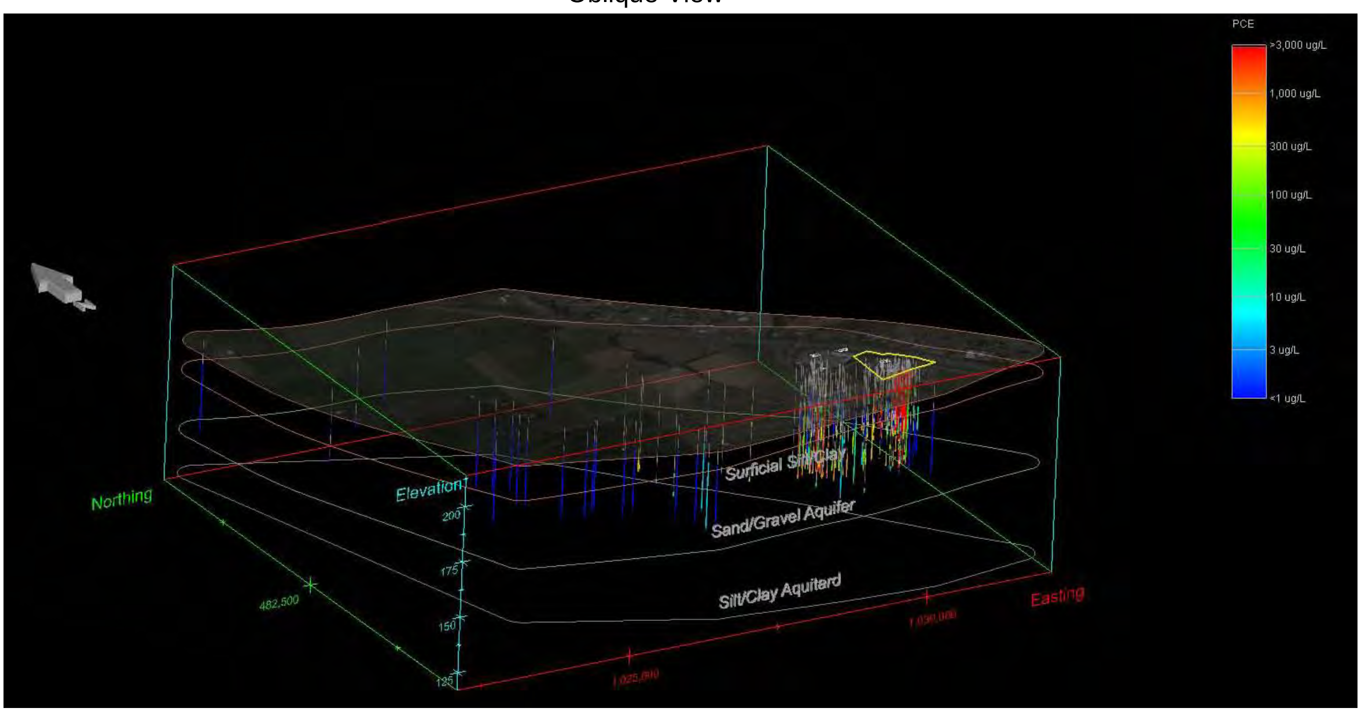
Figure A-4
PCE Greater than 4,000 ppb in Groundwater

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Plan View

Oblique View



CDM Smith

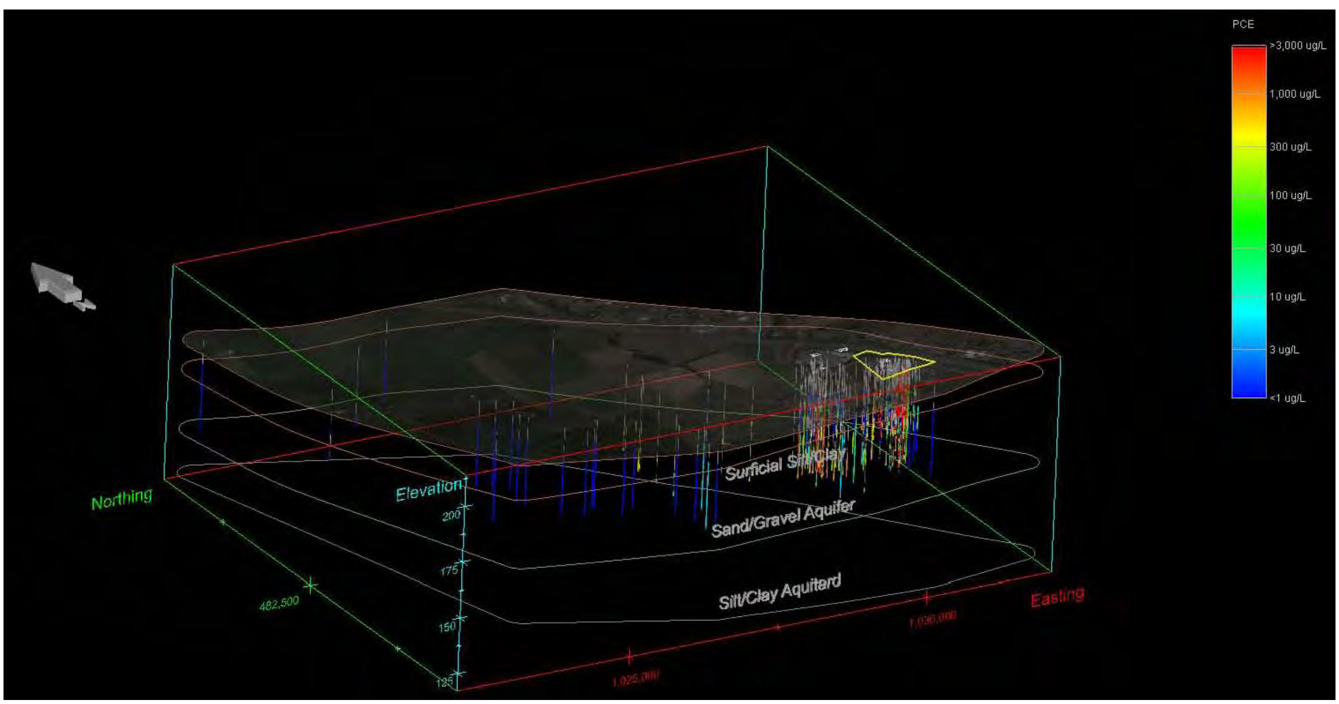
Figure A-5
PCE Greater than 10,000 ppb in Groundwater

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Plan View

Oblique View



CDM Smith

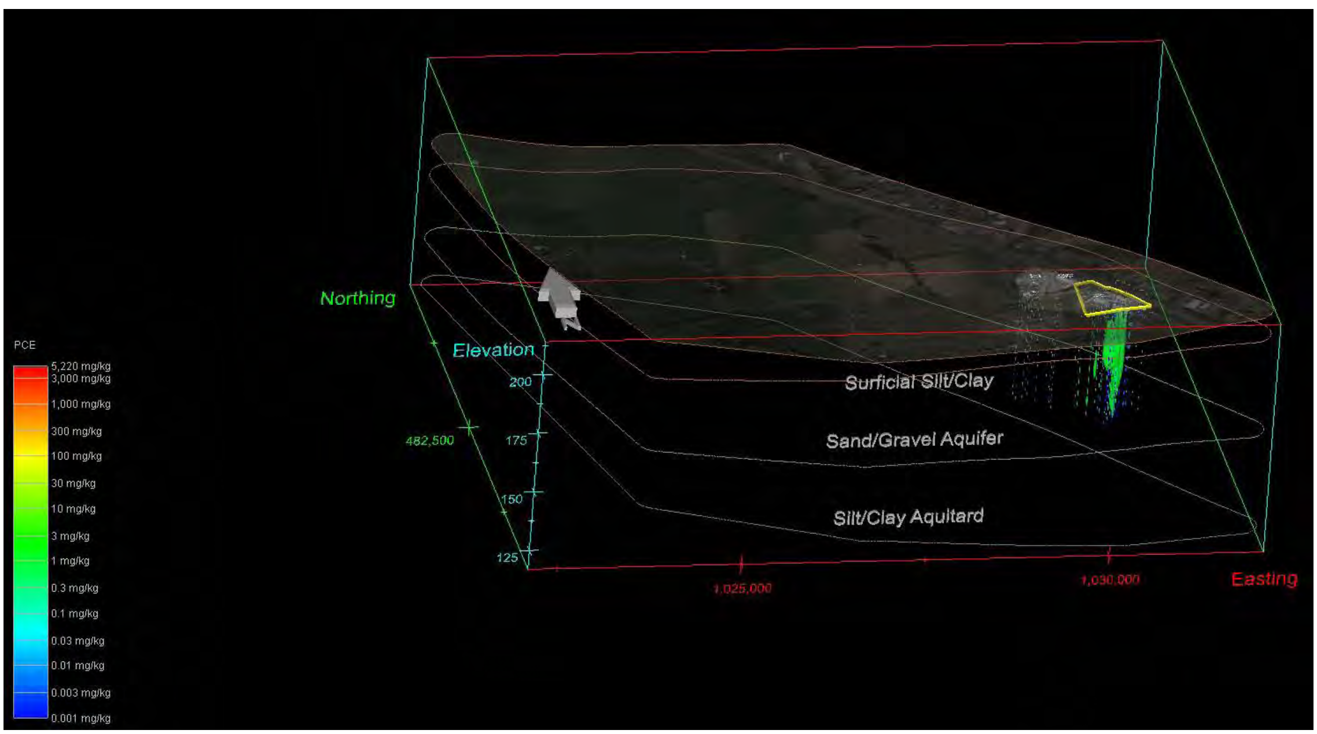
Figure A-6
PCE Greater than 50,000 ppb in Groundwater

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Plan View

Oblique View



CDM Smith

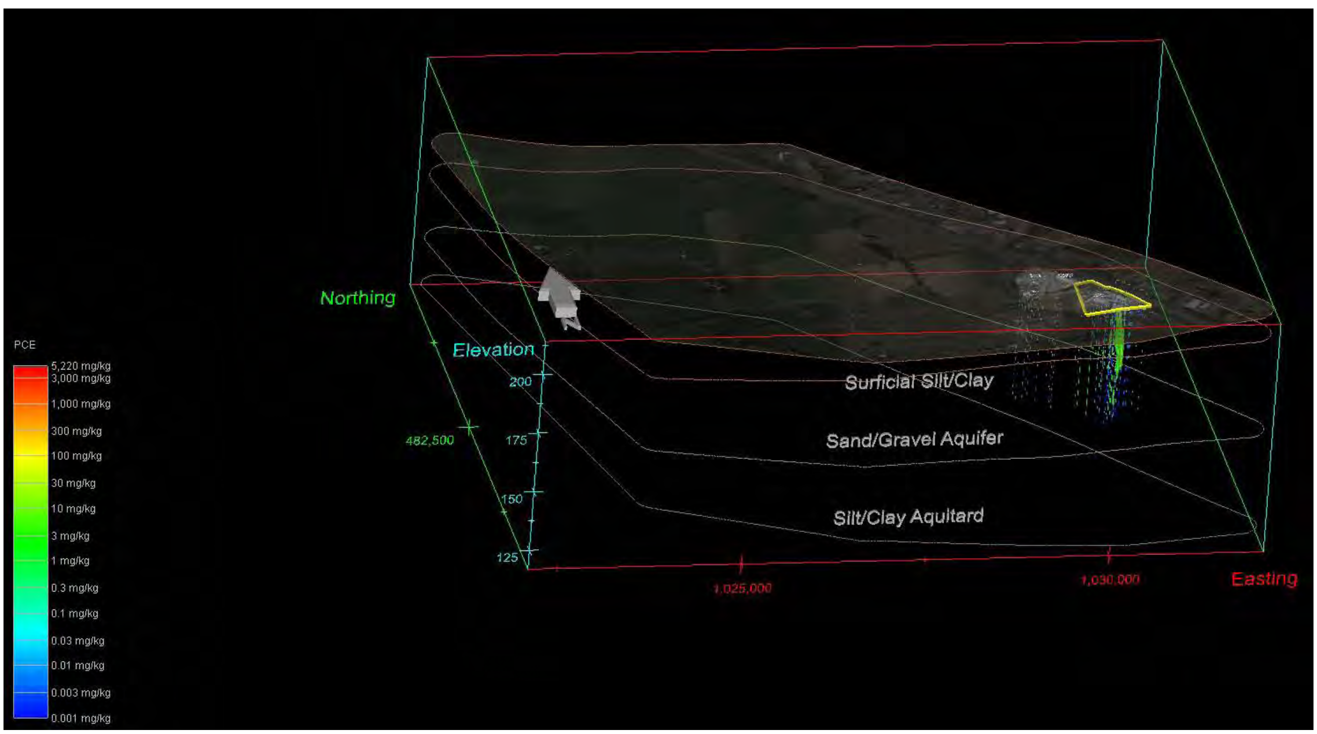
Figure A-7
PCE Greater than 1 mg/kg
in Soil between 5 and 55 ft bgs

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Plan View

Oblique View



CDM Smith

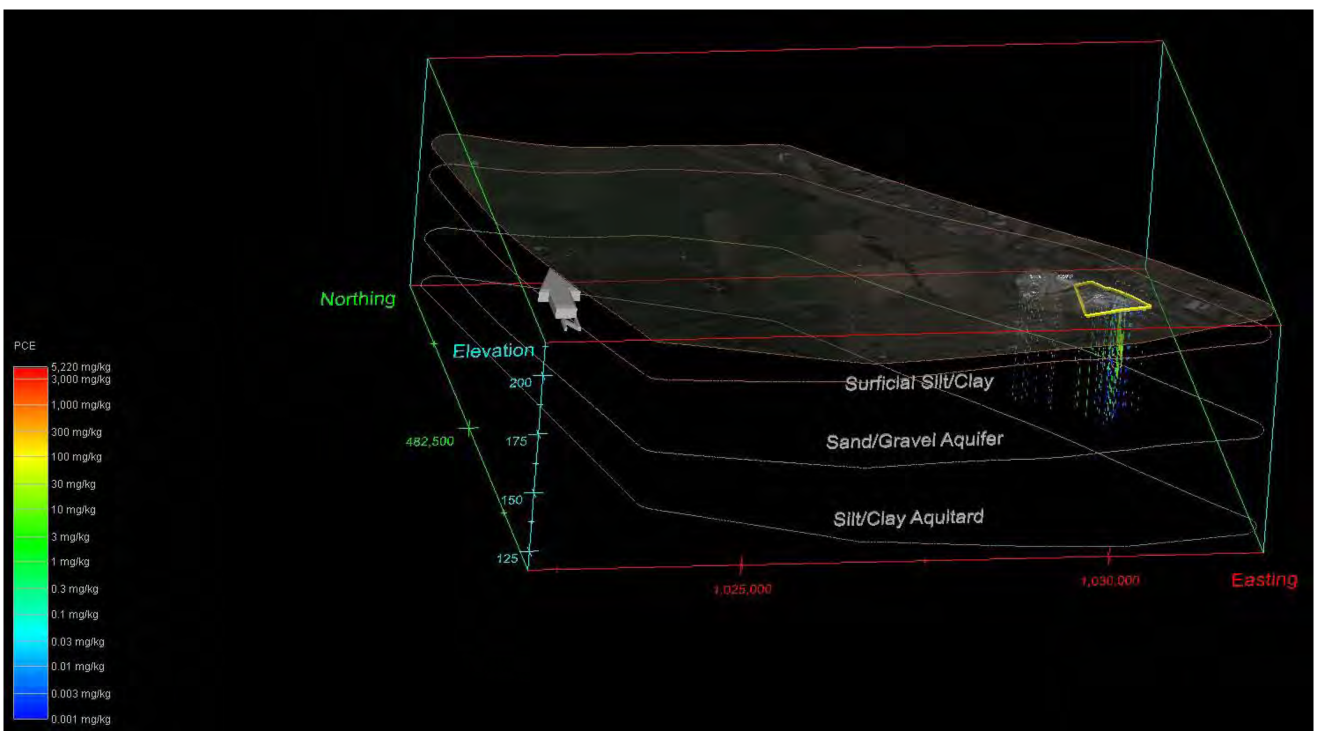
Figure A-8
PCE Greater than 10 mg/kg
in Soil between 5 and 55 ft bgs

EPA REGION 10

Hamilton / Labree Roads
Superfund Site

Plan View

Oblique View



CDM Smith

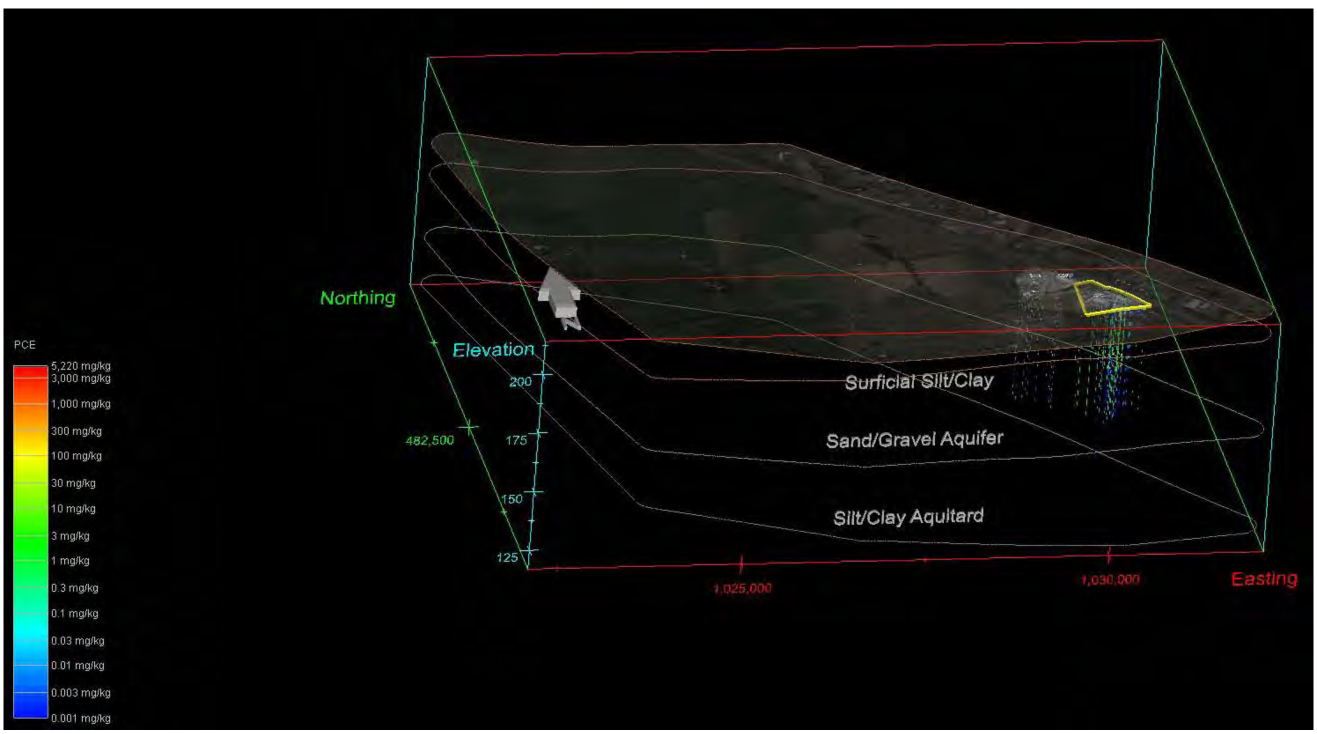
Figure A-9
PCE Greater than 38 mg/kg in Soil between 5 and 55 ft bgs

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Plan View

Oblique View



CDM Smith

Figure A-10
PCE Greater than 777 mg/kg in Soil between 5 and 55 ft bgs

EPA REGION 10

Hamilton / Labree Roads Superfund Site

Appendix B

Summary of Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) Compliance

Table B-1 Chemical-Specific ARARs/TBCs

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL				
Soil: EPA Soil Screening Guidance	EPA/540/R-96/018	Provides methodology for calculating risk-based, site-specific soil screening levels.	TBC	Used to standardize and accelerate site cleanup.
Groundwater: MCLs; Safe Drinking Water Act, National Primary Drinking Water Regulations	40 CFR 141.11-.16	MCLs regulate concentration of contaminants in public drinking water supplies but may also be considered for groundwater aquifers used for drinking water.	Relevant and Appropriate	Relevant to VOCs, SVOCs, and metals in groundwater.
Maximum Contaminant Limit Goals (MCLGs); Safe Drinking Water Act, National Primary Drinking Water Regulations	40 CFR 141.50-.54	MCLGs are health-based criteria that should be evaluated for groundwater contamination.	Relevant and Appropriate	Relevant to contaminants in groundwater.
Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites	EPA/540/G-88/003	Provides information on remedial technologies to address groundwater contamination.	TBC	Relevant to contaminants in groundwater.
Guidelines for Ground-Water Classification Under the EPA Groundwater Protection Strategy	813R86001 (nepis.epa.gov)	Presents guidelines for classifying groundwater in one of three classification categories based on ecological importance, replaceability, and vulnerability considerations.	TBC	Useful in identifying ARARs and establishing cleanup goals for site groundwater based on policy that different groundwaters merit different levels of protection.
Surface Water: Clean Water Act Section 304—Federal Ambient Water Quality (National Recommended Water Quality Criteria, November 2002)	EPA-822-R-02-047	Provides chemical concentrations for acceptable ambient water quality.	Relevant and Appropriate	Potentially relevant and appropriate to ambient surface water quality and point-source discharges to the surface water in Berwick Creek should remedial activities cause a release to surface water. The PCE value for human exposure to both water and organisms is 0.69 µg/L and to organisms only is 3.3 µg/L.

