DRAFT FEASIBILITY STUDY REPORT
BOTHELL RIVERSIDE SITE HVOC AREA
BOTHELL, WASHINGTON

HWA Project No. 2007-098-2018

Prepared for
City of Bothell

February 7, 2018

HWA GEOSCIENCES INC.

- *Geotechnical Engineering*
- *Hydrogeology*
- *Geoenvironmental Services*
- *Inspection & Testing*

Table of Contents

Table of Contents (continued)

LIST OF TABLES

LIST OF FIGURES (FOLLOWING TEXT)

FEASIBILITY STUDY
BOTHELL RIVERSIDE SITE HVOC AREA
BOTHELL, WASHINGTON

1. INTRODUCTION

This feasibility study (FS) was prepared for the Bothell Riverside site (Site) HVOC area located in Bothell, Washington (Figures 1, 2). This FS was conducted under Agreed Order DE 6295, executed in 2009 and amended in April 2010 and in 2013, between the City of Bothell (City) and the Washington State Department of Ecology (Ecology), to address soil and ground water contamination related to historical releases of hazardous substances at the Site. Requirements under the Agreed Order include preparation of a Remedial Investigation (RI) Report followed by the development of a FS and draft Cleanup Action Plan (dCAP).

RI and Interim Action activities were performed between December 2009 and April 2017 following Ecology's approval of the final RI/FS Work Plan (Ecology letter dated August 18, 2009) and in accordance with the Ecology-approved project work plans (Parametrix, 2009a; HWA, 2012; HWA, 2013). The RI report (HWA, 2017) documents the results of the RI and interim action soil and ground water cleanups conducted in 2010, 2013, 2104 and 2017 at the Riverside Site total petroleum hydrocarbon (TPH) and halogenated volatile organic compound (HVOC) areas.

Three interim action cleanups were conducted prior to the RI: 1) a soil excavation and removal cleanup conducted in 2010 (before roadway realignment) to address TPH impacts, 2) a ground water pump-and-treat system installed in 2014 to address HVOC impacts to ground water and surface water, and 3) a second soil excavation and removal cleanup conducted in 2017 to address residual TPH impacts. These interim actions address different contaminants in different (not co-located) areas from two separate releases. These areas are referred to as the Riverside TPH area and the Riverside HVOC area. This FS is for the HVOC area only.

The City owns the Site, a portion of which accommodates the newly realigned State Route (SR) 522. The remnant portion of the former property north of the new roadway will be redeveloped as part of the City's overall Downtown Revitalization Plan, and the portion of the former property south of the new roadway will be incorporated into the City's park system.

Tasks performed to-date to fulfill the Agreed Order include:

1. Preparation and submittal of the *Remedial Investigation and Feasibility Study Work Plan* (HWA, 2009) to Ecology;
2. Remedial investigation activities in 2009;
3. Initiation of a feasibility study in 2009;
4. Preparation and submittal of the *Bothell Riverside Remedial Investigation/Feasibility Study,* and associated *Draft Cleanup Action Plan* which were not finalized or approved pending completion of interim actions and monitoring (Parametrix, 2009a, b);

5. Preparation and submittal to Ecology of the *Remedial Investigation Feasibility Study Final Work Plan, Bothell Landing Site Bothell, Washington*, September 19, 2011 (HWA, 2011) and Addendum 1 adopting the approved area-wide network (December 2011) including wells at the Riverside site;
6. Completion of the 2010 initial phase of interim action petroleum soil cleanup and subsequent reporting (*Documentation of Interim Action at Bothell Riverside Site)* (HWA, 2011);
7. Preparation and submittal of a *Focused Feasibility Study* (HWA, 2012) and *Interim Action Work Plan* (HWA, 2013) to Ecology for HVOC impacts to ground water and surface water;
8. Installation of a ground water pump-and-treat system to address HVOC impacts to ground water and surface water in 2014;
9. Preparation of a draft Remedial Investigation report (HWA, August 8, 2015);
10. Completion of the 2017 interim action petroleum soil cleanup and subsequent reporting (*Riverside TPH Site Residual Soil Excavation Report, Bothell, Washington)* (HWA, 2017); and,
11. Preparation of a final Remedial Investigation report (HWA, May 23, 2017).

This FS is one of the two final deliverables required to fulfill the terms and conditions of the Agreed Order (Deliverable 7).

1.1 SITE LOCATION AND DESCRIPTION

Per Section 1.1 of the final RI report, the Bothell Riverside Site was defined in the Agreed Order (prior to completion of the RI) as consisting of the extent of contamination caused by the release of hazardous substances at a location in the general vicinity of Woodinville Drive (SR 522) and NE 180th at a former two-acre property where petroleum hydrocarbon impacts were initially discovered. The two-acre parcel no longer exists in its original configuration, although the City currently owns that land, which includes public right-of-way for the newly constructed and re-aligned SR 522, and portions of newly formed parcels on the north and south sides of the new roadway. The remnant portions of the former two-acre property and vacated former SR 522 roadway have been conjugated into new City parcels and are being sold to private parties for redevelopment. The southern portion of the property will become a part of the City's park system (HWA, 2017).