Table B-1 Chemical-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL (Continued)				
Clean Water Act's National Toxics Rule	40 CFR 131.36	Provides values that have to be met for point-source discharges to surface water.	Applicable	Potentially applicable to point-source discharges to Berwick Creek and onsite storm water ditches should remedial activities cause release to surface water. If applicable, these values would have to be met at the mixing zone boundary established for the discharge. The PCE value for human exposure to both water and organisms is 0.8 µg/L and to organisms only is 8.85 µg/L.
Hazardous Waste: RCRA Part 261 - Identification and Listing of Hazardous Waste	40 CFR Part 261-265, 270, and 271	Defines those solid wastes, which are subject to regulations as hazardous wastes, and lists specific chemical- and industry-source wastes.	Applicable	Applicable to determining whether wastes are considered hazardous under RCRA.
RCRA TCLP and Land Ban Requirements for Landfilling	40 CFR 261	Requirements and restrictions on hazardous waste disposal in landfills.	Applicable	Applicable to disposal of contaminated material.
RCRA Land Disposal Restrictions	40 CFR 268	Establishes standards for land disposal of RCRA hazardous waste. Requires treatment to diminish a waste's toxicity and/or minimize contaminant migration.	Applicable	Applicable if remedial activities generate and include land disposal of waste that is characterized as hazardous.
Other: EPA Region III Risk-based Concentration Table	NA	Establishes chemical screening guidelines for use during risk assessment.	TBC	May be useful in development of cleanup goals.
Oak Ridge National Laboratory Screening Criteria	http:/epa-prgs.ornl.gov/chemicals/index.shtml	Establishes regional chemical screening levels to be used in risk assessments.	TBC	May be useful in development of cleanup goals.
National Ambient Air Quality Standards	40 CFR 50.6, 50.12	Provides acceptable ambient air quality levels for particulate matter and lead.	Applicable	Applicable to earth-moving activities as well as to treatment processes that may include mixing or other processes that result in potential releases of particulates or lead.

Table B-1 Chemical-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
STATE – WASHINGTON				
Soil: Model Toxics Control Act Regulations	WAC 173-340-740, -745	Regulates the investigation and cleanup of releases to the environment that may pose a threat to human health or the environment. Establishes cleanup levels for soil.	Applicable	The Method A soil value for PCE is 0.05 mg/kg for both unrestricted and industrial land use for human health protection. The unrestricted land use Method B value for PCE is 22 mg/kg for protection from direct contact (residential); 110 mg/kg (commercial/industrial), and 924 mg/kg (recreational).
Groundwater: MTCA Regulations	WAC 173-340-720	Regulates the investigation and cleanup of releases to the environment that may pose a threat to human health or the environment. Establishes cleanup levels for groundwater.	Applicable	MTCA groundwater cleanup levels are potentially applicable to HRIA groundwater. The Method A groundwater cleanup value for PCE is 5 μg/L, and the Method B groundwater cleanup value for PCE is 0.81 μg/L.
Water Quality Standards	WAC 173-200-040	Provides criteria establishing maximum contaminant concentrations for the protection of a variety of beneficial uses of Washington's groundwater.	TBC	Not applicable to cleanups approved under MTCA 70.105D or by EPA under CERCLA. Cleanup standards for such sites shall be developed under WAC 173-340-720.
Sediment: Sediment Cleanup Standards	WAC 173-204-560	Provide standards to eliminate adverse effects on biological resources and significant health threats to humans from sediment contamination.	Applicable	Sediment cleanup objectives are the freshwater sediment standards provided in 173-204-340. Ecology determines on a case by case basis the criteria, methods and procedures necessary to meet the intent of the chapter.
Sediment Cleanup Standards	WAC 173-340-760	Sediment cleanup actions conducted under this chapter must comply with the requirements of chapter 173-204 WAC.	Applicable	Applicable to establishment of sediment PRGs.
Surface Water: MTCA Regulations	WAC 173-340-730	Regulates the investigation and cleanup of releases to the environment that may pose a threat to human health or the environment. Establishes cleanup levels for surface water.	Applicable	Applicable if remedial activities cause a release to surface water. MTCA surface water cleanup levels are potentially applicable to Berwick Creek and the small and unnamed ditches. The Method B value for PCE is 0.39 μg/L.

Table B-1 Chemical-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
STATE – WASHINGTON (Continued)				
Air: MTCA Regulations	WAC 173-340-750	Regulates the investigation and cleanup of releases to the environment that may pose a threat to human health or the environment. Establishes cleanup levels for air.	Applicable	Applicable if remedial activities cause a release to air.
Hazardous Waste: Washington Hazardous Waste Management Act Regulations	WAC 173-303	Requirements and restrictions on hazardous waste disposal.	Applicable	This regulation is potentially applicable to alternatives that would involve disposal of contaminated media in an offsite location. The area of contamination policy allows contaminated media to be consolidated within the same area of a site without triggering RCRA or Washington dangerous waste regulations. Several waste streams from the site could be hazardous wastes as they could contain PCE at concentrations high enough to fail the TCLP; the PCE TCLP threshold is 0.7 mg/L.
Other: MTCA Regulations: Cleanup Standards: (General)	WAC 173-340 -700	Provides an overview of the methods for establishing cleanup standards that apply to a release or threatened release of a hazardous substance at a site.	Applicable	Applicable to establishment of PRGs.
MTCA Regulations: (General Policies)	WAC 173-340 -702	Defines the general policies and principles that shall be followed when establishing and implementing cleanup standards. Shall be used in combination with other sections of this chapter	Applicable	Applicable to establishment of PRGs.

Table B-1 Chemical-Specific ARARs/TBCs (Continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
STATE – WASHINGTON (Continued)				
MTCA Regulations: Cleanup Standards	WAC 173-340-703	Describes elimination of certain hazardous substances that contribute a small percentage of the overall threat to human health and the environment at a site, and use of the remaining hazardous substance(s) as an indicator for purposes of defining site cleanup requirements.	Applicable	Applicable to establishment of PRGs.
	WAC 173-340-704 Use of Method A	Provides a method to establish cleanup levels for sites that have few hazardous substances.		
	WAC 173-340-705 Use of Method B	Provides a method to establish cleanup levels for sites unless one or more of the conditions for using Method A or Method C are demonstrated to exist and the person conducting the cleanup action elects to use that method.		
	WAC 173-340-706 Use of Method C	Method C cleanup levels represent concentrations that are protective of human health and the environment for specified site uses and conditions. A site (or portion of a site) that qualifies for a Method C cleanup level for one medium does not necessarily qualify for a Method C cleanup level in other media. Each medium must be evaluated separately using the criteria applicable to that medium.		

Acronyms:
ARAR: applicable or relevant and appropriate requirement
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act
CFR: Code of Federal Regulations
EPA: U. S. Environmental Protection Agency
HRIA: Hamilton Road Impacted Area
mg/kg: milligram per kilogram
µg/L: microgram per liter
mg/L: milligram per liter
MTCA: Model Toxics Control Act
PCE: tetrachloroethene
RCRA: Resource Conservation and Recovery Act
SVOC: semivolatile organic compound
TBC: to be considered
TCLP: Toxicity Characteristic Leaching Procedure
VOC: volatile organic compound
WAC: Washington Administrative Code

Table B-2 Location-Specific ARARs/TBCs

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL				
Federal Protection of Wetlands and Management of Floodplains	Executive Order Nos. 11990 and 11988	Establishes requirements for the preservation of wetlands and floodplain areas.	Applicable	May be applicable to remedial actions that affect wetland and floodplain areas if any affected properties are located within wetlands or floodplain areas.
National Historic Preservation Act Archeological Resources Protection Act	16 USC 470; et. Seq.; 40 CFR 6.301 (b); 36 CFR Part 800 16 USC 469; 40 CFR 6.301 (c)	Minimizes impact of actions on historic properties and landmarks. Provides protection from actions that may cause irreparable harm, loss, or destruction of artifacts.	Applicable	Applicable to actions at historic properties or landmarks or properties at the site that contain historical and archeological data.
Native American Graves Protection and Repatriation Act	43 CFR Part 10	Protects Native American burials from desecration through the removal and trafficking of human remains and “cultural items,” including funerary and sacred objects.	Applicable	Potentially applicable to remedial actions at the site because it is possible that the disturbance of Native American materials could occur as a result of work in the stream bed or subsurface excavations elsewhere at the site. Such materials are not known to be present at the site but could be inadvertently uncovered during soil or sediment removal.
Endangered Species Act of 1973	16 USC 1531-1543; 50 CFR Parts 17, 401; 40 CFR 6.302 (h)	Provides protection of critical habitat upon which endangered or threatened species depend.	Applicable	Applicable to actions that impact critical habitat of endangered or threatened species. USFWS has determined that federal threatened species (bald eagle and bull trout) may use the project area.

Table B-2 Location-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL (Continued)				
Magnuson-Stevens Fishery Conservation and Management Act Regulations	50 CFR Part 600	Consideration of the effects of federal actions on EFH for certain species is required. Federal agencies whose actions might adversely affect an EFH-managed species must formally consult with NOAA fisheries regarding the action. If NOAA fisheries were to determine that an action would adversely affect EFH, the agency would provide EFH conservation recommendations.	Applicable	Potentially applicable to actions within Berwick Creek, which has been designated EFH for both coho and Chinook salmon.
Clean Water Act, Section 401, Water Quality Certification	33 USC 1340	Requires a certification of water quality to be issued by the responsible government authority to state that remedial actions will not violate applicable water quality standards.	Applicable	Substantive requirements potentially applicable to in-water remedial actions at Berwick Creek.
Clean Water Act (Dredge and Fill Requirements)	33 USC 1251-1376; 40 CFR 230, 231	Provides protection to waters in and around the site.	Relevant and Appropriate	Relevant and appropriate to actions involving capping, berm construction, and/or onsite disposal of contaminated soil that may impact local water bodies.
STATE - WASHINGTON				
Washington Hydraulics Project Approval	WAC 220-110 WAC 220-110-040 through -224	Requires WDFW approval for projects that will use, divert, obstruct, or change the natural flow or bed of waters of the state. Substantive technical provisions include considerations for bank protection; channel change/realignment; temporary bypass culvert, flume, or channel; dredging in freshwater areas; gravel removal; outfall structures; and/or water diversions.	Applicable	Applicable to remedial actions taken at Berwick Creek. Will require adherence to instream work windows, which are typically issued under the authority of this program.

Acronyms:
ARAR: applicable or relevant and appropriate requirement
CFR: Code of Federal Regulations
EFH: Essential Fish Habitat
NOAA: National Oceanic and Atmospheric Administration
TBC: to be considered
USC: United States Code
USFWS: U.S. Fish and Wildlife Service
WAC: Washington Administrative Code
WDFW: Washington Department of Fish and Wildlife

Table B-3 Action-Specific ARARs/TBCs

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL				
Hazardous Waste: RCRA Subtitle C Hazardous Waste Treatment Facility Design and Operating Standards for Treatment and Disposal Systems, (i.e., landfill, incinerators, tanks, containers, etc.) (Minimum Technology Requirements)	40 CFR 264 and 265	Develops standards for hazardous waste treatment and disposal activities.	Applicable	Applicable if remedial activities include the management of hazardous wastes at treatment and disposal facilities.
RCRA Manifesting, Transport, and Recordkeeping Requirements	40 CFR 262	Develops guidelines for record-keeping of the management actions for hazardous wastes.	Applicable	Applicable if remedial activities include the offsite transport of hazardous waste.
RCRA Storage Requirements	40 CFR 264; 40 CFR 265, Subparts I and J	Develops standards for the storage of hazardous wastes.	Applicable	Applicable if remedial activities include the storage of hazardous waste greater than 90 days.
RCRA Subtitle D Nonhazardous Waste Management Standards	40 CFR 257	Develops standards for the management of non-hazardous wastes.	Applicable	Applicable if remedial activities include the management of non-hazardous wastes.
Off-Site Transport of Hazardous Waste	EPA OSWER Directive 9834.11	Establishes technical guidelines for the offsite transport of hazardous wastes.	TBC	TBC if remedial activities include the offsite transport and management of hazardous waste.
DOT Rules for Hazardous Materials Transport	49 CFR 107,171.1-171.500	Establishes specific DOT rules and technical guidelines for the offsite transport of hazardous materials.	Applicable	Applicable if remedial activities include the offsite transport and management of hazardous waste.
RCRA - Part 262 Standards for Generators. Part 263 Standards for Transporters	40 CFR Parts 262 and 263	Applicable to generators and transporters of hazardous waste.	Applicable	Applicable to offsite disposal or treatment of hazardous waste.
RCRA - Part 264, Subtitle C	40 CFR Part 264	Applicable to the treatment, storage, transportation, and disposal of hazardous waste defined in 40 CFR Part 261.	Applicable	Applicable to offsite disposal or treatment of hazardous waste.
RCRA - Part 268 Land Disposal Restrictions	40 CFR Part 268	Establishes standards for land disposal of RCRA hazardous waste. Requires treatment to diminish a waste's toxicity and/or minimize contaminant migration.	Applicable	Applicable if remedial activities include land disposal of RCRA hazardous waste.

Table B-3 Action-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL (Continued)				
Transportation of Hazardous Wastes	49 CFR 170-189	Federal Highway Administration, Department of Transportation National Highway Traffic Safety Administration regulations are codified in 23 CFR Parts 1-1399.	Applicable	Applicable to remedial activities that involve the offsite transportation of hazardous waste.
Groundwater: EPA Underground Injection Control Regulations	40 CFR 144 and 146	Regulates injections of underground sources of drinking water by specific classes of injection wells.	Relevant and Appropriate	Relevant to use of any remediation technologies that involve injections into drinking water aquifer.
Surface Water: Clean Water Act's National Pollutant Discharge Elimination System (NPDES) Regulations	40 CFR Part 122-125	The NPDES program requires that permits be obtained for point-source discharges of pollutants to surface water. Under this regulation, a point-source discharge to a surface water body cannot cause an exceedance of water quality standards in the receiving water body outside the mixing zone.	Applicable	Although permits would not be required for onsite actions under CERCLA, the substantive regulatory requirements of the NPDES permit program are potentially applicable to the direct discharge of treated groundwater to a surface water body, such as Berwick Creek as well as the unnamed or small ditches connected to Berwick Creek.
Clean Water Act's National Toxics Rule (NTR)	40 CFR 131.36	Provides values that have to be met for point-source discharges to surface water.	Applicable	Potentially applicable to point-source discharges to Berwick Creek and onsite storm water ditches. If applicable, these values would have to be met at the mixing zone boundary established for the discharge. The PCE value for human exposure to both water and organisms is 0.8 µg/L and to organisms only is 8.85 µg/L.
Clean Water Act Section 304 - Federal Ambient Water Quality	National Recommended Water Quality Criteria, November 2002, and 67 Federal Register 79091-79095, December 27, 2002	Provides chemical concentrations for acceptable ambient water quality.	Relevant and Appropriate	Potentially relevant and appropriate to point-source discharges to Berwick Creek. The PCE value for human exposure to both water and organisms is 0.69 µg/L and to organisms only is 3.3 µg/L

Table B-3 Action-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
FEDERAL (Continued)				
Other: Surface Mining Control Act of 1977	25 USC. 1201 et. seq.; 30 CFR Parts 816.11, .95, .97, .100, .102, .111, 113, .114, .116	Provides requirements for removing contaminated soils.	Relevant and Appropriate	Includes requirements for postings (.11), stabilization (erosion control)(.95), minimizing disturbances(.97), reclamation (.100), sloping (.102) and revegetation (.100, .102, .111, .113, .114).
Clean Air Act	42 USC 7401, Section 1 12	Established limits on pollutant emissions to atmosphere from specific industrial and commercial activities. Establishes standards to protect public health and welfare and ambient air quality.	Relevant and Appropriate	Some treatment alternatives may impact ambient air quality.
National Ambient Air Quality Standards	40 CFR 50.6	Requires that the remedial action include fugitive dust control measures.	Applicable	Applicable to earth-moving activities as well as to treatment processes that may include mixing or other processes that result in potential releases of particulates.
National Emission Standards for Hazardous Air Pollutants	40 CFR Part 261	Establishes specific emissions levels allowed for toxic air pollutants.	Applicable	Applicable to treatment alternatives that may emit toxic pollutants to the air.
Clean Water Act's Pretreatment Regulations	40 CFR Part 503.5	Limits pollutants in wastewater discharges to sanitary sewer systems to protect POTWs from accepting wastewater that would damage their system or cause them to exceed their NPDES permit discharge limits.	Applicable	Potentially applicable to the discharge of treated groundwater to City of Chehalis POTW. The City of Chehalis pretreatment ordinance would be potentially applicable as well.
Storm water Permit Program	40 CFR 122.26	Best management practices must be used and appropriate monitoring performed to ensure that storm water runoff does not cause an exceedance of water quality standards in a receiving surface water body.	Applicable	Substantive requirements of the general storm water permit program for storm water discharges associated with construction activities disturbing over 1 acre are potentially applicable to remedial actions at HRIA.

Table B-3 Action-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
STATE - WASHINGTON				
Solid Waste: Washington Solid Waste Handling Standards	WAC 173-350	Provides waste management requirements for non-hazardous wastes.	Applicable or Relevant and Appropriate	Potentially applicable to offsite disposal of solid nonhazardous wastes and are potentially relevant and appropriate to onsite remedial actions governing contaminated media management. Requirements for contaminated media disposal will be found in the permit of the landfill that agrees to accept the waste.
Hazardous Waste: Hazardous Waste Management Act Regulations	WAC 173-303	Regulates disposal of contaminated media in an offsite location. Generators of solid waste must determine whether that waste is hazardous (dangerous) waste. If the wastes destined for offsite disposal are determined to be hazardous, then EPA will accumulate, manifest, and transport them as required by WAC 173-303-170, 180, 190, and 200 to an offsite facility that is acceptable under the Off-Site Disposal Rule (40 CFR 300.440). (The area of contamination policy allows contaminated media to be consolidated within the same area of a site without triggering RCRA or Washington dangerous waste regulations.)	Applicable	Applicable if any hazardous materials are taken off site. Several waste streams from the site could be hazardous wastes if they contain PCE at concentrations high enough to fail the TCLP. PCE TCLP threshold is 0.7 mg/L. Materials that are potential hazardous wastes include stream sediments, drill cuttings, groundwater (purge water, etc.), and spent activated carbon units from the treatment system.
Surface Water: Washington State Water Quality Standards for Surface Waters	WAC 173-201A	Provides limitations on parameters such as turbidity, temperature, dissolved oxygen, and pH for protection of organisms. Protects freshwater aquatic life by specifying protection criteria by stretch of surface waters. Tributaries of waters whose uses are designated salmon and trout spawning, core rearing and migration, or extraordinary primary contact recreation are protected at the same level as the waters themselves.	Applicable	Limitations would not serve as cleanup standards but would be potentially applicable to remedial actions.