Whereas the Site was originally defined as a two-acre property (which no longer exists due to re-platting of parcels and construction of the new roadway) the findings of the RI demonstrated that hazardous substances at the Bothell Riverside Site have come to be located as shown in Figure 3. The Riverside Site includes two separate and distinct areas: 1) the Riverside TPH area, and 2) the Riverside HVOC area.

1.2 Site Conditions / Nature and Extent of Contamination

Site conditions (topography, geology, hydrogeology, aquifer and soil properties, surface water hydrology) and nature and extent of contamination (chemicals of concern for soil and ground water) are addressed in the Final RI report (HWA, 2017).

Per Section 2.1 of the final RI report, the Site area is generally flat with an elevation of approximately 35 feet above mean sea level. The surrounding land is generally flat or slopes to the south towards the Sammamish River.

Ground water remediation is underway as an interim action, via a hydraulic barrier / pump-and-treat system. The system includes ground water extraction and discharge to the sanitary sewer via a King County Industrial Waste Discharge permit. The ground water extraction and treatment system began operation in December 2013, with four original extraction wells, and is still operating. Two additional extraction wells (EW-5 and EW-6) were installed in October 2016, with Ecology's input and approval. Total discharge to-date is around approximately 12 million gallons, with average flows of around 10,000 to 15,000 gallons per day.

Quarterly monitoring has been conducted in accordance with the interim action work plan (HWA, 2103) which includes sampling some wells on a quarterly basis and some wells on a semi-annual basis, as well as quarterly sampling of total discharge to satisfy the King County discharge permit requirements.

Monitoring data subsequent to preparation of the 2017 RI, collected as part of the ongoing interim action cleanup, are summarized in the most recent ground water sampling report, *Ground Water Monitoring Results Year 4, Quarter 4 – January 2018* (HWA, 2018a). Table 1 presents all the tabulated ground water data through January 2018. Figures 4 and 5 show graphed ground water PCE data over time from monitoring wells and extraction wells. Figures 6 and 7 show ground water HVOC data from compliance well RMW-7.

Analytical results of the quarterly monitoring indicate the extraction wells have been and continue to recover HVOC-impacted ground water. Analytical results indicate generally decreasing trends, with seasonal fluctuations, in HVOC concentrations in compliance monitoring well RMW-7. This suggests some shrinking of the plume, although the generally similar concentrations in the other wells suggest a steady state condition, where HVOCs from upgradient areas may be replacing ground water pumped from the system.

Analytical results from the ground water monitoring and extraction wells show that the extraction system is acting as a barrier and capturing HVOC-impacted ground water that might otherwise be discharging into the river, as intended.

2 CLEANUP OBJECTIVES AND PRELIMINARY CLEANUP STANDARDS

2.1 Conceptual Site Model

The conceptual site model for the Riverside Site HVOC area identifies the primary contaminant sources, release mechanisms, transport mechanisms, secondary contaminant sources, potential pathways, and exposure routes. Existing chemical data, Site characterization data, and identification of potential human and ecological receptors were used to develop the model presented in Figure 8.

2.2 Primary Sources of Contamination and Primary Release Mechanisms

The primary contaminant source is a small release of tetrachloroethene (PCE) to the ground somewhere at the north (upgradient) end of the Riverside HVOC area. The primary potential release mechanisms for PCE and associated HVOCs is likely a surface release via spilling or dumping of PCE.

2.3 Secondary Sources and Release Mechanisms

When a released contaminant is retained in an environmental medium such as soil, the medium functions as a secondary source for further chemical release. Secondary release mechanisms for contaminants at the HVOC area include the following:

- Leaching from soil to ground water
- Volatilization from soil and ground water to air

The degree of contaminant leaching is controlled by chemical properties of the contaminants, ground water chemical properties, physical properties of the soil, characteristics of the ground water flow system, and precipitation recharge. Volatilization is controlled by the concentration and chemical properties of the contaminants, physical properties of the soil, and soil gas characteristics.

2.4 Pathways and Potential Receptors

An exposure pathway is a mechanism by which contaminants of concern (COCs) are assumed to contact receptors. The U.S. Environmental Protection Agency (EPA,1989) describes a complete exposure pathway in terms of four components:

1. A source and mechanism of chemical release (e.g., a release of COCs to the subsurface)
2. A retention or transport medium (e.g., ground water)
3. A receptor at a point of potential exposure to a contaminated medium (e.g., commercial worker in an on-site building located above the ground water plume)
4. An exposure route at the exposure point (e.g., inhalation of vapors)

If any of these four components is not present, then a potential exposure pathway is considered incomplete and is not evaluated further in a risk assessment. If all four components are present, a pathway is considered complete.