Table B-3 Action-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
STATE – WASHINGTON (Continued)				
Washington Surface Water Quality Standards—Short-Term Modifications	WAC 173-201A-410	Provides for short-term modifications of standards for specific water bodies on a short-term basis when necessary to accommodate essential activities, respond to emergencies, or to otherwise protect the public interest.	Applicable	The substantive requirements of this regulation are potentially applicable for remedial action in-water work at Berwick Creek.
Other: Washington Water Well Construction Act Regulations	WAC 173-160	Provides requirements for water well construction.	Applicable	Potentially applicable to the installation, operation, or closure of monitoring and treatment wells at HRIA.
Washington Hydraulics Project Approval	WAC 220-110	Requires WDFW approval for projects that will use, divert, obstruct, or change the natural flow or bed of waters of the state. WDFW typically issues in stream work windows under the authority of this program.	Applicable	Substantive technical provisions written for freshwater hydraulic projects covered in WAC 220-110-040 through -224 are potentially applicable to work within or affecting Berwick Creek
Washington Clean Air Act and Implementing Regulations SWCAA Regulation	WAC 173-400 WAC 173-460 SWCAA 400	Air emissions at the site boundary must fall below the acceptable source impact limit of 1.1 µg/m^3 PCE (WAC 173-460-150). Compliance could be demonstrated through modeling of PCE sources from treatment technologies with air emissions. WAC 173-400 also requires control of fugitive dust emissions during construction.	Applicable	Applicable to earth-moving activities as well as to treatment processes that may include mixing or other processes that result in potential releases of emissions to air.
Model Toxics Control Act Regulations: Selection of Cleanup Action	WAC 173-340-360	Model Toxics Control Act Regulations: Describes the minimum requirements and procedures for selecting cleanup actions. Because cleanup actions will often involve the use of several cleanup action components at a single site, the overall cleanup action shall meet the requirements of this section.	Applicable	Applicable to various components of the remediation alternatives.

Table B-3 Action-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
STATE – WASHINGTON (Continued)				
Model Toxics Control Act: Regulations Compliance Monitoring Requirements	WAC 173-340-410	Describes minimum compliance monitoring requirements. Three types of compliance monitoring: protection (confirm that human health and the environment are adequately protected during construction and the operation and maintenance period of an interim action as described in the safety and health plan); performance (confirm that the interim action has attained cleanup standards and, if appropriate, remediation levels or other performance standards such as construction quality control measurements or monitoring necessary to demonstrate compliance with a permit or, where a permit exemption applies, the substantive requirements of other laws); and conformational monitoring (confirm that human health and the environment are adequately protected during construction and the operation and maintenance period of an interim action or cleanup action as described in the safety and health plan). In all cases, compliance monitoring plans are required.	Applicable	Applicable to monitoring components of the remediation alternatives.
Model Toxics Control Act Regulations: Interim Actions	WAC 173-340-430	An interim action is distinguished from a cleanup action in that an interim action only partially addresses the cleanup of a site. This regulation describes the general requirements for interim actions, timing, and relationship to the larger cleanup action.	Applicable	

Table B-3 Action-Specific ARARs/TBCs (continued)

Standard, Requirement, Criterion, or Limitation	Citation Or Reference	Description	Status	Comments
STATE – WASHINGTON (Continued)				
Model Toxics Control Act Regulations: Institutional Controls	WAC 173-340-440	Institutional controls (ICs) are measures undertaken to limit or prohibit activities that may interfere with the integrity of an interim action or cleanup action or that may result in exposure to hazardous substances at a site. ICs may include use restrictions such as limitations on the use of property or resources or requirements that cleanup action occur if existing structures or pavement are disturbed or removed; maintenance requirements for engineered controls such as the inspection and repair of monitoring wells, treatment systems, caps or groundwater barrier systems; and educational programs such as signs, postings, public notices, health advisories, mailings, and similar measures that educate the public and/or employees about site contamination and ways to limit exposure.	Applicable	Applicable to IC components of the remediation alternatives.
SEPA	WAC 192-11	Requires a review of potential damage that occurs to the environment as a result of human activities.	Applicable	SEPA checklist may be required prior to construction of a remediation system at the site.
Storm Water Management	WAC 173-220	Best management practices must be used and appropriate monitoring performed to ensure that storm water runoff does not cause an exceedance of water quality standards in a receiving surface water body.	Applicable	Substantive requirements applicable to construction, grading, and excavation activities conducted as part of site remediation.
MTCA Regulations: (General Policies)	WAC 173-340-702	Defines the general policies and principles that shall be followed when establishing and implementing cleanup standards. Shall be used in combination with other sections of this chapter.	Applicable	Applicable to establishment of cleanup alternatives.

Acronyms:

ARAR: applicable or relevant and appropriate requirement
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act
CFR: Code of Federal Regulations
EPA: U.S. Environmental Protection Agency
DOT: U.S. Department of Transportation
HRIA: Hamilton Road Impacted Area

Table B-3 Action-Specific ARARs/TBCs (continued)

Acronyms (continued):

IC: institutional control
mg/kg: milligram per kilogram
µg/m^3: microgram per cubic meter
NPDES: National Pollutant Discharge Elimination System
PCE: tetrachloroethene
POTW: publicly owned treatment works
RCRA: Resource Conservation and Recovery Act
SEPA: State Environmental Policy Act
SWCAA: Southwest Clean Air Agency
TBC: to be considered
TCLP: Toxicity Characteristic Leaching Procedure
VOC: volatile organic compound
WAC: Washington Administrative Code
WDFW: Washington Department of Fish and Wildlife

Appendix C

Screening of Alternatives

Table C-1 Screening of Technologies and Process Options Applicable to HRIA Creek Bed Sediment/Bank Surface Soil

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost			Reasons for Elimination of Process Option from Consideration
					Effectiveness	Implementability	Relative Cost	
No Action	No Action	No Action	No action is performed at the site.	Retained	Not effective but required for consideration by the NCP as a baseline for comparison. Unlikely to be acceptable due to the level of contaminants on site. Not protective of human health and the environment.	Easily implemented but is not acceptable to regulatory agencies and does not meet ARARs.	None	Retained (required by NCP as stand-alone alternative)
Institutional Controls	Land Use Controls	Governmental and Proprietary Controls	Contact with contaminated medium would be controlled through zoning and restrictions governing land use of the site.	Retained	Restricts future uses of the site that are not protective of human health and the environment but does not physically address contamination.	Implemented using legal instruments and labor resources; potential public resistance; zoning requires the cooperation of the municipality.	Low	Retained
		Informational Devices	Contact with contaminated medium would be controlled through legal instruments, such as Notices of Environmental Contamination or deed notices	Retained	Restricts future uses of the site that are not protective of human health and the environment but does not physically address contamination.	Somewhat easily implemented using legal instruments and labor resources; potential public resistance.	Low	Retained
	Community Awareness	Information and Education Programs	Community information and education programs would be undertaken to enhance awareness of potential hazards and remedies.	Retained	Protects human receptors by enhancing awareness of potential site hazards and remedies. Does not directly affect ecological receptors and does not physically address contaminants.	Easily implemented using available technical and community involvement labor resources.	Low	Retained
Monitoring	Sampling and Analysis	Sediment/Bank Soil Sampling	Periodic monitoring of sediment/bank soil would be conducted.	Retained	Protects human receptors by monitoring contaminant concentrations and migration. Does not directly affect receptors and does not physically address contaminants.	Easily implemented using available technical labor and equipment resources.	Low to Moderate	Retained
Containment	Capping	Asphalt Cap	Pave area to prevent exposure to contaminated materials and limit water infiltration.	Retained	Protects human receptors by eliminating surface exposure of contaminants and minimizes water infiltration into subsurface with the use of a relatively thin cap construction. Does not physically address existing contamination. Limitations include the following: potential for saturated contaminated sediment under cap to release contamination to the subsurface and potential impacts to ecological receptors by burial of organisms or loss of habitat.	Implemented using available construction resources and materials. Requires increased maintenance for long-term protectiveness. Careful selection of cap material needed to ensure habitat of federal threatened species (Coho salmon) is maintained.	Moderate	Eliminated from consideration due to effectiveness issues (potential release of contaminants to subsurface soil and groundwater).
		Clay Cap	Uses a layer of clay to prevent exposure to contaminated materials and limit water infiltration.	Retained	Protects human receptors by eliminating surface exposure of contaminants and minimizes water infiltration into subsurface. Does not physically address existing contamination. Limitations include the following: potential for saturated contaminated sediment under cap to release contamination to the subsurface, potential impacts to ecological receptors by burial of organisms or loss of habitat, and potential for erosion of cap materials due to stream flow. Effectiveness of clay caps may decrease over time due to development of desiccation cracking.	Implemented using available construction resources and materials. Requires increased maintenance for long-term protectiveness. Careful selection of cap material needed to ensure habitat of federal threatened species (Coho salmon) is maintained.	Low to Moderate	Eliminated from consideration due to effectiveness issues (potential release of contaminants to subsurface soil and groundwater).
		Geomembrane Cap	Uses textile material and associated sub-base and topsoil layers to prevent exposure to contaminated materials and limit water infiltration.	Retained	Protects human receptors by eliminating surface exposure of contaminants and minimizes water infiltration into subsurface with the use of a relatively thin cap construction. Does not physically address existing contamination. Limitations include the following: potential for failure of cap due to pressure of saturated sediments on impermeable geomembrane liner, potential for saturated contaminated sediment under cap to release contamination to the subsurface, flooding of nearby road due to creation of impermeable surface within creek bed, and potential impacts to ecological receptors by burial of organisms or loss of habitat.	Implemented using available construction resources. May require specialized synthetic materials. Requires increased maintenance for long-term protectiveness. Careful selection of cap material needed to ensure habitat of federal threatened species (Coho salmon) is maintained.	Moderate	Eliminated from consideration due to effectiveness issues (potential failure of cap and potential release of contaminants to subsurface soil and groundwater).
		Soil/Crushed Concrete Cap	Uses a layer of soil or crushed concrete to limit exposure to contaminated materials.	Retained	Protects human receptors by eliminating surface exposure of contaminants. Would not prevent water infiltration into the subsurface. Does not physically address existing contamination. Limitations include the following: potential for saturated contaminated sediment under cap to release contamination to the subsurface, potential impacts to ecological receptors by burial of organisms or loss of habitat, and potential for erosion of cap materials due to stream flow.	Easily implemented using available construction resources and materials. Requires some maintenance for long-term protectiveness. Careful selection of cap material needed to ensure habitat of federal threatened species (Coho salmon) is maintained.	Low to Moderate	Eliminated from consideration due to effectiveness issues (potential release of contaminants to subsurface soil and groundwater and erosion of cap material).

Table C-1 Screening of Technologies and Process Options Applicable to HRIA Creek Bed Sediment/Bank Surface Soil

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost: Effectiveness	Implementability	Relative Cost	Reasons for Elimination of Process Option from Consideration
Removal	Excavation	Mechanical Excavation & Backfill	Excavation of contaminated sediment to the extent possible using typical construction equipment and backfill of excavated area to provide a physical barrier to prevent recharge of creek by contaminated groundwater.	Retained	Protects human receptors by eliminating surface exposure of contaminants and reducing subsurface contaminants. Effective technique for removing contaminated sediments from the site. Must be combined with transport, disposal, and/or treatment technologies. Engineered controls may be necessary to capture emissions of contaminants volatized during removal of contaminated sediment.	Easily implemented using available construction resources. Must be combined with source controls during implementation to provide protection to workers and the environment. As part of the excavation, the stream would need to be relocated, and it may be feasible to make the diversion permanent. Diversion necessary to prevent recontamination of sediments by groundwater and to prevent contamination of surface water.	Moderate	Retained
Disposal	Disposal	Offsite Disposal	Disposal of material (treated or untreated) at an offsite permitted facility.	Retained	Protects receptors by eliminating exposure to contaminants and eliminating pathway for transport of contaminants to groundwater. Must be combined with removal, transport, and/or treatment technologies.	Relatively easy to implement using an authorized disposal facility but may require treatment prior to disposal and requires approval of disposal facility.	High	Retained
		Onsite Disposal	Disposal of treated material onsite.	Retained	Protects receptors by eliminating exposure to contaminants and eliminating pathway for transport of contaminants to groundwater. Effective method of disposing of treated soil. Must be combined with removal and/or treatment technologies.	Easily implemented using available construction resources.	Moderate	Retained
Treatment	Thermal	In-situ Vitrification	A high temperature process that melts contaminated soil in-situ, forming an unleachable monolith.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Effective in destroying organic compounds. Off-gas treatment may be necessary to capture any organic contaminants that are vaporized during treatment. Saturated soil may lead to higher costs. Effectiveness is highly dependent on the nature of the subsurface and heterogeneity of the soils.	Relatively difficult to implement due to limited availability of specialized equipment and operators. The technology requires a significant, reliable source of electrical power.	High	Eliminated from consideration due to cost and implementability issues (power requirements and equipment availability).
		In-situ Steam Injection	Injection of steam heats the soil and groundwater and enhances the release of contaminants from the soil matrix by decreasing viscosity and accelerating volatilization.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Very effective in mobilizing residual DNAPL for collection and treatment. Requires vapor-phase or dual-phase extraction and treatment; however, vapor extraction would not be effective at the Site due to low permeability silt and clay layer and shallow groundwater table.	Relatively easy to implement using readily available equipment if size of treatment zone is limited. Can be applied under roads and existing buildings. Groundwater flux high but appropriate. The technology requires a significant, reliable source of electrical power in order to provide capacity to heat saturated soil within sand and gravel aquifer. Creek may need to be relocated during treatment. Presence of low permeability silt and clay layer above the aquifer may necessitate creation of a permeable zone via installation of a gravel-filled trench in order for SVE to be implemented.	High	Eliminated from consideration as a stand-alone alternative for sediments/surface soil since technology is not applicable to shallow sediment, however, retained for consideration if technology is used for subsurface soils and sediment/surface soils are consolidated into that treatment approach.
		In-situ Electrical Resistance Heating	Uses arrays of electrodes to apply electrical current to the subsurface. Heat generated by electrical resistance in the soil creates steam in-situ and works similarly to steam injection.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Very effective in mobilizing residual DNAPL for collection and treatment. Requires vapor-phase or dual-phase extraction and treatment; however, vapor extraction would not be effective at the Site due to low permeability silt and clay layer and shallow groundwater table.	Relatively easy to implement using readily available equipment if size of treatment zone is limited. Groundwater flux high but appropriate	Moderate to High	Eliminated from consideration as a stand-alone alternative for sediments/surface soil, due to effectiveness issues (low permeability soil), however, retained for consideration if technology is used for subsurface soils and sediment/surface soils are consolidated into that treatment approach.
		In-situ Thermal Conductive Heating	Electricity is used to raise the temperature of heater wells or blankets. The heat is transferred to the surrounding formation via thermal conduction. Soil can reach temperatures in excess of 500 degrees Celsius. Treatment modules contain vapor ports that are connected to a process trailer where untreated contaminants are oxidized or absorbed from the vapor stream.	Retained	Thermal conductive heating demonstrated to be highly effective in removing chlorinated solvents from soils; however, thermal conduction heating has great difficulty in treating the saturated zone. Uneven heating would not be conducive to thermally enhanced bioremediation.	Commercial license for the technology granted to one vendor. The technology requires a significant, reliable source of electrical power. Blanket deployed in 8 ft x 20 ft x 1 ft modules. While this technology can heat the subsurface to very high temperatures, the maximum temperature of water is its boiling point. Thus, to heat the subsurface beyond the boiling point of water, soil would be desiccated, which may cause subsidence and structural issues at the surface.	Very High	Eliminated from consideration as a stand-alone alternative for sediments/surface soil due to cost and implementability issues, however ,retained for consideration if technology is used for subsurface soils and sediment/surface soils are consolidated into that treatment approach.

Table C-1 Screening of Technologies and Process Options Applicable to HRIA Creek Bed Sediment/Bank Surface Soil

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost: Effectiveness	Implementability	Relative Cost	Reasons for Elimination of Process Option from Consideration
Treatment (continued)	Thermal (continued)	Ex-situ Incineration	High temperature (2000 °F) burning of soil that destroys organic materials. Can be conducted either on site or off site.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Treated sediment would be backfilled or disposed following incineration.	Difficult to implement due to limited availability of equipment and operators. Anticipate difficulty obtaining local acceptance to site an incinerator for onsite treatment.	Very High	Eliminated from consideration due to cost and implementability issues (availability of equipment and personnel).
		Ex-Situ Thermal Desorption	Thermal desorption is a process that volatilizes organic materials by increasing temperatures to 300 to 600 °C, which are captured and processed in an off-gas treatment system or recycled.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Clay and silty soils and high humic content soils increase reaction times as a result of binding of contaminants. Particle size can reduce performance of technology so sediment may need to be pre-screened and re-worked.	Moderately difficult to implement due to location of remedial action area within creek bed. Equipment and labor resources somewhat readily available. Requires specialized technical personnel for installation of equipment. Dewatering would be necessary for saturated sediments prior to treatment. Off-gas treatment may be required for dust and vapor emissions. May encounter difficulties meeting air discharge requirements. High energy requirements due to high contaminant concentrations. Process has intensive startup and monitoring requirements	High	Eliminated from consideration due to cost.
	Biological	Enhanced In-situ Bioremediation	Uses injection of an electron donor and nutrients to stimulate indigenous bacteria.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Most effective on dissolved-phase organics. Recent studies show that it can be effective in source areas with residual NAPL as well.	Somewhat difficult to implement. Equipment readily available. Administrative issues anticipated for injecting material in an aquatic environment designated as essential fish habitat. Amendment delivery can be challenging in heterogeneous formations, particularly in clayey formations present at the site. Limitations to implementability include the following: delivery method for nutrients, presence of nutrients in subsurface, and type of microorganisms present in subsurface.	Moderate	Eliminated from consideration due to implementability issues (amendment delivery challenges).
		Ex-situ Bioremediation	Excavated sediment would be mixed with water and nutrients. Employs the construction of biological treatment cells to break down organic contaminants to less toxic constituents.	Retained	Protects receptors by eliminating exposure to contaminated soil and reducing concentrations of contaminants in excavated sediment. Effective in treating organic contaminants. Clayey soils can create materials handling problems that limit effectiveness and would need to be re-worked.	Relatively easy to implement using readily available equipment and the low volume of contaminated sediment (approximately 1,400 cubic yards) could be treated in a small area on site. May require off-gas treatment system to address air emissions during handling of excavated material. Requires O&M to monitor and control variables, such as temperature to ensure bioremediation continues to occur.	Moderate	Retained
	Physical	Ex-situ Solidification/ Stabilization	Contaminants would be either encased in a low-permeability matrix or stabilized chemically.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Technology has low or limited expected effectiveness against VOCs especially if the sediment has high organic content; therefore, receptors may not be protected.	Relatively easy to implement using readily available equipment. Administrative difficulties can be anticipated, including modifying an aquatic environment designated as essential fish habitat.	High	Eliminated from consideration due to effectiveness issues (low effectiveness for organic contaminants).
		In-situ Soil Vapor Extraction	Establishes a vacuum in vadose zone to volatilize and extract organic contaminants from soil.	Retained	Protects receptors by reducing concentration of contaminants in subsurface. Effective for removing organic contaminants from vadose zone. Limited effectiveness as site geology consists of low permeability silt and clay surface layer, which would limit the radius of influence of the wells and may cause short circuiting. In addition, the water table is located within 4 feet of ground surface.	Relatively easy to implement using readily available equipment. System may require off-gas treatment to address air emissions. Residual liquids and spent activated carbon may require further treatment.	Moderate	Eliminated from consideration due to effectiveness issues (site geology limitations on radius of influence and presence of shallow water table).
		Ex-situ Soil Vapor Extraction	A vacuum would be induced on excavated sediment to promote air flow through the contaminated sediment to remove organic contaminants.	Retained	Protects receptors by eliminating exposure to contaminated sediment and reducing concentration of contaminants in excavated sediment. May not be as effective when soil contains moderate to high clay content, so clayey material would need to be re-worked.	Relatively easy to implement using readily available equipment and the low volume of contaminated sediment (approximately 1400 cubic yards). However, proportion of indirect costs compared to volume of material to be treated may make this technology less efficient than other applicable ex-situ technologies. May require off-gas treatment system to address air emissions during handling of excavated material.	Moderate to High	Eliminated from consideration based on effectiveness and cost issues compared to other applicable technologies.

Table C-1 Screening of Technologies and Process Options Applicable to HRIA Creek Bed Sediment/Bank Surface Soil

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost: Effectiveness	Implementability	Relative Cost	Reasons for Elimination of Process Option from Consideration
Treatment (continued)	Physical (continued)	In-situ Soil Flushing	Process that injects water/surfactants into the subsurface soil. Requires use of extraction wells or trenches to capture contaminants in the groundwater.	Retained	Protects receptors by reducing concentration of contaminants in subsurface. Effective for removing some contaminants from soil but may lead to increased chance of mobilizing contaminants into groundwater. Target contaminant group is inorganics. It can be used to treat organic contaminants but may be less cost-effective than alternative technologies. Not as effective when soil contains moderate to high clay content. Effectiveness in part depends on ability to capture surfactant solution for extraction and treatment. Potential issue with release of surfactant solution to surface water and groundwater.	Somewhat difficult to implement due to specialized equipment required, permitting concerns, and presence of low permeability soils. Extraction system required to capture flushing fluids. Air emissions of volatile contaminants from recovered flushing fluids should be collected and treated.	Moderate	Eliminated from consideration due to effectiveness (mobilization of contaminants, site geology, release of solution to surface water and groundwater) and implementability issues (specialized equipment availability and site geology).
		Ex-situ Soil Washing	Excavated sediments would be mixed with a washing solution that removes the contaminants from the soil.	Retained	Protects receptors by eliminated exposure to contaminated sediment and reducing contaminant levels in excavated sediment. Not as effective when soil contains moderate to high clay content. Effectiveness may be limited by difficulty in removing organics adsorbed onto clay-size particles. Target contaminant groups are SVOCs, fuels, and heavy metals but can be used for VOCs with limited expected effectiveness.	Somewhat easy to implement using readily available equipment. Low volume of contaminated sediment (approximately 1,400 cubic yards) could be treated in a small area on site. May require off-gas treatment system to address air emissions during handling of excavated material. Requires capture and treatment of washing solution.	High	Eliminated from consideration due to cost and effectiveness issues (clay content of sediment and limited expected effectiveness for organic contaminants).
	Chemical	In-situ Chemical Oxidation	An oxidizing agent (e.g., hydrogen peroxide, Fenton's Reagent, potassium permanganate, persulfate, or ozone) is injected into the subsurface. Organic compounds are destroyed upon reaction with the oxidant.	Retained	Protects receptors by reducing concentration of contaminants in subsurface. Effective organic destruction if adequate contact between reagents and contaminants occurs. Can adversely impact anaerobic degradation in source area. Need to flood soil matrix with chemical oxidants. Expected effectiveness low due to restricted radius of influence caused by low permeability silt and clay surface layer.	Relatively easy to implement using readily available equipment. Delivery can be challenging in heterogeneous formations. Administrative difficulties can be anticipated, including need to meet substantive requirements of injection permits for reagents and injecting material in an aquatic environment designated as essential fish habitat.	Moderate to High	Eliminated from consideration due to effectiveness issues (adverse impact to anaerobic degradation and low radius of influence).
		Ex-situ Chemical Oxidation	Excavated sediment would be mixed with water and chemical oxidants. Organic compounds are destroyed upon reaction with the oxidant. Employs the construction of treatment cells to break down organic material.	Retained	Protects receptors by reducing concentration of contaminants in subsurface. Effective organic destruction if adequate contact between reagents and contaminants occurs. Effectiveness can be limited by incomplete oxidation or formation of intermediate contaminants or when soil contains moderate to high clay content so clayey material would need to be re-worked.	Relatively easy to implement using readily available equipment, as the low volume of contaminated sediment (approximately 1400 cubic yards) could be treated in a small area onsite. May require off-gas treatment system to address air emissions during handling of excavated material.	Moderate to High	Retained

Acronyms:
ARAR: applicable or relevant and appropriate requirement
C: Celsius
DNAPL: dense non-aqueous phase liquid
F: Fahrenheit
ft: feet
NCP: National Oil and Hazardous Substances Pollution Contingency Plan
O&M: operations and maintenance
PCE: tetrachloroethene
SVOC semivolatile organic compounds
VOC: volatile organic compounds

Table C-2 Screening of Technologies and Process Options Applicable to HRIA Groundwater

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost: Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater (PCE > 4,000 μg/L)	Reasons for Elimination of Process Option from Consideration
No Action	No Action	No Action	No action is performed at the site.	Retained	Not effective but required for consideration by the NCP as a baseline for comparison. Unlikely to be acceptable due to the level of contaminants on site. Not protective of human health and the environment.	Easily implemented but is not acceptable to regulatory agencies and does not meet ARARs.	None	Yes	Retained (required by NCP as stand-alone alternative)
Institutional Controls	Land Use Controls	Governmental and Proprietary Controls	Restricts land use at the site.	Retained	Protects human receptors by restricting use of land. Does not directly affect ecological receptors and does not physically address contamination.	Implemented using legal instruments and labor resources; potential public resistance; controls may require the cooperation of the municipality or county governments.	Low	Yes	Retained
	Groundwater Use Controls	Governmental and Proprietary Controls	Groundwater use restrictions would restrict use of groundwater in the zone of contamination.	Retained	Protects human receptors by restricting use of groundwater. Does not directly affect ecological receptors and does not physically address contamination.	Implemented using legal instruments and labor resources; potential public resistance.	Low	Yes	Retained
	Community Awareness	Information and Education Programs	Community information and education programs would be undertaken to enhance awareness of potential hazards and remedies.	Retained	Protects human receptors by enhancing awareness of potential site hazards and remedies. Does not directly affect ecological receptors and does not physically address contaminants.	Easily implemented using available technical and community involvement labor resources.	Low	Yes	Retained
Monitoring	Sampling and Analysis	Groundwater and/or Air Sampling	Periodic monitoring of groundwater and/or air would be conducted.	Retained	Protects human receptors by monitoring contaminant concentrations and migration. Does not directly affect receptors and does not physically address contaminants.	Easily implemented using available technical labor and equipment resources.	Low to Moderate	Yes	Retained
Monitored Natural Attenuation	Monitored Natural Attenuation	Monitored Natural Attenuation	Natural destructive (biodegradation and chemical reactions) and nondestructive mechanisms (dilution, dispersion, volatilization, and adsorption) that reduce contaminant levels.	Retained	Protects human receptors by monitoring contaminant concentrations and migration. Can be effective where natural conditions promote contaminant degradation. Does not directly affect receptors and does not physically address contaminants. Contaminants may migrate before they are degraded. Institutional controls may be required. Sampling indicates the overall geochemistry of the aquifer near the source area is unfavorable for biodegradation. Groundwater in source area shown to be unfavorable to biodegradation. May be effective for degradation products that degrade aerobically, such as vinyl chloride and ethane/ethene.	Easily implemented using available technical labor and equipment resources.	Low	No	Eliminated from consideration as a primary action due to effectiveness issues (aquifer geochemistry); however, it could potentially be used as a secondary or follow on action after the interim action at HRIA is complete.
Containment	Vertical Barrier	Slurry Wall	A subsurface barrier consisting of a trench filled with a slurry of either a soil/ bentonite mixture or a cement/ bentonite mixture, which provides a physical barrier to the contaminated groundwater. May require groundwater extraction to maintain hydraulic control.	Retained	Protects human receptors by eliminating migration of contaminated groundwater horizontally. Does not directly affect ecological receptors and does not physically address contamination. Slurry wall barrier is effective in preventing additional groundwater contamination from migrating off site or for diverting uncontaminated groundwater around a contaminant source. Limited effectiveness if confining layer is not continuous below source area. Use of this technology does not guarantee that further remediation in the future may not be necessary, and there is potential for the slurry wall to degrade or deteriorate over time. In addition, there is potential for contaminated groundwater to flow around the barrier.	Somewhat difficult to implement using readily available equipment due to width, length, and depth of the plume and large amount of heavy construction necessary. Slurry wall would be keyed into confining layer present at the site at a depth of approximately 40 to 50 ft bgs. If slurry wall is used to contain the plume by installing a barrier around the site, then additional technologies, such as groundwater extraction, would be necessary to control groundwater levels at the site.	High	No	Eliminated from consideration due to effectiveness issues (wall degradation potential, potential need for future remediation, and for contaminated groundwater to flow around barrier) and implementability issues (size of plume) and cost.

Table C-2 Screening of Technologies and Process Options Applicable to HRIA Groundwater

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost			Retained for High Concentration Groundwater (PCE > 4,000 μg/L)	Reasons for Elimination of Process Option from Consideration
					Effectiveness	Implementability	Cost		
Containment (continued)	Vertical Barrier (continued)	Grout Curtain	A grout curtain is a solid, low-permeability subsurface vertical barrier formed by injecting grout (e.g., Portland cement) through well points or an injection auger. May require groundwater extraction to maintain hydraulic control.	Retained	Protects human receptors by eliminating migration of contaminated groundwater. Does not directly affect ecological receptors and does not physically address contamination. Grout curtain barrier is effective in preventing additional groundwater contamination from migrating off site or for diverting uncontaminated groundwater around a contaminant source. Limited effectiveness if confining layer is not continuous below source area. Use of this technology does not guarantee that further remediation in the future may not be necessary. In addition, there is potential for contaminated groundwater to flow around the barrier.	Somewhat difficult to implement using readily available equipment due to width, length, and depth of the plume and large amount of heavy construction necessary. Grout curtains are not subject to the depth limitations of other vertical barriers considered, but it may be difficult to verify whether or not a continuous vertical barrier has been keyed into an impermeable lower layer. Spacing of grout injections is important as the grout can migrate.	Moderate to High	No	Eliminated from consideration due to both effectiveness (potential need for future remediation and for contaminated groundwater to flow around barrier) and implementability issues (size of plume and grout distribution challenges).
	Hydraulic Containment through pumping	Extraction Wells	Use of extraction wells to create hydraulic barriers. Potential scenarios for hydraulic barriers include containment of source area groundwater, containment of the leading edge of the high concentration plume, or preventing contaminated groundwater from migrating off site.	Retained	Protects human receptors by reducing migration of contaminated groundwater and by reducing concentrations of contaminants in groundwater. The potential presence of residual NAPL will provide a continuing source of groundwater contamination, limiting extraction effectiveness for long-term source removal. System design could fail to contain the contaminant plume as predicted, allowing the plume to continue to migrate. Must be combined with treatment and disposal.	Readily implementable using available equipment; however, may require compatible material resistant to degradation for high concentrations. Would require long-term use of extraction wells installed at depths up to 50 feet bgs. Also requires modeling to determine placement of extraction wells to capture groundwater plume.	Moderate to High	Yes	Retained
Removal	Surfactant Enhanced Extraction	Surfactant Flushing	Injection of surfactant(s) into a zone of contaminated groundwater to mobilize and solubilize contaminants, followed by downgradient extraction of the contaminated groundwater and surfactant mixture.	Retained	Protects human receptors by reducing concentrations of contaminants. Increases the movement of viscous and low-solubility organic contaminants. Effective in removing organics from the subsurface when used in conjunction with collection methods, such as extraction wells; however, technology cannot attain stringent cleanup criteria, such as typical drinking water goals, in the zone of contamination. Potential toxic effects of residual surfactants in subsurface and potential for offsite migration of contaminants due to increased solubility created by surfactant injection.	Moderately easy to implement with available equipment. Can potentially reduce pump-and-treat times, but administrative difficulties are anticipated. May be required to meet substantive requirements of Underground Injection Control (UIC) permit. Would require long-term use of extraction wells and recapture and treatment of surfactants	High	No	Eliminated due to effectiveness (offsite migration concerns, and toxic effects of surfactants), implementability issues (recapture of surfactants), and cost.
Disposal	Discharge	Discharge to POTW	Discharge of treated water or treatment waste residuals to offsite facility by sanitary sewer.	Retained	Protects human receptors by reducing migration of contaminated groundwater. Effective method for disposing of waste residuals and treated water. Water may require pre-treatment to meet the facility acceptance requirements.	Readily implementable using available construction resources. If sanitary sewer system is present near the site. Discharged water would be required to meet pre-treatment standards.	Low to Moderate	Yes	Retained
		Discharge to Surface Water Body	Discharge of extracted groundwater either directly to a surface water body or to a storm sewer, which leads to a surface water body.	Retained	Protects human receptors by reducing migration of contaminated groundwater and by reducing concentrations of contaminants in groundwater. Must be combined with treatment technologies.	Easily implementable using available construction resources. Would be required to meet substantive requirements of NPDES permit for discharge.	Low	Yes	Retained
		Re-Injection	Disposal of treated water on site into the subsurface using injection wells or an infiltration gallery.	Retained	Protects human receptors by reducing migration of contaminated groundwater through groundwater mounding resulting from injecting treated groundwater at the leading edge of the plume. Effectiveness could be limited by biofouling of injection wells and/or infiltration galleries. Must be combined with treatment technologies. In the source area, potential to lose control of plume, cause migration of residual NAPL, or disperse plume away from the source area.	Moderately easy to implement using available construction resources and equipment, but may require ongoing maintenance. May be required to meet substantive requirements of EPA UIC permit.	Moderate	Yes	Retained.

Table C-2 Screening of Technologies and Process Options Applicable to HRIA Groundwater

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost: Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater (PCE > 4,000 μg/L)	Reasons for Elimination of Process Option from Consideration
Treatment	Biological	In-situ Bio-remediation	Uses injection of amendments (e.g. includes both electron donors and inorganic reductants to stimulate biotic and abiotic degradation of contaminants.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Technology provides mass reduction in source areas as well as plume treatment. Technology can be implemented either throughout the contaminant volume or as a "bio-barrier" by injecting amendments in a line that transects the VOC plume perpendicular to groundwater flow. Groundwater circulation can limit effectiveness if it allows contaminants to escape from zones of active biodegradation (i.e., anaerobic zones). Overall natural geochemistry of aquifer has been found to be unfavorable for anaerobic degradation processes with only limited attenuation of PCE to daughter products occurring.	Relatively easy to implement using readily available equipment. Also there is a large suite of suitable bioremediation amendments that can be selected during design. Remedial delivery can be challenging in heterogeneous formations. Limitations include delivery method for amendments, pressurized injections into confined aquifer, efficiency of distribution, and presence of native biodegrading microorganisms.	Moderate	Yes	Retained
		Ex-situ Bio-remediation	Degradation of contaminants in extracted groundwater by naturally occurring microorganisms through the addition of nutrients, oxygen, and/or substrates in an engineered reactor.	Retained	Protects human receptors by reducing migration of contaminated groundwater and by reducing concentrations of contaminants in groundwater. Technology used primarily to treat VOCs, SVOCs, fuel hydrocarbons, and biodegradable organic matter. Nuisance microorganisms may preferentially colonize bioreactors, leading to reduced effectiveness. Overall geochemistry of aquifer has been found to be unfavorable for biodegradation.	Relatively easy to implement using readily available equipment. Startup time can be slow if organisms need to be acclimated to the wastes. Discharge of treated effluent may be regulated. Very high contaminant concentrations may be toxic to microorganisms. Would require long-term use of extraction wells.	Moderate to High	No	Eliminated from consideration due to effectiveness (geochemistry of aquifer and nuisance microorganisms) and implementability issues (toxicity to microorganisms and time for startup).
		Phyto-remediation	The use of plants to remediate environmental media in-situ.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Technology is limited to shallow soils, streams, and the upper portion of the water table aquifer. Climatic or seasonal conditions may interfere or inhibit plant growth, slow remediation efforts, or increase the length of the treatment period. High concentrations of hazardous materials can be toxic to plants.	Not implementable due to depth of contamination in groundwater aquifer (up to 50 feet below ground surface). Technology will likely require a large surface area of land for remediation, which is not available at the site.	Low to Moderate	No	Eliminated from consideration due to effectiveness (toxicity to plants) and implementability issues (depth of contamination, area required for plants).
	Physical/ Chemical (In-situ)	Permeable Reactive Barrier (Zero Valent Iron [ZVI])	Contaminated groundwater flows (or is pulled by pumping) through the reactive zone where the contaminant reacts with the ZVI.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Technology provides mass reduction in source areas as well as plume treatment. Permeable reactive barriers (PRBs) can be constructed by excavating a trench and backfilling with ZVI. As groundwater passes through the barrier, it reacts with the ZVI. Passive treatment walls may lose their reactive capacity, requiring replacement of reactive medium. Permeability may decrease due to precipitation of metal salts or be limited due to biological activity or chemical precipitation. In addition, some reaction byproducts will not completely degrade, and may require another treatment technology to address them.	Somewhat difficult to implement due to width and depth of contaminant plume and use of a proprietary material. Equipment and labor resources readily available. In addition, pressure injection and or additional of distribution enhancers may be needed to inject particles into the subsurface.	High	No	ZVI PRB eliminated from consideration as a primary action due to cost relative to other physical/chemical treatment technologies; however, use of ZVI is retained for consideration as an amendment for Enhanced In Situ Bioremediation. Selection of amendment type would occur during remedial design.

Table C-2 Screening of Technologies and Process Options Applicable to HRIA Groundwater

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost: Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater (PCE > 4,000 μg/L)	Reasons for Elimination of Process Option from Consideration
Treatment (continued)	Physical/ Chemical (In-situ) (continued)	In-situ Chemical Oxidation	An oxidizing agent (e.g., hydrogen peroxide, Fenton's Reagent, potassium permanganate, persulfate, or ozone) is injected into the subsurface. Organic compounds are destroyed upon reaction with the oxidant.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Effective organic destruction if adequate contact between reagents and contaminants occurs (i.e., adequate quantity of oxidizer distributed and in contact with contaminants long enough for oxidation to occur). Technology provides mass reduction in source areas as well as plume treatment. One limitation on effectiveness is the limited lifespan of the oxidizing agent. Less effective at treating free product NAPL as large quantities of oxidant would be required. Can interfere with anaerobic degradation processes.	Relatively easy to implement using readily available equipment. Chemical delivery can be challenging in heterogeneous formations. Administrative difficulties can be anticipated, including meeting substantive requirements of applicable injection permits for reagents. The short life span of oxidant would require a frequency of injections and relatively large quantity of oxidant.	Moderate	Yes	Retained
		Electrokinetics	An electrical potential would be applied across the contaminated zone through the use of electrodes in the ground. Water and ions migrate under the influence of the DC electrical field. The contaminants are either recovered at the electrodes or the process is coupled with other in-situ processes.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Technology is most applicable to low permeability soils, such as clays and silt-clay mixtures; however, the groundwater aquifer at the site is located in highly permeable soils consisting of fine-grained sand to coarse gravel, with cobbles prevalent.	Somewhat difficult to implement due to width of contaminant plume, need for a large power source, and need for special equipment that is not readily available.	Very High	No	Eliminated from consideration due to cost and implementability issues (power requirements and equipment availability).
	Physical/ Chemical (Ex-Situ)	Ex-Situ Advanced Oxidation	Advanced Oxidation Processes including ultraviolet (UV) radiation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Effective treatment of most organics. Soil oxidant demand can limit effectiveness. Free radical scavengers can inhibit contaminant destruction efficiency.	Moderate implementability using commercially available systems. Off-gas treatment by activated carbon adsorption or catalytic oxidation may be needed. Challenges to implementation include ensuring adequate distribution/mixing of oxidant. Would require long-term use of extraction wells. Costs may be higher than competing technologies because of energy requirements.	High	No	Eliminated from consideration due to cost.
	Thermal	In-Situ Steam Stripping/SVE	Steam is forced into an aquifer through injection wells to vaporize volatile and semivolatile contaminants. Vaporized components rise to the unsaturated zone where they are removed by vacuum extraction and then treated.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. The target contaminant groups for hot water or steam flushing/stripping are VOCs, including DNAPL. Soil type, contaminant characteristics and concentrations, geology, and hydrogeology will significantly impact process effectiveness. Another limitation to effectiveness present at the site is that the unsaturated zone is not very deep.	Somewhat difficult to implement due to need for compatible materials resistant to corrosion and degradation that may not be readily available. Specialized technical personnel required for installation of system. Well locations would be limited by existing development. Creek may need to be relocated during treatment. System would require off-gas treatment to address air emissions. Presence of low permeability silt and clay layer above the aquifer may necessitate creation of a permeable zone via installation of a gravel-filled trench in order for SVE to be implemented. Process would have high energy requirements for steam generation.	High	Yes	Retained
		In-situ Electrical Resistance Heating	Uses arrays of electrodes to apply electrical current to the subsurface. Heat generated by electrical resistance in the soil creates steam in-situ and works similarly to steam injection.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Very effective in mobilizing residual DNAPL for collection and treatment. Requires vapor-phase or dual-phase extraction and treatment.	Relatively easy to implement using readily available equipment if size of treatment zone is limited. Groundwater flux high but appropriate. The technology requires a significant, reliable source of electrical power in order to provide capacity to heat saturated soil within sand and gravel aquifer. Creek may need to be relocated during treatment. Presence of low permeability silt and clay layer above the aquifer may necessitate creation of a permeable zone via installation of a gravel-filled trench in order for SVE to be implemented.	Moderate to High	Yes	Retained