Potential exposure routes for human and ecological receptors include the following:

Soil - Soil pathways (e.g., direct contact, ingestion, soil to ground water) are not considered because soil HVOC concentrations in this area do not exceed cleanup levels or appear to be a concern.

Ground water - The main potential exposure pathway is ground water to surface water, specifically via discharge of HVOC-impacted ground water into the Sammamish River.

Surface Water – Surface water pathways include 1) dermal contact, ingestion of water, or ingestion of fish, by aquatic species or recreational users of the Sammamish River. The river is used for boating, kayaking, fishing, and swimming.

Vapor - Vapor pathways (e.g., inhalation, indoor air) are not considered due to the absence of present or planned buildings in this area.

2.5 FATE AND TRANSPORT

The primary contaminant transport mechanisms are advection and dispersion caused by seepage of ground water through the Site's shallow aquifer and into the Sammamish River.

2.6 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Cleanup actions under Model Toxic Control Act (MTCA, WAC 173-340-710) require the identification of all applicable or relevant and appropriate requirements (ARARs). These requirements are defined as:

"Applicable" requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site.

"Relevant and appropriate" requirements means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site.

The potential ARARs for the Site include three types:

- Chemical-specific
- Location-specific
- Action-specific

Chemical-specific ARARs are typically health- or risk-based values that when applied to site-specific conditions represent cleanup standards. Location-specific ARARs are related to the geographical position and/or physical condition of the site and may affect the type of remedial action selected. Action-specific ARARs are usually technology-based or activity-based requirements or limitations on actions or conditions taken with respect to specific hazardous substances. The action-specific requirements do not determine the selected remedial alternative, but indicate how or to what level a selected alternative must perform.

Potential ARARs were identified for each medium of potential concern. These potential ARARs are shown in Table 2.

2.7 ASSESSMENT OF RISK

Exposure to contaminants could occur via the potentially complete exposure pathways described in Section 2.4 above. Based on the nature of the Site and the extent of contamination, current risks include:

- Ground water –migration of impacted ground water to adjacent surface water
- Surface water –direct contact with or ingestion of water, by human and ecological receptors, and ingestion of aquatic species by humans

2.8 PRELIMINARY CLEANUP STANDARDS

Cleanup standards consist of appropriate cleanup levels applied at a defined point of compliance that meet applicable state and federal laws (WAC 173-340-700). HVOC area cleanup levels are described below.

2.8.1 Soil

Soil cleanup levels are the MTCA Method A Soil Cleanup Levels for Unrestricted Land Uses (WAC 173-340-900, Table 740-1), and MTCA Method B Direct Contact values:

- PCE — 0.05 mg/kg (Method A)
- Trichloroethene (TCE) — 0.03 mg/kg (Method A)
- (cis) 1,2-Dichloroethene (Cis-1,2 DCE) — 160 mg/kg (Method B)
- Vinyl Chloride (VC) — 175 mg/kg (Method B)

Method A Soil Cleanup Levels were selected because they are protective of human health, and the Site is relatively straightforward and only involves a few hazardous substances. Method B values were used for COCs with no Method A value.

2.8.2 Ground Water

Appropriate levels of cleanup for ground water are determined by the highest beneficial use of that ground water. Shallow, likely perched, ground water present at the Site is not currently used for drinking water, and no water wells are located near the Site. Due to the main concern for impacts to surface water, surface water cleanup levels were evaluated in addition to ground water values. The rationale for selecting cleanup levels is as follows:

- MTCA Method B surface water cleanup levels
- MTCA Method B ground water cleanup levels if there is no surface water cleanup level
- Method PQL (practical quantitation limit) if the PQL is higher than MTCA cleanup levels

Proposed cleanup levels are summarized below and shown on Table 3.

- PCE - 0.69 µg/L[1]
- TCE - 2.5 µg/L[1]
- 1,2 DCE (mixed isomers) - 72 µg/L[2]
- cis-1,2-DCE - 16 µg/L[2]
- trans-1,2-DCE - 100 µg/L[3]
- VC - 0.025 µg/L[4]

Footnotes:

1 - Surface Water ARAR - Human Health - Fresh Water - Clean Water Act §304
2 - Ground Water, Method B, Non-carcinogen, Standard Formula Value
3 - Ground Water ARAR - State Primary Maximum Contaminant Level (MCL)
4 - VC 0.025 Surface Water, Method B, Carcinogen, Standard Formula Value

Due to the proximity of the HVOC-impacted ground water to the river, surface water cleanup levels are proposed, although the point of compliance and sampling locations/methods (i.e., ground water monitoring wells) are in ground water. Direct sampling of surface water in the river is unlikely to detect any HVOCs due to the relatively low concentrations in ground water and dilution in the river.