Table C-2 Screening of Technologies and Process Options Applicable to HRIA Groundwater

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost: Effectiveness	Implementability	Cost	Retained for High Concentration Groundwater (PCE > 4,000 μg/L)	Reasons for Elimination of Process Option from Consideration
Treatment (continued)	Thermal (continued)	In-situ Thermal Conductive Heating	Electricity is used to raise the temperature of heater wells. The heat is transferred to the surrounding formation via thermal conduction. The heater wells and adjacent soil can reach temperatures in excess of 500 degrees Celsius. As the soil is heated, contaminants are vaporized or destroyed and drawn by vacuum into the wells in a direction countercurrent to the heat flow.	Retained	Thermal wells have been demonstrated to be highly effective in removing VOCs, including DNAPL, from soils. Requires vapor-phase or dual-phase extraction and treatment	The technology requires a significant, reliable source of electrical power and/or propane or natural gas. Vertical wells would need to be installed in triangular grids at a spacing of 5 to 7 feet between wells. While this technology can heat the subsurface to very high temperatures, the maximum temperature of water is its boiling point. Thus, to heat the subsurface beyond the boiling point of water, soil would be desiccated, which may cause subsidence and structural issues at the surface. Additionally, where the recharge rate of groundwater into the site is greater than the boiling rate of the heater wells, soil temperatures can be raised above 100 degrees Celsius, and it will be necessary to control water influx. Creek may need to be relocated during treatment.	Very High	Yes	Retained
	Physical (In-Situ)	Air Sparging/SVE	Air sparging involves the injection of air or oxygen into the contaminated aquifer. Injected air strips organic contaminants in-situ and helps to flush the contaminants into the unsaturated zone. SVE is usually implemented in conjunction with air sparging to remove the vapor-phase contamination from the vadose zone by vacuum extraction and vapor treatment and to mitigate impacts to surface receptors.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Effective for volatile, relatively insoluble organics. Oxygen added to the contaminated groundwater and vadose-zone soils also can enhance aerobic biodegradation of contaminants below and above the water table but will have adverse effects on anaerobic degradation. Air flow through the saturated zone may not be uniform, which implies that there can be uncontrolled movement of potentially dangerous vapors. Could increase exposure to surface receptors if not implemented in conjunction with SVE. However, SVE would have limited effectiveness as site geology consists of low permeability silt and clay layer above the aquifer.	Somewhat difficult to implement in source area due to need for compatible materials resistant to corrosion that may not be readily available. Specialized technical personnel required for installation of system. Well locations would be limited by existing development. System would require off-gas treatment to address air emissions. Would require long-term use of air sparging and soil vapor extraction wells. Presence of low permeability silt and clay layer above the aquifer may necessitate creation of a permeable zone via installation of a gravel-filled trench in order for SVE to be implemented.	Moderate	No	Eliminated from consideration due to effectiveness (low permeability soil and non uniform air flow), limited vadose zone, and implementability issues (corrosion resistant materials and availability of equipment and personnel).
	Physical (Ex-Situ)	Air Stripping	Mass transfer of volatile contaminants from water to air by increasing surface area of the groundwater exposed to air.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Effective removal of volatile, relatively insoluble organics (including PCE) but is susceptible to biological and inorganic fouling. Effective at treating a wide variety of VOCs.	Somewhat easy to implement using available equipment and labor resources. Off-gas treatment by activated carbon adsorption or catalytic oxidation may be needed. Operations and maintenance requirements include periodic column cleaning. Source area would require compatible materials resistant to corrosion that may not be readily available.	Moderate	Yes	Retained
		Granular Activated Carbon (GAC)	Extracted groundwater or off-gas is pumped through a reactor vessel containing GAC to which contaminants adsorb and are removed.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Effective removal of most organics. May be susceptible to biological and inorganic fouling. Technology is particularly effective for polishing water discharges from other remedial technologies to attain regulatory compliance, and contaminant removal efficiencies are high. Carbon has a short-term duration, especially for high concentrations.	Readily implementable using available equipment. Logistic and economic disadvantages arise from the need to transport and decontaminate spent carbon. Costs are high if used as the primary treatment on waste streams with high contaminant concentration levels. O&M requirements include monitoring of influent and effluent stream, regeneration and replacement of carbon, and backwashing.	Low to High	Yes	Retained
		Reverse Osmosis	Membrane separation of contaminants from water by pressure-gradient forces.	Retained	Protects human receptors by reducing concentrations of contaminants in groundwater. Mainly used as pre- or post-treatment process. Presence of oil or grease can interfere with effectiveness. High potential for fouling of membrane if suspended solid levels are high.	Somewhat difficult to implement. Equipment not readily available. Requires power source. O&M difficult as it requires disposal of brine (supernatant) and adjustment of membranes. May need to be used in conjunction with heat exchanger and membrane pervaporation.	High	No	Eliminated from consideration due to cost and implementability (equipment availability and O&M requirements).

Acronyms:
DNAPL: dense non-aqueous phase liquid
GAC: granular activated carbon
HRIA: Hamilton Road Impacted Area
NCP: National Oil and Hazardous Substances Pollution Contingency Plan
O&M: operations and maintenance
PCE: tetrachloroethene
SVE: soil vapor extraction
SVOC: semivolatile organic compounds
VOC: volatile organic compounds

Table C-3 Screening of Technologies and Process Options Applicable to HRIA Subsurface Soil

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost			Reasons for Elimination of Process Option from Consideration
					Effectiveness	Implementability	Relative Cost	
No Action	No Action	No Action	No action is performed at the site.	Retained	Not effective but required for consideration by the NCP as a baseline for comparison. Unlikely to be acceptable due to the level of contaminants on site. Not protective of human health and the environment.	Easily implemented, but is not acceptable to regulatory agencies and does not meet ARARs.	None	Retained (required by NCP as stand-alone alternative).
Institutional Controls	Land Use Controls	Governmental and Proprietary Controls	Contact with contaminated medium would be controlled through zoning and restrictions governing land use of the site.	Retained	Restricts future uses of the site that are not protective of human health and the environment but does not physically address contamination.	Implemented using legal instruments and labor resources; potential public resistance; zoning requires the cooperation of the municipality.	Low	Retained
		Informational Devices	Contact with contaminated medium would be controlled through legal instruments, such as Notices of Environmental Contamination or deed notices.	Retained	Restricts future uses of the site that are not protective of human health and the environment but does not physically address contamination.	Somewhat easily implemented using legal instruments and labor resources; potential public resistance.	Low	Retained
	Community Awareness	Information and Education Programs	Community information and education programs would be undertaken to enhance awareness of potential hazards and remedies.	Retained	Protects human receptors by enhancing awareness of potential site hazards and remedies. Does not directly affect ecological receptors and does not physically address contaminants.	Easily implemented using available technical and community involvement labor resources.	Low	Retained
Monitoring	Sampling and Analysis	Soil Sampling	Periodic monitoring of soil would be conducted.	Retained	Protects human receptors by monitoring contaminant concentrations and migration. Does not directly affect receptors and does not physically address contaminants.	Easily implemented using available technical labor and equipment resources.	Low to Moderate	Retained
Containment	Capping	Asphalt Cap	Pave area to prevent exposure to contaminated materials and limit water infiltration.	Retained	Protects human receptors by eliminating surface exposure of contaminants and minimizes water infiltration into subsurface with the use of a relatively thin cap construction. Does not physically address existing contamination. Does not lessen toxicity, mobility, or volume of contamination in subsurface soil. Most effective when contamination is present above the water table. Limitations include the following: potential for saturated contaminated subsurface soil under cap to release contamination to groundwater, location of contaminated subsurface soil below the water table and continued horizontal migration of contaminated groundwater off site.	Implemented using available construction resources and materials. Requires increased maintenance for long-term protectiveness.	Moderate	Eliminated from consideration due to effectiveness issues (potential release of contaminants to subsurface groundwater).
		Clay Cap	Uses a layer of clay to prevent exposure to contaminated materials and limit water infiltration.	Retained	Protects human receptors by eliminating surface exposure of contaminants and minimizes water infiltration into subsurface with the use of a relatively thin cap construction. Does not physically address existing contamination. Does not lessen toxicity, mobility, or volume of contamination in subsurface soil. Most effective when contamination is present above the water table. Limitations include the following: potential for saturated contaminated subsurface soil under cap to release contamination to groundwater, location of contaminated subsurface soil below the water table, and continued horizontal migration of contaminated groundwater off site. Effectiveness of clay caps may decrease over time due to development of desiccation cracking.	Implemented using available construction resources and materials. Requires increased maintenance for long-term protectiveness. Careful selection of cap material needed to ensure habitat of federal threatened species (Coho salmon) is maintained.	Low to Moderate	Eliminated from consideration due to effectiveness issues (potential release of contaminants to subsurface groundwater).
Removal	Excavation	Mechanical Excavation and Backfill	Excavation of contaminated soil to the extent possible using typical construction equipment.	Retained	Protects human receptors by eliminating surface exposure of contaminants and reducing subsurface contaminants. Effective technique for removing contaminated soil from the site. Must be combined with transport, disposal, and/or treatment technologies. Engineered controls may be necessary to capture emissions of contaminants volatized during removal of contaminated sediment.	Difficult to implement due to depth of excavation and due to location of soil below the water table. Must be combined with source controls during implementation to provide protection to workers and the environment. As part of the excavation, the stream would need to be relocated, and it may be feasible to make the diversion permanent. In addition, dewatering and water treatment would be required.	Moderate	Eliminated from consideration due to implementability issues (location of contaminated soil below the water table and depth of excavation).
Treatment	Thermal	In-situ Vitrification	A high temperature process that melts contaminated soil in-situ, forming an unleachable monolith.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Effective in destroying organic compounds. Off-gas treatment may be necessary to capture any organic contaminants that are vaporized during treatment. Saturated soil may lead to higher costs. Effectiveness is highly dependent on the nature of the subsurface and heterogeneity of the soils.	Relatively difficult to implement due to limited availability of specialized equipment and operators. The technology requires a significant, reliable source of electrical power.	High	Eliminated from consideration due to cost and implementability issues (power requirements and equipment availability) and effectiveness issues (saturated soil).

Table C-3 Screening of Technologies and Process Options Applicable to HRIA Subsurface Soil

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost: Effectiveness	Implementability	Relative Cost	Reasons for Elimination of Process Option from Consideration
Treatment (continued)	Thermal (continued)	In-situ Steam Injection	Injection of steam heats the soil and groundwater and enhances the release of contaminants from the soil matrix by decreasing viscosity and accelerating volatilization.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Very effective in mobilizing residual DNAPL for collection and treatment. Requires vapor-phase or dual-phase extraction and treatment; however, vapor extraction would not be effective at the site due to low permeability silt and clay layer and shallow groundwater table.	Relatively easy to implement using readily available equipment if size of treatment zone is limited. Can be applied under roads and existing buildings. Groundwater flux high, but appropriate. The technology requires a significant, reliable source of electrical power in order to provide capacity to heat saturated soil within sand and gravel aquifer. Creek may need to be relocated during treatment. Presence of low permeability silt and clay layer above the aquifer may necessitate creation of a permeable zone via installation of a gravel-filled trench in order for SVE to be implemented.	High	Retained
		In-situ Electrical Resistance Heating	Uses arrays of electrodes to apply electrical current to the subsurface. Heat generated by electrical resistance in the soil creates steam in-situ and works similarly to steam injection.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Very effective in mobilizing residual DNAPL for collection and treatment. Requires vapor-phase or dual-phase extraction and treatment; however, vapor extraction would not be effective at the site due to low permeability silt and clay layer and shallow groundwater table.	Relatively easy to implement using readily available equipment if size of treatment zone is limited. Groundwater flux high, but appropriate. The technology requires a significant, reliable source of electrical power in order to provide capacity to heat saturated soil within sand and gravel aquifer. Creek may need to be relocated during treatment. Presence of low permeability silt and clay layer above the aquifer may necessitate creation of a permeable zone via installation of a gravel-filled trench in order for SVE to be implemented.	Moderate to High	Retained
		In-situ Thermal Conductive Heating	Electricity is used to raise the temperature of heater wells. The heat is transferred to the surrounding formation via thermal conduction. The heater wells and adjacent soil can reach temperatures in excess of 500 °C. As the soil is heated, contaminants are vaporized or destroyed and drawn by vacuum into the wells in a direction countercurrent to the heat flow.	Retained	Thermal wells have been demonstrated to be highly effective in removing chlorinated solvents from soils; however, thermal conduction heating has great difficulty in treating the saturated zone. Uneven heating would not be conducive to thermally enhanced bioremediation.	The technology requires a significant, reliable source of electrical power. Vertical wells would need to be installed in triangular grids at a spacing of 5 to 7 feet between wells. While this technology can heat the subsurface to very high temperatures, the maximum temperature of water is its boiling point. Thus, to heat the subsurface beyond the boiling point of water, soil would be desiccated, which may cause subsidence and structural issues at the surface. Additionally, where the recharge rate of groundwater into the site is greater than the boiling rate of the heater wells, soil temperatures can be raised above 100 degrees Celsius and it will be necessary to control water influx.	Very High	Retained
		Ex-situ Incineration	High temperature (2000 °F) burning of soil that destroys organic materials. Can be conducted either on site or off site.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Treated sediment would be backfilled or disposed following incineration.	Difficult to implement due to limited availability of equipment and operators. Anticipate difficulty obtaining local acceptance to site an incinerator for onsite treatment.	Very High	Eliminated from consideration due to cost and implementability issues (availability of equipment and personnel).
		Ex-Situ Low Temperature Thermal Desorption	Low temperature (300 to 600 °C) process that volatilizes organic materials, which are captured and processed in an off-gas treatment system or recycled.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Clay and silty soils and high humic content soils increase reaction times as a result of binding of contaminants. Particle size can reduce performance of technology so sediment may need to be pre-screened and re-worked.	Moderately difficult to implement due to location of remedial action area beneath creek bed and below water table. Equipment and labor resources somewhat readily available. Requires specialized technical personnel for installation of equipment. Dewatering would be necessary for saturated soil prior to treatment. Off-gas treatment may be required for dust and vapor emissions. May encounter difficulties meeting air discharge requirements. High energy requirements due to high contaminant concentrations. Process has intensive startup and monitoring requirements	High	Eliminated from consideration due to cost.
	Biological	Enhanced In-situ Bioremediation	Uses injection of an amendments (e.g. includes both electron donors and inorganic reductants, such as zero valent iron) to stimulate biotic and abiotic degradation of contaminants.	Retained	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Most effective on dissolved-phase organics. Recent studies show that it can be effective in source areas with residual DNAPL as well. Overall natural geochemistry of aquifer has been found to be unfavorable for biodegradation with only minor biodegradation of PCE to daughter products occurring.	Relatively easy to implement using readily available equipment. Also there is a large suite of suitable bioremediation amendments that can be selected during design. Amendment delivery can be challenging in heterogeneous formations, particularly in clayey formations present at the site. Limitations to implementability include the following: delivery method for nutrients, presence of nutrients in subsurface, and type of microorganisms present in subsurface. Requires relatively long timeframe for remediation (years to decades) if high concentrations of VOCs, including DNAPL are present, due to limited bioavailability of residual VOCs.	Moderate	Retained.

Table C-3 Screening of Technologies and Process Options Applicable to HRIA Subsurface Soil

General Response Action	Technology Type	Process Option	Description	Technical Implementability Screening	Screening for Effectiveness, Implementability, and Relative Cost: Effectiveness	Implementability	Relative Cost	Reasons for Elimination of Process Option from Consideration
Treatment (continued)	Biological (continued)	Phyto-remediation	The use of plants to remediate environmental media in-situ.	Retained	Protects human receptors by reducing concentrations of contaminants in soil. Technology is limited to shallow soils, streams, and the upper portion of the water table aquifer. Climatic or seasonal conditions may interfere or inhibit plant growth, slow remediation efforts, or increase the length of the treatment period. High concentrations of hazardous materials can be toxic to plants.	Not implementable due to depth of contamination in subsurface (up to 30 feet below ground surface). Technology will likely require a large surface area of land for remediation, which is not available at the site.	Low to Moderate	Eliminated from consideration due to effectiveness (toxicity to plants) and implementability issues (depth of contamination, area required for plants).
	Physical	In-situ Soil Vapor Extraction	Establishes a vacuum in vadose zone to volatilize and extract organic contaminants from soil.	Retained	Protects receptors by reducing concentration of contaminants in subsurface. Effective for removing organic contaminants from vadose zone. Limited effectiveness as site geology consists of low permeability silt and clay surface layer, which would limit the radius of influence of the wells and may cause short circuiting. In addition, the water table is located within 4 feet of ground surface, and the contaminated soil is located below the water table.	Relatively easy to implement using readily available equipment. System may require off-gas treatment to address air emissions. Residual liquids and spent activated carbon may require further treatment. Groundwater table would need to be lowered to increase the depth of the vadose zone. Presence of low permeability silt and clay layer above the aquifer may necessitate creation of a permeable zone via installation of a gravel-filled trench in order for SVE to be implemented.	Moderate	Eliminated from consideration due to effectiveness issues (low permeability silt/clay layer and shallow water table).
	Physical (continued)	In-situ Soil Flushing	Process that injects water/surfactants into the subsurface soil. Requires use of extraction wells or trenches to capture contaminants in the groundwater.	Retained	Protects receptors by reducing concentration of contaminants in subsurface. Effective for removing some contaminants from soil but may lead to increased chance of mobilizing contaminants into groundwater. Target contaminant group is inorganics. It can be used to treat organic contaminants, but may be less cost-effective than alternative technologies. Not as effective when soil contains moderate to high clay content. Effectiveness in part depends on ability to capture surfactant solution for extraction and treatment. Potential issue with release of surfactant solution to surface water and groundwater.	Somewhat difficult to implement due to specialized equipment required. Extraction system required to capture flushing fluids. Air emissions of volatile contaminants from recovered flushing fluids should be collected and treated.	Moderate	Eliminated from consideration due to effectiveness (mobilization of contaminants and release of solution to surface water and groundwater) and implementability issues (specialized equipment availability).
	Chemical	In-situ Chemical Oxidation	An oxidizing agent (e.g., hydrogen peroxide, Fenton's Reagent, potassium permanganate, persulfate, or ozone) is injected into the subsurface. Dissolved organic compounds are destroyed upon reaction with the oxidant.	Retained	Protects receptors by reducing concentration of contaminants in subsurface. Effective organic destruction if adequate contact between reagents and dissolved contaminants occurs. Can adversely impact anaerobic degradation in source area. Need to flood soil matrix with chemical oxidants.	Relatively easy to implement using readily available equipment. Delivery can be challenging in heterogeneous formations. Administrative difficulties can be anticipated, including need to meet substantive requirements of injection permits for reagents. Short life of oxidants requires frequent injections, especially to treat high VOC concentrations in soils containing DNAPL. Requires relatively long timeframe for remediation (years to decades) if high concentrations of VOCs, including DNAPL are present, due to limited availability of residual VOCs.	Moderate to High	Retained

Acronyms:
ARAR: applicable or relevant and appropriate requirement
DNAPL: dense non-aqueous phase liquid
GAC: granular activated carbon
HRIA: Hamilton Road Impacted Area
NCP: National Oil and Hazardous Substances Pollution Contingency Plan
O&M: operations and maintenance
PCE: tetrachloroethene
SVE: soil vapor extraction
SVOC: semivolatile organic compounds
VOC: volatile organic compounds

Appendix D

Detailed Alternative Analysis Cost Information

Cost Estimate for Alternative SD-2

Removal of Contaminated Creek Bed Sediment Soil with

Offsite Treatment and Disposal and Re-routing of Stream

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LS	$52,000	$52,000		
2	*Diversion of Berwick Creek:*						
	Fish roundup	1	DAY	$3,500	$3,500		
	Pump - creek water	4	WK	$2,000	$8,000		
	4-ft PVC pipe	350	LF	$178	$62,300		
	Dam materials	65	CY	$20	$1,300		
	Dam construction	2	LS	$10,000	$20,000		
3	*Excavation Dewatering:*						
	Well Water recovery and treatment system	1	LS	$30,000	$30,000		
	Wellhead plumbing and electrical connection	1	LS	$11,600	$11,600		
4	*Excavate Contaminated Silt:*						
	Excavation	1,400	LCY	$50	$70,000		
	Contaminated soil disposal (includes transport)	1,875	TON	$462	$866,300		
5	*Creek Restoration:*						
	GCL in creek bed	4,000	SF	$1	$4,700		
	Habitat restoration	1	LS	$65,000	$65,000		
6	*Supplemental Investigation*						
	Additional Characterization – Berwick Creek	1	LS	$19,130	$19,100		
	Subtotal (1)				$1,213,800		
7	*Confirmation Sampling*						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	(b) Sample Collection and Analysis (3 locations)						
	(1) sample collection	1	EVENT	$6,000		$6,000	$5,607
	(2) sample analysis	3	LS	$500		$1,500	$1,402
	Subtotal (2)				$15,000	$7,500	$7,009
8	*Excavation Dewatering O&M:*						
	Water treatment operation	1	MO	$10,000		$10,000	$9,346
	System electrical usage	1	MO	$2,000		$2,000	$1,869
	Carbon change-outs	2,000	LB	$4		$7,000	$6,542
	Subtotal (3)					$19,000	$17,757
	CONSTRUCTION SUBTOTAL				$1,228,800		
	Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$122,880		
	Contractor Overhead	15% of Construction Subtotal			$184,320		
	Contractor Profit	10% of Construction Subtotal			$122,880		
	Contingency	40% of Construction Subtotal			$491,520		

Cost Estimate for Alternative SD-2

Removal of Contaminated Creek Bed Sediment Soil with

Offsite Treatment and Disposal and Re-routing of Stream

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost	
						Annual	Present Worth
	CONSTRUCTION TOTAL				$2,150,400		
	Project Management	10% of Construction Total			$215,040		
	Engineering	15% of Construction Total			$322,560		
	Services During Construction	15% of Construction Total			$322,560		
	TOTAL CAPITAL COSTS				$3,010,560		
	OPERATION & MAINTENANCE SUBTOTAL					$26,500	$24,766
	O&M Project Management and Support	5% of O&M Subtotal				$1,325	$1,238
	O&M Contingency	25% of O&M Subtotal				$6,625	$6,192
	TOTAL ESTIMATED COSTS				$3,011,000	$34,000	$32,000
	NET PRESENT WORTH				$3,043,000		

Cost Details for Alternative SD-2

Number	Item		Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*		1	LS	$52,000	$52,000		
	Cost Source:	Engineering Estimate, various projects 7% of activity cost						
2	*Diversion of Berwick Creek:*							
	Fish roundup		1	DAY	$3,500	$3,500		
	Cost Source:	Duration: Paramatrix FS (2008)						
		2 Staff at $80/hr for 1 - 10 hour day						
	Pump - creek water		4	WK	$2,000	$8,000		
	Cost Source:	Cost Works 2012						
		01 54 3340 4900 ($1,425 / month) + 20 hrs maintenance/week @$80/hr						
	4-ft PVC pipe		350	LF	$178	$62,300		
	Cost Source:	Cost Works 2012						
		22 11 1378 0178 and assumes excavation costs are included in dam materials/construction costs						
	Dam materials		65	CY	$20	$1,300		
	Cost Source:	Engineering Estimate/ PA ponds for berm constructed of soil						
	Dam construction		2	LS	$10,000	$20,000		
	Cost Source:	Paramatrix FS (2008)						
		Includes traffic control necessary for construction						
3	*Excavation Dewatering:*							
	Well Water recovery and treatment system		1	LS	$30,000	$30,000		
	Cost Source:	Vendor Quote and escalation factor						
	Wellhead plumbing and electrical connection		1	LS	$11,600	$11,600		
	Cost Source:	Engineering Estimate/Means 2006						
		240' 4" PVC header pipe, 40' 2" PVC indiv. pipe runs from header pipe to wells, 280' 2" PVC elec.						
		Conduit (33 71 1917 4580), 4 new well vaults (EE) at each well, 200' temp fence (01 56 2650 0100)						
4	*Excavate Contaminated Silt:*							
	Excavation		1,400	LCY	$50	$70,000		
	Cost Source:	Cost Works 2012						
		Excavator, hydraulic crawler mounted 1 CY capacity ($2000/wk) plus operator ($80/hr)						
	Contaminated soil disposal (includes transport)		1,875	TON	$462	$866,300		
	Cost Source:	Cost Works 2012						
		02 81 2010 1270 + 02 81 2010 6020 and assumes 220 miles shipment via bulk hauler						
5	*Creek Restoration:*							
	GCL in creek bed		4,000	SF	$1	$4,700		
	Cost Source:	Cost Works 2012 item 025613102311						
	Habitat restoration		1	LS	$65,000	$65,000		
	Cost Source:	Previous Project Actual Costs						
6	*Supplemental Investigation*							
	Additional Characterization – Berwick Creek		1	LS	$19,130	$19,100		
	Cost Source:	Engineering Estimate						
		HSA and Geologist for 1 day						
		1 Day Sampling (8 sediment, 8 surface water), 28 total sampling including travel and misc costs						
7	*Confirmation Sampling*							
	(a) Develop Sampling Plan		1	LS	$15,000	$15,000		
	Cost Source:	Engineering Estimate						
		150 Professional Hours at $100/hour						
	(b) Sample Collection and Analysis (3 locations)							
	(1) sample collection		1	EVENT	$6,000		$6,000	$5,607
	Cost Source:	Engineering Estimate (based on previous project experience)						

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Cost Details for Alternative SD-2

Number	Item		Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
	(2) sample analysis		3	LS	$500		$1,500	$1,402
	Cost Source:	Engineering Estimate						
		Analysis by Manchester Lab						
8	*Excavation Dewatering O&M:*							
	Water treatment operation		1	MO	$10,000		$10,000	$9,346
	Cost Source:	Engineering Estimate						
		1 O&M Operator (160 hours x $50/hour) + $2000 misc O&M Supplies						
	System electrical usage		1	MO	$2,000		$2,000	$1,869
	Cost Source:	On going Remedial Action Costs for Electricity						
	Carbon change-outs		2,000	LB	$4		$7,000	$6,542
	Cost Source:	On going Remedial Action Costs for Activated Carbon Change Out (EPA Region III)						

CDM Smith

Cost Estimate for Alternative SD-3a

Removal of Contaminated Creek Bed Sediment Soil with

Ex situ Chemical Oxidation, Onsite Disposal and Re-routing of Stream

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LS	$52,000	$52,000		
2	*Diversion of Berwick Creek:*						
	Fish roundup	1	DAY	$3,500	$3,500		
	Pump - creek water	4	WK	$2,000	$8,000		
	4-ft HDPE	350	LF	$178	$62,300		
	Dam materials	65	CY	$20	$1,300		
	Dam construction	2	LS	$10,000	$20,000		
3	*Excavation Dewatering:*						
	Well Water recovery and treatment system	1	LS	$30,000	$30,000		
	Wellhead plumbing and electrical connection	1	LS	$11,600	$11,600		
4	*Excavate Contaminated Silt:*						
	Excavation	1,400	CY	$50	$70,000		
	Dewatering excavated silt	1,400	CY	$8	$11,200		
5	*Creek Restoration:*						
	GCL in creek bed	4,000	SF	$1	$4,700		
	Habitat restoration	1	LS	$65,000	$65,000		
6	*Ex situ Chemical Oxidation*						
	TreatabilityStudy	1	LS	$179,000	$179,000		
	Ex situ soil mixer - equipment	4	DAY	$4,000	$16,000		
	Chemical Oxidation Treatment	1,400	CY	$500	$700,000		
7	*Onsite Disposal of Treated Material*	1,400	CY	$10	$14,000		
8	*Supplemental Investigation*						
	Additional Characterization – Berwick Creek	1	LS	$19,130	$19,100		
	Subtotal (1)				$1,267,700		
9	Confirmation Sampling						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	(b) Sample Collection and Analysis (3 locations)						
	(1) sample collection	1	EVENT	$6,000		$6,000	$5,607
	(2) sample analysis	3	LS	$500		$1,500	$1,402
	(c) Treatment Pile Sample Collection and Analysis	3	EVENT	$5,000		$15,000	$14,019
	Subtotal (2)				$15,000	$22,500	$21,028
10	*Excavation Dewatering O&M:*						
	Water treatment operation	1	MO	$10,000		$10,000	$9,346
	System electrical usage	1	MO	$2,000		$2,000	$1,869
	Carbon change-outs	2,000	LB	$4		$7,000	$6,542
	Subtotal (3)					$19,000	$17,757
	CONSTRUCTION SUBTOTAL				$1,282,700		
	Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$128,270		
	Contractor Overhead	15% of Construction Subtotal			$192,405		
	Contractor Profit	10% of Construction Subtotal			$128,270		
	Contingency	40% of Construction Subtotal			$513,080		
	CONSTRUCTION TOTAL				$2,244,725		
	Project Management	10% of Construction Total			$224,473		
	Engineering	15% of Construction Total			$336,709		
	Services During Construction	15% of Construction Total			$336,709		
	TOTAL CAPITAL COSTS				$3,142,615		

CDM Smith

Cost Estimate for Alternative SD-3a

Removal of Contaminated Creek Bed Sediment Soil with

Ex situ Chemical Oxidation, Onsite Disposal and Re-routing of Stream

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost	
						Annual	Present Worth
	OPERATION & MAINTENANCE SUBTOTAL					$41,500	$38,785
	O&M Project Management and Support	5% of O&M Subtotal				$2,075	$1,939
	O&M Contingency	25% of O&M Subtotal				$10,375	$9,696
	TOTAL ESTIMATED COSTS				$3,143,000	$54,000	$50,000
	NET PRESENT WORTH				$3,193,000		

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Cost Detail for Alternative SD-3a

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LS	$52,000	$52,000		
	Cost Source: Engineering Estimate, various projects 7% of activity cost						
2	*Diversion of Berwick Creek:*						
	Fish roundup	1	DAY	$3,500	$3,500		
	Cost Source: Duration: Paramatrix FS (2008) 2 Staff at $80/hr for 1 - 10 hour day						
	Pump - creek water	4	WK	$2,000	$8,000		
	Cost Source: Cost Works 2012 01 54 3340 4900 ($1,425 / month) + 20 hrs maintenance/week @$80/hr						
	4-ft PVC pipe	350	LF	$178	$62,300		
	Cost Source: Cost Works 2012 22 11 1378 0178 and assumes excavation costs are included in dam materials/construction costs						
	Dam materials	65	CY	$20	$1,300		
	Cost Source: Engineering Estimate/ PA ponds for berm constructed of soil						
	Dam construction	2	LS	$10,000	$20,000		
	Cost Source: Paramatrix FS (2008) Includes traffic control necessary for construction						
3	*Excavation Dewatering:*						
	Well Water recovery and treatment system	1	LS	$30,000	$30,000		
	Cost Source: Vendor Quote and escalation factor						
	Wellhead plumbing and electrical connection	1	LS	$11,600	$11,600		
	Cost Source: Engineering Estimate/Means 2006 240' 4" PVC header pipe, 40' 2" PVC indiv. pipe runs from header pipe to wells, 280' 2" PVC elec. Conduit (33 71 1917 4580), 4 new well vaults (EE) at each well, 200' temp fence (01 56 2650 0100)						
4	*Excavate Contaminated Silt:*						
	Excavation	1,400	LCY	$50	$70,000		
	Cost Source: Cost Works 2012 Excavator, hydraulic crawler mounted 1 CY capacity ($2000/wk) plus operator ($80/hr)						
	Dewatering excavated silt	1,400	CY	$8	$11,200		
	Cost Source: Engineering Estimate						
5	*Creek Restoration:*						
	GCL in creek bed	4,000	SF	$1	$4,700		
	Cost Source: Cost Works 2012 item 025613102311						
	Habitat restoration	1	LS	$65,000	$65,000		
	Cost Source: Previous Project Actual Costs						
6	*Ex situ Chemical Oxidation*						
	TreatabilityStudy	1	LS	$179,000	$179,000		
	Cost Source: Engineering Estimate (25% of full implementation due to small volume)						
	Ex situ soil mixer - equipment	4	DAY	$4,000	$16,000		
	Cost Source: www.regenesis.com Regenox Technical Bulletin 11						
	Chemical Oxidation Treatment	1,400	CY	$500	$700,000		
	Cost Source: www.ftr.gov/matrix2/section4/4-16.html - Conservative Unit Cost Rate (cy basis)						
7	*Onsite Disposal of Treated Material*	1,400	CY	$10	$14,000		
	Cost Source: Engineering Estimate, onsite relocation of treated materials						
8	*Supplemental Investigation*						
	Additional Characterization – Berwick Creek	1	LS	$19,130	$19,100		
	Cost Source: Engineering Estimate HSA and Geologist for 1 day 1 Day Sampling (8 sediment, 8 surface water), 28 total sampling including travel and misc costs						

Cost Detail for Alternative SD-3a

Number	Item		Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
9	*Confirmation Sampling*							
	(a) Develop Sampling Plan		1	LS	$15,000	$15,000		
	Cost Source:	Engineering Estimate						
		150 Professional Hours at $100/hour						
	(b) Sample Collection and Analysis (3 locations)							
	Cost Source:	Engineering Estimate						
	(1) sample collection		1	EVENT	$6,000		$6,000	$5,607
	Cost Source:	Engineering Estimate						
	(2) sample analysis		3	LS	$500		$1,500	$1,402
	Cost Source:	Engineering Estimate						
		Analysis by Manchester Lab						
	(c) Treatment Pile Sample Collection and Analysis		3	EVENT	$5,000		$15,000	$14,019
	Cost Source:	Engineering Estimate						
10	*Excavation Dewatering O&M:*							
	Water treatment operation		1	MO	$10,000		$10,000	$9,346
	Cost Source:	Engineering Estimate						
		1 O&M Operator (160 hours x $50/hour) + $2000 misc O&M Supplies						
	System electrical usage		1	MO	$2,000		$2,000	$1,869
	Cost Source:	On going Remedial Action Costs for Electricity						
	Carbon change-outs		2,000	LB	$4		$7,000	$6,542
	Cost Source:	On going Remedial Action Costs for Activated Carbon Change Out (EPA Region III)						

Cost Estimate for Alternative SD-3b

Removal of Contaminated Creek Bed Sediment Soil with

Ex situ Bioremediation, Onsite Disposal and Re-routing of Stream

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost	
						Annual	Present Worth
1	*Mobilization*	1	LS	$52,000	$52,000		
2	*Diversion of Berwick Creek:*						
	Fish roundup	1	DAY	$3,500	$3,500		
	Pump - creek water	4	WK	$2,000	$8,000		
	4-ft PVC pipe	350	LF	$178	$62,300		
	Dam materials	65	CY	$20	$1,300		
	Dam construction	2	LS	$10,000	$20,000		
3	*Excavation Dewatering:*						
	Well Water recovery and treatment system	1	LS	$30,000	$30,000		
	Wellhead plumbing and electrical connection	1	LS	$11,600	$11,600		
4	*Excavate Contaminated Silt:*						
	Excavation	1,400	CY	$50	$70,000		
	Dewatering excavated silt	1,400	CY	$8	$11,200		
5	*Creek Restoration:*						
	GCL in creek bed	4,000	SF	$1	$4,700		
	Habitat restoration	1	LS	$65,000	$65,000		
6	*Ex situ Bioremediation*						
	TreatabilityStudy	1	LS	$179,000	$179,000		
	Ex situ soil mixer - equipment	4	DAY	$4,000	$16,000		
	Solid Phase Bioremediation	1,400	CY	$500	$700,000		
7	*Onsite Disposal of Treated Material*	1,400	CY	$10	$14,000		
8	*Supplemental Investigation*						
	Additional Characterization – Berwick Creek	1	LS	$19,130	$19,100		
	Subtotal (1)				$1,267,700		
9	*Confirmation Sampling*						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	(b) Sample Collection and Analysis (3 locations)						
	(1) sample collection	1	EVENT	$6,000		$6,000	$5,607
	(2) sample analysis	3	LS	$500		$1,500	$1,402
	(c) Treatment Pile Sample Collection and Analysis	3	EVENT	$5,000		$15,000	$14,019
	Subtotal (2)				$15,000	$22,500	$21,028
10	*Excavation Dewatering O&M:*						
	Water treatment operation	1	MO	$10,000		$10,000	$9,346
	System electrical usage	1	MO	$2,000		$2,000	$1,869
	Carbon change-outs	2,000	LB	$4		$7,000	$6,542
	Subtotal (3)					$19,000	$17,757
	CONSTRUCTION SUBTOTAL				$1,282,700		
	Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$128,270		
	Contractor Overhead	15% of Construction Subtotal			$192,405		
	Contractor Profit	10% of Construction Subtotal			$128,270		
	Contingency	40% of Construction Subtotal			$513,080		
	CONSTRUCTION TOTAL				$2,244,725		
	Project Management	10% of Construction Total			$224,473		
	Engineering	15% of Construction Total			$336,709		
	Services During Construction	15% of Construction Total			$336,709		
	TOTAL CAPITAL COSTS				$3,142,615		

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Cost Estimate for Alternative SD-3b

Removal of Contaminated Creek Bed Sediment Soil with

Ex situ Bioremediation, Onsite Disposal and Re-routing of Stream

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost	
						Annual	Present Worth
	OPERATION & MAINTENANCE SUBTOTAL					$41,500	$38,785
	O&M Project Management and Support	5% of O&M Subtotal				$2,075	$1,939
	O&M Contingency	25% of O&M Subtotal				$10,375	$9,696
	TOTAL ESTIMATED COSTS				$3,143,000	$54,000	$50,000
	NET PRESENT WORTH				$3,193,000		

Cost Detail for Alternative SD-3b

Number	Item		Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*		1	LS	$52,000	$52,000		
		Cost Source: Engineering Estimate, various projects 7% of activity cost						
2	*Diversion of Berwick Creek:*							
	Fish roundup		1	DAY	$3,500	$3,500		
		Cost Source: Duration: Paramatrix FS (2008)						
		2 Staff at $80/hr for 1 - 10 hour day						
	Pump - creek water		4	WK	$2,000	$8,000		
		Cost Source: Cost Works 2012						
		01 54 3340 4900 ($1,425 / month) + 20 hrs maintenance/week @$80/hr						
	4-ft PVC pipe		350	LF	$178	$62,300		
		Cost Source: Cost Works 2012						
		22 11 1378 0178 and assumes excavation costs are included in dam materials/construction costs						
	Dam materials		65	CY	$20	$1,300		
		Cost Source: Engineering Estimate/ PA ponds for berm constructed of soil						
	Dam construction		2	LS	$10,000	$20,000		
		Cost Source: Paramatrix FS (2008)						
		Includes traffic control necessary for construction						
3	*Excavation Dewatering:*							
	Well Water recovery and treatment system		1	LS	$30,000	$30,000		
		Cost Source: Vendor Quote and escalation factor						
	Wellhead plumbing and electrical connection		1	LS	$11,600	$11,600		
		Cost Source: Engineering Estimate/Means 2006						
		240' 4" PVC header pipe, 40' 2" PVC indiv. pipe runs from header pipe to wells, 280' 2" PVC elec.						
		Conduit (33 71 1917 4580), 4 new well vaults (EE) at each well, 200' temp fence (01 56 2650 0100)						
4	*Excavate Contaminated Silt:*							
	Excavation		1,400	LCY	$50	$70,000		
		Cost Source: Cost Works 2012						
		Excavator, hydraulic crawler mounted 1 CY capacity ($2000/wk) plus operator ($80/hr)						
	Dewatering excavated silt		1,400	CY	$8	$11,200		
		Cost Source: Engineering Estimate						
5	*Creek Restoration:*							
	GCL in creek bed		4,000	SF	$1	$4,700		
		Cost Source: Cost Works 2012 item 025613102311						
	Habitat restoration		1	LS	$65,000	$65,000		
		Cost Source: Previous Project Actual Costs						
6	*Ex situ Bioremediation*							
	TreatabilityStudy		1	LS	$179,000	$179,000		
		Cost Source: Engineering Estimate (25% of full implementation due to small volume)						
	Ex situ soil mixer - equipment		1	DAY	$16,000	$16,000		
		Cost Source: www.regenesis.com Regenox Technical Bulletin 11						
	Solid Phase Bioremediation	Source: FRTR; Tower Chem	1,400	CY	$500	$700,000		
7	*Onsite Disposal of Treated Material*		1,400	CY	$10	$14,000		
		Cost Source: Engineering Estimate, onsite relocation of treated materials						
8	*Supplemental Investigation*							
	Additional Characterization – Berwick Creek		1	LS	$19,130	$19,100		
		Cost Source: Engineering Estimate						
		HSA and Geologist for 1 day						
		1 Day Sampling (8 sediment, 8 surface water), 28 total sampling including travel and misc costs						

Cost Detail for Alternative SD-3b

Number	Item		Quantity	Units	Unit Cost	Capital Cost	O&M Cost	
							Annual	Present Worth
9	*Confirmation Sampling*							
	(a) Develop Sampling Plan		1	LS	$15,000	$15,000		
	Cost Source:	Engineering Estimate						
		150 Professional Hours at $100/hour						
	(b) Sample Collection and Analysis (3 locations)							
	Cost Source:	Engineering Estimate						
	(1) sample collection		1	EVENT	$6,000		$6,000	$5,607
	Cost Source:	Engineering Estimate						
	(2) sample analysis		3	LS	$500		$1,500	$1,402
	Cost Source:	Engineering Estimate						
		Analysis by Manchester Lab						
	(c) Treatment Pile Sample Collection and Analysis		3	EVENT	$5,000		$15,000	$14,019
	Cost Source:	Engineering Estimate						
10	*Excavation Dewatering O&M:*							
	Water treatment operation		1	MO	$10,000		$10,000	$9,346
	Cost Source:	Engineering Estimate						
		1 O&M Operator (160 hours x $50/hour) + $2000 misc O&M Supplies						
	System electrical usage		1	MO	$2,000		$2,000	$1,869
	Cost Source:	On going Remedial Action Costs for Electricity						
	Carbon change-outs		2,000	LB	$4		$7,000	$6,542
	Cost Source:	On going Remedial Action Costs for Activated Carbon Change Out (EPA Region III)						

Cost Estimate for Alternative HC-2

Hydraulic Containment with Institutional Controls and Monitoring

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LS	$52,000	$52,000		
2	*Hydraulic Control System:*						
	Water treatment system purchase	1	LS	$179,700	$179,700		
	Electrical power drop	1	LS	$10,000	$10,000		
	Wellhead plumbing and electrical connection	1	LS	$28,100	$28,100		
	Discharge plumbing	50	LF	$58	$2,900		
	Concrete pad w/ fencing	1	LS	$12,900	$12,900		
3	*Supplemental Investigation*						
	Additional Characterization - HRIA	1	LS	$98,000	$98,000		
4	*Institutional Controls*						
	Public Education						
	Community Interviews/Open House	1	LS	$38,000	$38,000		
	Preparation of Fact Sheets, Pamphlets, Handouts, etc	1	LS	$20,000	$20,000		
	Deed Restrictions						
	Legal research, coordination with government officials	1	LS	$90,000	$90,000		
	Subtotal (1)				$531,600		
5	*Confirmation Sampling*						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	(b) Groundwater sampling (semiannual)	2	EVENT	$17,500		$35,000	$434,316
	Sample Collection ($10K) + Analysis $500/sample for 15 samples						
	(c) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006
	Subtotal (2)				$15,000	$65,000	$557,322
6	*O&M:*						
	Maintenance and oversight including VI Sampling	1	YR	$140,000		$140,000	$1,737,266
	System electrical usage	1	YR	$18,000		$18,000	$223,363
	Major repair (1 per year, as a percent of system cost)	1	LS	$9,000		$9,000	$111,681
	Carbon change-outs	4,000	LB	$4		$14,000	$173,727
	Subtotal (3)					$181,000	$2,246,036
7	*Reporting:*						
	Review data and prepare annual reports	1	ls	$20,000		$20,000	$248,181
	5-Year Review (every 5 years for 30 years)	1	ls	$50,000		$50,000	$107,900
	Subtotal (4)					$70,000	$356,081
	CONSTRUCTION SUBTOTAL				$546,600		

Cost Estimate for Alternative HC-2

Hydraulic Containment with Institutional Controls and Monitoring

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
	Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$54,660		
	Contractor Overhead	15% of Construction Subtotal			$81,990		
	Contractor Profit	10% of Construction Subtotal			$54,660		
	Contingency	40% of Construction Subtotal			$218,640		
	CONSTRUCTION TOTAL				$956,550		
	Project Management	10% of Construction Total			$95,655		
	Engineering	15% of Construction Total			$143,483		
	Services During Construction	15% of Construction Total			$143,483		
	TOTAL CAPITAL COSTS				$1,339,170		
	OPERATION & MAINTENANCE SUBTOTAL					$316,000	$3,159,440
	O&M Project Management and Support	5% of O&M Subtotal				$15,800	$157,972
	O&M Contingency	25% of O&M Subtotal				$79,000	$789,860
	TOTAL ESTIMATED COSTS				$1,339,000	$411,000	$4,107,000
	NET PRESENT WORTH				$5,446,000		

CDM Smith

Cost Detail for Alternative HC-2

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LS	$52,000	$52,000		
	Cost Source: Engineering Estimate, various projects 10% of activity cost						
2	*Hydraulic Control System:*						
	Water treatment system purchase	1	LS	$179,700	$179,700		
	Cost Source: Vendor Quote						
	Includes shipping ($2k), electrical ($5k) and installation ($20k).						
	Electrical power drop	1	LS	$10,000	$10,000		
	Cost Source: Engineering Estimate						
	Wellhead plumbing and electrical connection	1	LS	$28,100	$28,100		
	Cost Source: Engineering Estimate (RS Means 2006)						
	710', 4" header pipe, 80', 2" PVC indiv. Pipe runs, 790', 2" elec.conduit. New vaults at 8 wells.						
	Discharge plumbing	50	LF	$58	$2,900		
	Cost Source: Engineering Estimate (RS Means 2007)						
	50 feet of discharge piping from system to Berwick Creek, with riprap stabilized outfall						
	Concrete pad w/ fencing	1	LS	$12,900	$12,900		
	Cost Source: Engineering Estimate (RS Means 2007)						
	Assume 8' tall industrial security fence + gate, 10x10concrete pad with curb ($1500), sump pump ($500)						
3	*Supplemental Investigation*						
	Additional Characterization - HRIA	1	LS	$98,000	$98,000		
	Cost Source: Engineering Estimate						
	15 Days of HSA with field geologist, 3 days GW sampling (3 person team) - 231 total VOC samples						
4	*Institutional Controls*						
	Public Education						
	Community Interviews/Open House	1	LS	$38,000	$38,000		
	Cost Source: Engineering Estimate						
	380 hours at $100/hour						
	Preparation of Fact Sheets, Pamphlets, Handouts, etc	1	LS	$20,000	$20,000		
	Cost Source: Engineering Estimate						
	200 hours at $100/hour						
	Deed Restrictions						
	Legal research, coordination with government officials	1	LS	$90,000	$90,000		
	Cost Source: Engineering Estimate						
	900 hours at $100/hour						
5	*Confirmation Sampling*						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	Cost Source: Engineering Estimate						
	150 hours at $100/hour						
	(b) Groundwater sampling (semiannual)	2	EVENT	$17,500		$35,000	$434,316
	Cost Source: Engineering Estimate						
	Sample Collection ($10K) + Analysis $500/sample for 15 samples						
	(c) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006
	Cost Source: Ongoing Remedial Action Costs						
6	*O&M:*						
	Maintenance and oversight including VI Sampling	1	YR	$140,000		$140,000	$1,737,266
	Cost Source: Ongoing Remedial Action Costs						
	System electrical usage	1	YR	$18,000		$18,000	$223,363
	Cost Source: Ongoing Remedial Action Costs for Electricity						
	Major repair (1 per year, as a percent of system cost)	1	LS	$9,000		$9,000	$111,681
	Cost Source: Previous Project Experience						
	Carbon change-outs	4,000	LB	$4		$14,000	$173,727
	Cost Source: Ongoing Remedial Action Costs for Activated Carbon Change Out (EPA Region III)						

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Cost Detail for Alternative HC-2

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
7	*Reporting:*						
	Review data and prepare annual reports	1	ls	$20,000		$20,000	$248,181
	Cost Source: Engineering Estimate						
	200 hours at $100/hour						
	5-Year Review (every 5 years for 30 years)	1	ls	$50,000		$50,000	$107,900
	Cost Source: Engineering Estimate						
	500 hours at $100/hour						

Cost Estimate for Alternative HC-3

In situ ERH with Institutional Controls and Monitoring

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LS	$100,000	$100,000		
	Electrical Resistance Heating Infrastructure:						
	Design, work plans, permits by vendor	1	LS	$207,000	$207,000		
	Electrode Materials Mobilization	1	LS	$657,000	$657,000		
	Probe boring installation and soil sampling	1	LS	$1,113,000	$1,113,000		
	Remediation system installation and start-up	1	LS	$814,000	$814,000		
	Security Fencing	1	LS	$30,300	$30,300		
	Drill Cuttings and Waste disposal	1	LS	$27,000	$27,000		
	Electrical utility connection	1	LS	$70,000	$70,000		
	Site Restoration	1	LS	$436,000	$436,000		
	Demobilization and final report	1	LS	$131,000	$131,000		
2	*Hydraulic Containment*						
	connection	1	LS	$10,100	$10,100		
	Discharge plumbing	1	LS	$17,000	$17,000		
	Well Installation (1 extraction, 3 injection)	5	EA	$3,250	$16,300		
	Traffic control	1	LS	$2,500	$2,500		
	Road crossings	30	SY	$64	$1,900		
3	*LTM Well Installation*						
	Mobilization	1	LS	$5,000	$5,000		
	Well Location Investigation	1	LS	$45,700	$45,700		
	Well installation	5	EA	$4,000	$20,000		
4	*Supplemental Investigation*						
	Additional Characterization - HRIA	1	LS	$98,000	$98,000		
5	*Institutional Controls*						
	Public Education						
	Community Interviews/Open House	1	LS	$38,000	$38,000		
	Preparation of Fact Sheets, Pamphlets, Handouts, etc	1	LS	$20,000	$20,000		
	Deed Restrictions						
	Legal research, coordination with government officials	1	LS	$90,000	$90,000		
	Subtotal (1)				$3,949,800		
6	*Sampling*						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	(b) One time Confirmation Soil Sampling	1	LS	$25,500		$25,500	$23,832
	(c) Groundwater sampling (semiannual)	2	EVENT	$17,500		$35,000	$434,316
	Sample Collection ($10K) + Analysis $500/sample for 15 samples						
	(d) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006
	Subtotal (2)				$15,000	$90,500	$581,154
7	*O&M:*						
7a	*Construction Dewater System O&M*						
	Water treatment operation	1	MO	$10,000		$10,000	$9,346
	System electrical usage	1	MO	$2,000		$2,000	$1,869
	Carbon change-outs	2,000	LB	$4		$7,000	$6,542
7b	*Electrical Resistance Heating O&M:*						
	Remediation system operation	1	LS	$1,445,000		$1,445,000	$1,350,467
	Electrical energy usage	1	LS	$634,000		$634,000	$592,523
	Carbon usage, transportation and regeneration	1	LS	$306,000		$306,000	$285,981
	Misc. operational costs (include vapor sampling)	1	LS	$56,000		$56,000	$694,906
	Management during operating period	1	LS	$97,640		$97,640	$91,252
	Subtotal (3)					$2,557,640	$3,032,888

Cost Estimate for Alternative HC-3

In situ ERH with Institutional Controls and Monitoring

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost	
						Annual	Present Worth
8	*Reporting:*						
	Review data and prepare annual reports	1	ls	$20,000		$20,000	$248,181
	5-Year Review (every 5 years for 30 years)	1	ls	$50,000		$50,000	$107,900
	Subtotal (4)					$70,000	$356,081
	CONSTRUCTION SUBTOTAL				$3,964,800		
	Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$396,480		
	Contractor Overhead	15% of Construction Subtotal			$594,720		
	Contractor Profit	10% of Construction Subtotal			$396,480		
	Contingency	15% of Construction Subtotal*			$594,720		
	CONSTRUCTION TOTAL				$5,947,200		
	Project Management	10% of Construction Total			$594,720		
	Engineering	15% of Construction Total			$892,080		
	Services During Construction	4% of Construction Total*			$237,888		
	TOTAL CAPITAL COSTS				$7,671,888		
	OPERATION & MAINTENANCE SUBTOTAL					$2,718,140	$3,970,123
	O&M Project Management and Support	5% of O&M Subtotal				$135,907	$198,506
	O&M Contingency	25% of O&M Subtotal				$679,535	$992,531
	TOTAL ESTIMATED COSTS				$7,672,000	$3,534,000	$5,161,000
	NET PRESENT WORTH				$12,833,000		

* Note: The percentage basis for this line item is lower than other alternatives based on costs covered in vendor quote.

Cost Detail for Alternative HC-3

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LS	$100,000	$100,000		
	Electrical Resistance Heating Infrastructure:						
	Design, work plans, permits by vendor	1	LS	$207,000	$207,000		
	Cost Source: Vendor Quote						
	Electrode Materials Mobilization	1	LS	$657,000	$657,000		
	Cost Source: Vendor Quote						
	Probe boring installation and soil sampling	1	LS	$1,113,000	$1,113,000		
	Cost Source: Vendor Quote						
	Remediation system installation and start-up	1	LS	$814,000	$814,000		
	Cost Source: Vendor Quote						
	Security Fencing	1	LS	$30,300	$30,300		
	Cost Source: Engineering Estimate (RS Means)						
	Assume 8' tall industrial security fence + gate						
	Drill Cuttings and Waste disposal	1	LS	$27,000	$27,000		
	Cost Source: Vendor Quote						
	Electrical utility connection	1	LS	$70,000	$70,000		
	Cost Source: Vendor Quote						
	Site Restoration	1 LS		$436,000	$436,000		
	Cost Source: Vendor Quote						
	Demobilization and final report	1	LS	$131,000	$131,000		
2	*Hydraulic Containment*						
	Pumps, wellhead plumbing, electrical connection	1	LS	$10,100	$10,100		
	Cost Source: Engineering Estimate (RS Means 2007)						
	120 lf, 2" PVC (20' x 6 wells) (22 11 1375 2510), 6-1hp sub. pumps @$ 650 (221429168110 - MII - CostBook 2010) , $4,000 elec						
	Discharge plumbing	1	LS	$17,000	$17,000		
	Cost Source: Engineering Estimate (RS Means 2007)						
	300 lf, 4" PVC, 400 lf 2" PVC (Schedule 80)						
	Well Installation (1 extraction, 3 injection)	5	EA	$3,250	$16,300		
	Cost Source: Engineering Estimate (Vendor Quote)						
	Assumes HSA, 2" wells and Contractor Oversight						
	Traffic control	1	LS	$2,500	$2,500		
	Cost Source: Engineering Estimate						
	Road crossings	30	SY	$64	$1,900		
	Cost Source: RS Means						
3	*LTM Well Installation*						
	Mobilization	1	LS	$5,000	$5,000		
	Cost Source: Engineering Estimate (Vendor Quote)						
	Well Location Investigation	1	LS	$45,700	$45,700		
	Cost Source: Vendor Quote						
	Well installation	5	EA	$4,000	$20,000		
	Cost Source: Engineering Estimate (Vendor Quote)						
	Assumes HSA, 2" wells and Contractor Oversight						
4	*Supplemental Investigation*						
	Additional Characterization - HRIA	1	LS	$98,000	$98,000		
	Cost Source: Engineering Estimate						
	15 Days of HSA with field geologist, 3 days GW sampling (3 person team) - 231 total VOC samples						

Cost Detail for Alternative HC-3

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
5	*Institutional Controls*						
	Public Education						
	Community Interviews/Open House	1	LS	$38,000	$38,000		
	Cost Source: Engineering Estimate						
	380 hours at $100/hour						
	Preparation of Fact Sheets, Pamphlets, Handouts, etc	1	LS	$20,000	$20,000		
	Cost Source: Engineering Estimate						
	200 hours at $100/hour						
	Deed Restrictions						
	Legal research, coordination with government officials	1	LS	$90,000	$90,000		
	Cost Source: Engineering Estimate						
	900 hours at $100/hour						
6	*Sampling*						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	Cost Source: Engineering Estimate						
	150 hours at $100/hour						
	(b) One time Confirmation Soil Sampling	1	LS	$25,500		$25,500	$23,832
	Cost Source: Engineering Estimate (Vendor Quote)						
	Mob., 10 borings@$1580, $330 per diem, labor 1 x 10 hrs x $80, plus ODC. To Manchester for analysis.						
	(c) Groundwater sampling (semiannual)	2	EVENT	$17,500		$35,000	$434,316
	Cost Source: Engineering Estimate						
	Sample Collection ($10K) + Analysis $500/sample for 15 samples						
	(d) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006
	Cost Source: Ongoing Remedial Action Costs						
7	*O&M:*						
7a	*Construction Dewater System O&M*						
	Water treatment operation	1	MO	$10,000		$10,000	$9,346
	Cost Source: Engineering Estimate						
	1 O&M Operator (160 hours x $50/hour) + $2000 misc O&M Supplies						
	System electrical usage	1	MO	$2,000		$2,000	$1,869
	Cost Source: On going Remedial Action Costs for Electricity						
	Carbon change-outs	2,000	LB	$4		$7,000	$6,542
	Cost Source: Ongoing Remedial Action Costs for Activated Carbon Change Out (EPA Region III)						
7b	*Electrical Resistance Heating O&M:*						
	Remediation system operation	1	LS	$1,445,000		$1,445,000	$1,350,467
	Cost Source: Vendor Quote						
	Electrical energy usage	1	LS	$634,000		$634,000	$592,523
	Cost Source: Vendor Quote						
	Carbon usage, transportation and regeneration	1	LS	$306,000		$306,000	$285,981
	Cost Source: Vendor Quote						
	Misc. operational costs (include vapor sampling)	1	LS	$56,000		$56,000	$694,906
	Cost Source: Vendor Quote						
	Management during operating period	1	LS	$97,640		$97,640	$91,252
	Cost Source: Vendor Quote (4% of implementation costs)						
8	*Reporting:*						
	Review data and prepare annual reports	1	ls	$20,000		$20,000	$248,181
	Cost Source: Engineering Estimate						
	200 hours at $100/hour						
	5-Year Review (every 5 years for 30 years)	1	ls	$50,000		$50,000	$107,900
	Cost Source: Engineering Estimate						
	500 hours at $100/hour						

Cost Estimate for Alternative HC-4

In situ Chemical Oxidation with Institutional Controls and Monitoring

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LA	$100,000	$100,000		
2	*Chemical Oxidation Infrastructure:*						
	Treatability Study	1	LS	$50,000	$50,000		
	Install injection points	79	EA	$10,300	$813,700		
	Install piezometers and temp monitors	27	EA	$1,900	$51,300		
	Purchase permanganate - 3 Injection Rounds	528,000	LB	$3	$1,563,000		
	Install injection system	1	LS	$30,000	$30,000		
3	*Chemical Oxidation Injections:*						
	Injection event, including management	1	LS	$272,900	$272,900		
	System water usage	300,000	GAL	$0.3	$99,000		
	System electrical usage	3	MO	$2,000	$6,000		
	Groundwater and VI sampling between injections	3	EA	$20,000	$60,000		
	One-time confirmation soil sampling	3	DAY	$7,000	$21,000		
4	*LTM Well Installation*						
	Mobilization	1	LS	$5,000	$5,000		
	Well Location Investigation	1	LS	$45,700	$45,700		
	Well installation	5	EA	$4,000	$20,000		
5	*Supplemental Investigation*						
	Additional Characterization - HRIA	1	LS	$98,000	$98,000		
6	*Institutional Controls*						
	Public Education						
	Community Interviews/Open House	1	LS	$38,000	$38,000		
	Preparation of Fact Sheets, Pamphlets, Handouts, etc	1	LS	$20,000	$20,000		
	Deed Restrictions						
	Legal research, coordination with government officials	1	LS	$90,000	$90,000		
	Subtotal (1)				$3,383,600		
7	Sampling						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	(b) One time Confirmation Soil Sampling	1	LS	$25,500		$25,500	$23,832
	(c) Groundwater sampling (semiannual)	2	EVENT	$17,500		$35,000	$434,316
	Sample Collection ($10K) + Analysis $500/sample for 15 samples						
	(d) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006
	Subtotal (2)				$15,000	$90,500	$581,154
8	*Reporting:*						
	Review data and prepare annual reports	1	LS	$20,000		$20,000	$248,181
	5-Year Review (every 5 years for 30 years)	1	LS	$50,000		$50,000	$107,900
	Subtotal (3)					$70,000	$356,081
	CONSTRUCTION SUBTOTAL				$3,398,600		
	Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$339,860		
	Contractor Overhead	15% of Construction Subtotal			$509,790		
	Contractor Profit	10% of Construction Subtotal			$339,860		
	Contingency	40% of Construction Subtotal			$1,359,440		
	CONSTRUCTION TOTAL				$5,947,550		
	Project Management	10% of Construction Total			$594,755		
	Engineering	15% of Construction Total			$892,133		
	Services During Construction	15% of Construction Total			$892,133		
	TOTAL CAPITAL COSTS				$8,326,570		
	OPERATION & MAINTENANCE SUBTOTAL					$160,500	$937,235

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Cost Estimate for Alternative HC-4

In situ Chemical Oxidation with Institutional Controls and Monitoring

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost	
						Annual	Present Worth
	O&M Project Management and Support	5% of O&M Subtotal				$8,025	$46,862
	O&M Contingency	25% of O&M Subtotal				$40,125	$234,309
	TOTAL ESTIMATED COSTS				$8,327,000	$209,000	$1,218,000
	NET PRESENT WORTH				$9,545,000		

Cost Detail for Alternative HC-4

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LA	$100,000	$100,000		
	Cost Source: Engineering Estimate						
	Estimated at approximately 7% of implementation costs						
2	*Chemical Oxidation Infrastructure:*						
	Treatability Study	1	LS	$50,000	$50,000		
	Cost Source: Engineering Estimate						
	Estimated at 2% of full implementation costs						
	Install DPT injection points	76	EA	$10,300	$782,800		
	Cost Source: Engineering Estimate						
	Install piezometers and temp monitors	27	EA	$1,900	$51,300		
	Cost Source: Engineering Estimate						
	Purchase permanganate - 3 Injection Rounds	528,000	LB	$3	$1,563,000		
	Cost Source: Vendor Quote and Engineering Estimate						
	Estimated at 2,200 lbs per injection						
	Install injection system	1	LS	$30,000	$30,000		
	Cost Source: Engineering Estimate						
3	*Chemical Oxidation Injections:*						
	Injection event, including management	1	LS	$272,900	$272,900		
	Cost Source: Engineering Estimate						
	System water usage	300,000	GAL	$0.3	$99,000		
	Cost Source: Engineering Estimate (Vendor Quote)						
	Local souce for water						
	System electrical usage	3	MO	$2,000	$6,000		
	Cost Source: Ongoing Remedial Action Costs for Electricity						
	Groundwater and VI sampling between injections	3	EA	$20,000	$60,000		
	Cost Source: Engineering Estimate						
	Assumes analysis by Manchester lab, one report per year						
	One-time confirmation soil sampling	3	DAY	$7,000	$21,000		
	Cost Source: Engineering Estimate						
4	*LTM Well Installation*						
	Mobilization	1	LS	$5,000	$5,000		
	Cost Source: Engineering Estimate						
	Well Location Investigation	1	LS	$45,700	$45,700		
	Cost Source: Vendor Quote and Engineering Estimate						
	Well installation	5	EA	$4,000	$20,000		
	Cost Source Engineering Estimate						
	Assumes HSA, 2" wells and Contractor Oversight						
5	*Supplemental Investigation*						
	Additional Characterization - HRIA	1	LS	$98,000	$98,000		
	Cost Source: Engineering Estimate						
	15 Days of HAS with field geologist, 3 days GW sampling (3 person team) - 231 total VOC samples						
6	*Institutional Controls*						
	Public Education						
	Community Interviews/Open House	1	LS	$38,000	$38,000		
	Cost Source: Engineering Estimate						
	380 hours at $100/hour						
	Preparation of Fact Sheets, Pamphlets, Handouts, etc	1	LS	$20,000	$20,000		
	Cost Source: Engineering Estimate						
	200 hours at $100/hour						
	Deed Restrictions						
	Legal research, coordination with government officials	1	LS	$90,000	$90,000		
	Cost Source: Engineering Estimate						
	900 hours at $100/hour						
7	Sampling						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	Cost Source: Engineering Estimate						
	150 hours at $100/hour						
	(b) One time Confirmation Soil Sampling	1	LS	$25,500		$25,500	$23,832
	Cost Source: Engineering Estimate (Vendor Quote)						
	Mob., 10 borings@$1580, $330 per diem, labor 1 x 10 hrs x $80, plus ODC. To Manchester for analysis.						
	(c) Groundwater sampling (semiannual)	2	EVENT	$17,500		$35,000	$434,316
	Cost Source: Engineering Estimate						
	Sample Collection ($10K) + Analysis $500/sample for 15 samples						
	(d) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006
	Cost Source: Ongoing Remedial Action Costs						

Cost Detail for Alternative HC-4

Number	Item		Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
8	*Reporting:*							
	Review data and prepare annual reports		1	ls	$20,000		$20,000	$248,181
		Cost Source: Engineering Estimate						
		200 hours at $100/hour						
	5-Year Review (every 5 years for 30 years)		1	ls	$50,000		$50,000	$107,900
		Cost Source: Engineering Estimate						
		500 hours at $100/hour						

Cost Estimate for Alternative HC-5

Enhanced In situ Bioremediation with Institutional Controls and Monitoring

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LS	$100,000	$100,000		
2	*Enhanced Bioremediation Infrastructure:*						
	Treatability Study	1	LS	$50,000	$50,000		
	Install injection wells	79	EA	$10,300	$813,700		
	Injection Rounds (79 wells/round)	2	RD	$695,000	$1,390,000		
	Bioaugmentation Injections	2	LS/RD	$45,000	$90,000		
3	*Monitor Well Installation*						
	Mobilization	1	LS	$5,000	$5,000		
	Well Location Investigation	1	LS	$45,700	$45,700		
	Well installation	4	EA	$4,000	$16,000		
4	*Supplemental Investigation*						
	Additional Characterization - HRIA	1	LS	$98,000	$98,000		
5	*Institutional Controls*						
	Public Education						
	Community Interviews/Open House	1	LS	$38,000	$38,000		
	Preparation of Fact Sheets, Pamphlets, Handouts, etc	1	LS	$20,000	$20,000		
	Deed Restrictions						
	Legal research, coordination with government officials	1	LS	$90,000	$90,000		
	Subtotal (1)				$2,756,400		
6	Sampling						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	(b) Confirmation Sampling (Pre & 4 qtrly events - including VI)						
	Sample Collection ($25K) + Analysis $800/sample for 15 samples	12	LS	$37,000	$444,000		
	(c) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006
	(d) Groundwater sampling (semiannual)	2	EVENT	$17,500		$35,000	$434,316
	Sample Collection ($10K) + Analysis $500/sample for 15 samples						
	Subtotal (2)				$459,000	$65,000	$557,322
7	*Reporting:*						
	Review data and prepare annual reports	1	LS	20,000		$20,000	$248,181
	5-Year Review (every 5 years for 30 years)	1	LS	50,000		$50,000	$107,900
	Subtotal (3)					$70,000	$356,081
	CONSTRUCTION SUBTOTAL				$3,215,400		
	Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$321,540		
	Contractor Overhead	15% of Construction Subtotal			$482,310		
	Contractor Profit	10% of Construction Subtotal			$321,540		
	Contingency	40% of Construction Subtotal			$1,286,160		
	CONSTRUCTION TOTAL				$5,626,950		
	Project Management	10% of Construction Total			$562,695		
	Engineering	15% of Construction Total			$844,043		
	Services During Construction	15% of Construction Total			$844,043		
	TOTAL CAPITAL COSTS				$7,877,730		
	OPERATION & MAINTENANCE SUBTOTAL					$135,000	$913,403

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Cost Estimate for Alternative HC-5

Enhanced In situ Bioremediation with Institutional Controls and Monitoring

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost	
						Annual	Present Worth
	O&M Project Management and Support	5% of O&M Subtotal				$6,750	$45,670
	O&M Contingency	25% of O&M Subtotal				$33,750	$228,351
	TOTAL ESTIMATED COSTS				$7,878,000	$176,000	$1,187,000
	NET PRESENT WORTH				$9,065,000		

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Cost Detail for Alternative HC-5

Number	Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth
1	*Mobilization*	1	LS	$100,000	$100,000		
	Cost Source: Engineering Estimate Estimated at 7% of overall implementation cost						
2	*Enhanced Bioremediation Infrastructure:*						
	Treatability Study	1	LS	$50,000	$50,000		
	Cost Source: Engineering Estimate Estimated at 8% of overall implementation cost						
	Install injection wells	79	EA	$10,300	$813,700		
	Cost Source: Engineering Estimate						
	Injection Rounds (79 wells/round)	2	RD	$695,000	$1,390,000		
	Cost Source: Previous Project Experience						
	Bioaugmentation Injections	2	LS/RD	$45,000	$90,000		
	Cost Source: Engineering Estimate (Previous Project Experience)						
3	*Monitor Well Installation*						
	Mobilization	1	LS	$5,000	$5,000		
	Cost Source: Engineering Estimate (Vendor Quote)						
	Well Location Investigation	1	LS	$45,700	$45,700		
	Cost Source: Engineering Estimate (Vendor Quote)						
	Well installation	4	EA	$4,000	$16,000		
	Cost Source: Engineering Estimate Assumes HSA, 2" wells and Contractor Oversight						
4	*Supplemental Investigation*						
	Additional Characterization - HRIA	1	LS	$98,000	$98,000		
	Cost Source: Engineering Estimate 15 Days of HSA with field geologist, 3 days GW sampling (3 person team) - 231 total VOC samples						
5	*Institutional Controls*						
	Public Education						
	Community Interviews/Open House	1	LS	$38,000	$38,000		
	Cost Source: Engineering Estimate 380 hours at $100/hour						
	Preparation of Fact Sheets, Pamphlets, Handouts, etc	1	LS	$20,000	$20,000		
	Cost Source: Engineering Estimate 200 hours at $100/hour						
	Deed Restrictions						
	Legal research, coordination with government officials	1	LS	$90,000	$90,000		
	Cost Source: Engineering Estimate 900 hours at $100/hour						
6	Sampling						
	(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
	Cost Source: Engineering Estimate 150 hours at $100/hour						
	(b) Confirmation Sampling (Pre & 4 qtrly events including VI) Cost Source: Engineering Estimate Sample Collection ($25K) + Analysis $800/sample for 15 samples	12	LS	$37,000	$444,000		
	(c) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006
	Cost Source: Ongoing Remedial Action Costs						
	(d) Groundwater sampling (semiannual)	2	EVENT	$17,500		$35,000	$434,316
	Cost Source: Engineering Estimate Sample Collection ($10K) + Analysis $500/sample for 15 samples						
7	*Reporting:*						
	Review data and prepare annual reports	1	ls	$20,000		$20,000	$248,181
	Cost Source: Engineering Estimate 200 hours at $100/hour						
	5-Year Review (every 5 years for 30 years)	1	ls	$50,000		$50,000	$107,900
	Cost Source: Engineering Estimate 500 hours at $100/hour						

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Cost Estimate for Comprehensive Treatment Scenario (CTS) -2

Item	Quantity	Units	Unit Cost	Capital Cost	Long-Term O&M Cost	
					Annual	Present Worth
Mobilization	1	LS	$100,000	$100,000		
Supplemental Investigation						
HRIA Impact Area (ATL-HC5)	1	LS	$98,000	$98,000		
Creek Bed Sediment/Surface Soil						
Diversion of Berwick Creek (ALT-SD2):	1	LS	$95,100	$95,100		
Excavation Dewatering (ALT-SD2):	1	LS	$41,600	$41,600		
Excavation (ALT-SD2)	600	LCY	$50	$30,000		
Creek Restoration (ALT-SD2):	1	LS	$69,700	$69,700		
Subsurface Soil (with PCE greater than 10 mg/kg)						
Electrical Resistance Heating Infrastructure: (Vendor Quote)	1	LS	$1,035,000	$1,035,000		
Hydraulic Containment (ALT-HC3)	1	LS	$47,800	$47,800		
High Concentration Groundwater						
Enhanced Bioremediation Infrastructure (ALT-HC5):						
Treatability Study (ALT-HC5):	1	LS	$50,000	$50,000		
Install injection wells (ALT-HC5):	55	EA	$10,300	$566,500		
Injection Rounds (65 wells/round) (ALT-HC5):	2	RD	$484,000	$968,000		
Bioaugmentation Injections (ALT-HC5):	2	LS/RD	$31,000	$62,000		
Excavation and Off-Site Disposal of Soil > 10 mg/kg						
Excavation (ALT-SD2)	140	LCY	$50	$7,000		
Contaminated soil disposal (includes transporation) (ALT-SD2)	188	TON	$462	$86,856		
Monitoring and Instutional Controls						
LTM Well Installation (ALT-HC4)	1	LS	$70,700	$70,700		
Institutional Controls (ALT-HC4)	1	LS	$148,000	$148,000		
Sampling (ALT-HC3 through HC5)						
(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
(b) One time Confirmation Soil Sampling	1	LS	$25,500		$25,500	$23,832
(c) Groundwater sampling (semiannual for 30 years)	2	EVENT	$17,500		$35,000	$434,316
Sample Collection ($10K) + Analysis $500/sample for 15 samples						
(d) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006
Short-Term O&M of Remedy Implementation						
Construction of Dewatering System O&M (ALT-SD2)						
Water treatment operation (ALT-SD2)	1	MO	$10,000	$10,000		
System electrical usage (ALT-SD2)	1	MO	$2,000	$2,000		
Carbon change-outs (ALT-SD2)	2,000	LB	$3.50	$7,000		
Reporting						
Review data and prepare annual reports	1	LS	$20,000		$20,000	$248,181
5-Year Review (every 5 years for 30 years)	1	LS	$50,000		$50,000	$107,900
CONSTRUCTION SUBTOTAL				$3,510,256	$160,500	$937,235

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Cost Estimate for Comprehensive Treatment Scenario (CTS) -2

Item	Quantity	Units	Unit Cost	Capital Cost	Long-Term O&M Cost	
					Annual	Present Worth
Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$351,026		
Contractor Overhead	15% of Construction Subtotal			$526,538		
Contractor Profit	10% of Construction Subtotal			$351,026		
Contingency	40% of Construction Subtotal			$1,404,102		
CONSTRUCTION TOTAL				$6,142,948		
Project Management	10% of Construction Total			$614,295		
Engineering	15% of Construction Total			$921,442		
Services During Construction	15% of Construction Total			$921,442		
TOTAL CAPITAL COSTS				$8,600,127		
OPERATION & MAINTENANCE SUBTOTAL					$160,500	$937,235
O&M Project Management and Support	5% of O&M Subtotal				$8,025	$46,862
O&M Contingency	25% of O&M Subtotal				$40,125	$234,309
TOTAL ESTIMATED COSTS				$8,600,000	$209,000	$1,218,000
NET PRESENT WORTH				$9,818,000		

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Cost Estimate for Comprehensive Treatment Scenario (CTS) -3

Item	Quantity	Units	Unit Cost	Capital Cost	Long-Term O&M Cost	
					Annual	Present Worth
Mobilization	1	LS	$100,000	$100,000		
Supplemental Investigation						
HRIA Impact Area (ATL-HC5)	1	LS	$98,000	$98,000		
Creek Bed Sediment/Surface Soil						
Diversion of Berwick Creek (ALT-SD2):	1	LS	$95,100	$95,100		
Excavation Dewatering (ALT-SD2):	1	LS	$41,600	$41,600		
Excavation (ALT-SD2)	600	LCY	$50	$30,000		
Creek Restoration (ALT-SD2):	1	LS	$69,700	$69,700		
Subsurface Soil(with PCE greater than 10 mg/kg)						
Electrical Resistance Heating Infrastructure:	1	LS	$1,035,000	$1,035,000		
(Vendor Quote)						
Hydraulic Containment (ALT-HC3)	1	LS	$47,800	$47,800		
High Concentration Groundwater						
Chemical Oxidation Infrastructure (ALT-HC4):						
Treatability Study (ALT-HC4):	1	LS	$50,000	$50,000		
Install injection points (ALT-HC4):	64	EA	$10,000	$640,000		
Install piezometers and temp monitors (ALT-HC4):	27	EA	$1,900	$51,300		
Purchase permanganate - 3 Injection Rounds (ALT-HC4):	400,000	LB	$3	$1,184,000		
Install injection system (ALT-HC4):	1	LS	$30,000	$30,000		
Chemical Oxidation Injections (ALT-HC4):						
Injection event, including management (ALT-HC4)	1	LS	$273,000	$273,000		
System water usage (ALT-HC4)	300,000	GAL	$0.3	$99,000		
System electrical usage (ALT-HC4)	3	MO	$2,000	$6,000		
Groundwater and VI sampling between injections (ALT-HC4)	3	EA	$20,000	$60,000		
One-time confirmation soil sampling (ALT-HC4)	3	DAY	$7,000	$21,000		
Excavation and Off-Site Disposal of Soil > 10 mg/kg						
Excavation (ALT-SD2)	140	LCY	$50	$7,000		
Contaminated soil disposal (includes transporation) (ALT-SD2)	188	TON	$462	$86,856		
Monitoring and Instutional Controls						
LTM Well Installation (ALT-HC4)	1	LS	$70,700	$70,700		
Institutional Controls (ALT-HC4)	1	LS	$148,000	$148,000		
Sampling (ALT-HC3 through 5)						
(a) Develop Sampling Plan	1	LS	$15,000	$15,000		
(b) One time Confirmation Soil Sampling	1	LS	$25,500		$25,500	$23,832
(c) Groundwater sampling (semiannual for 30 years)	2	EVENT	$17,500		$35,000	$434,316
Sample Collection ($10K) + Analysis $500/sample for 15 samples						
(d) Mass Flux Measurements (5 events at 10 wells over 6 yrs)	1	EVENT	$30,000		$30,000	$123,006

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Cost Estimate for Comprehensive Treatment Scenario (CTS) -3

Item	Quantity	Units	Unit Cost	Capital Cost	Long-Term O&M Cost	
					Annual	Present Worth
Short-Term O&M of Remedy Implementation						
Construction of Dewatering System O&M (ALT-SD2)						
Water treatment operation (ALT-SD2)	1	MO	$10,000	$10,000		
System electrical usage (ALT-SD2)	1	MO	$2,000	$2,000		
Carbon change-outs (ALT-SD2)	2,000	LB	$3.50	$7,000		
Reporting						
Review data and prepare annual reports	1	LS	$20,000		$20,000	$248,181
5-Year Review (every 5 years for 30 years)	1	LS	$50,000		$50,000	$107,900
CONSTRUCTION SUBTOTAL				$4,278,056	$160,500	$937,235
Contractor Submittals, H&S, and Construction QA/QC	10% of Construction Subtotal			$427,806		
Contractor Overhead	15% of Construction Subtotal			$641,708		
Contractor Profit	10% of Construction Subtotal			$427,806		
Contingency	40% of Construction Subtotal			$1,711,222		
CONSTRUCTION TOTAL				$7,486,598		
Project Management	10% of Construction Total			$748,660		
Engineering	15% of Construction Total			$1,122,990		
Services During Construction	15% of Construction Total			$1,122,990		
TOTAL CAPITAL COSTS				$10,481,237		
OPERATION & MAINTENANCE SUBTOTAL					$160,500	$937,235
O&M Project Management and Support	5% of O&M Subtotal				$8,025	$46,862
O&M Contingency	25% of O&M Subtotal				$40,125	$234,309
TOTAL ESTIMATED COSTS				$10,481,000	$209,000	$1,218,000
NET PRESENT WORTH				$11,699,000		