Method B surface water cleanup levels. Standard Method B cleanup levels for surface waters shall be at least as stringent as all of the following:

- Surface water quality criteria per WAC 173-201A, including referenced Clean Water Act and EPA standards.
- Drinking water standards per WAC 173-340-720, for surface waters classified as suitable for domestic water supplies

Table 3 provides the basis for surface water cleanup levels**,** including MTCA Method B cleanup levels, and available federal and state ARARs, including Ecology Surface Water Quality Standards WAC 173-201A and referenced Clean Water Act and EPA standards.

2.8.3 Terrestrial Ecological Evaluation

The HVOC area qualifies for an exclusion from a terrestrial ecological evaluation (TEE), due to the absence of more than 1.5 acres contiguous undeveloped land within 500 feet of the Site. The nearest undeveloped land to the Site is the 30 to 40 foot-wide strip of vegetated river bank adjoining the Site. The large, undeveloped, wooded portion of the Park at Bothell Landing is located some 800 feet southwest of the Site. Currently vacant land north of the Site is slated for development in the near future and is currently covered by gravel and hydroseeding (i.e. no native vegetation or habitat potential).

2.9 VAPOR INTRUSION

Per the MTCA, RIs must include evaluation of vapor intrusion (VI) impacts to indoor air quality when volatile hazardous substances are present in the subsurface. The Ecology *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigations and Remedial Actions* (Ecology, 2009, revised 2016) provides a process for evaluating the VI pathway during an RI/FS (WAC 173-340-350) and subsurface media cleanup levels protective of indoor air quality. This process applies to buildings currently on a site, or future buildings, i.e., cleanup standards and actions must be protective of current and potential future site uses.

The guidance employs a tiered approach, starting with a preliminary assessment, and moving to Tier I and II assessments, if warranted. Initial screening steps in the preliminary assessment include the following:

- Are chemicals of sufficient volatility and toxicity known or reasonably suspected to be present?
- Are occupied buildings present (or could they be constructed in the future) above or near site contamination?

For the HVOC area, the first criterion is met, but the second is not, as no buildings are planned over the impacted area, thus no further VI evaluation is necessary.

2.10 POINT OF COMPLIANCE

The point of compliance is the specific location(s) at which a particular cleanup level must be met in order to demonstrate compliance of a cleanup action. MTCA defines standard and conditional points of compliance. Proposed points of compliance are described below.

2.10.1 Soil

The standard soil point of compliance under MTCA (WAC 173-340-740 (6)(b)) is:

- For soil cleanup levels based on protection of ground water, the point of compliance shall be established throughout the Site
- For soil cleanup levels based on protection from vapors, the point of compliance shall be established throughout the Site from the ground surface to the uppermost ground water saturated zone
- For soil cleanup levels based on human exposure via direct contact or other exposure pathways where contact with the soil is required to complete the pathway, the point of compliance shall be established in the soils throughout the Site from the ground surface to 15 feet bgs.

MTCA recognizes that, for cleanup actions that involve containment or capping, cleanup levels may not be met at the standard point of compliance, but the cleanup action would be determined to comply with cleanup standards provided:

- The selected remedy is permanent to the maximum extent practicable
- The cleanup action is protective of human health and terrestrial ecological receptors
- Institutional controls are implemented to limit activities that could interfere with the long-term integrity of the containment system
- Compliance monitoring and periodic reviews are conducted
- The capped or contained COCs and measures to prevent migration and contact with them are specified in a CAP

The cleanup alternatives are evaluated based on standard soil point of compliance for removal and treatment alternatives (WAC 173-340-740(6)(a)-(e), and for containment remedies (WAC 173-340-740(6)(f)).

2.10.2 Ground Water

The standard ground water point of compliance under MTCA (WAC 173-340-720(8)(b)) is in ground water throughout the Site from the uppermost level of the saturated zone to the lowest depth which could potentially be affected. For properties near or adjoining surface water bodies, a conditional point of compliance off the property may be approved, as close as practicable to the source and not to exceed the point or points where the ground water flows into the surface water (typically at the ground water to surface water discharge area).

For this Site (HVOC area), a conditional point of compliance is proposed as near as practicable to the river, i.e., at RMW-7 and RMW-13 located on the north bank of the river.

2.11 Remedial Action Objectives

Remedial action objectives (RAOs) are cleanup goals established for environmental media (soil or ground water) designed to protect human health and the environment under a specified land use. The RAOs take into account potential exposure pathways, receptors, and provide acceptable concentrations for COCs that are protective of all potential exposure pathways. The primary objective of site remediation will be to minimize all applicable exposure pathways, including:

- Ground water to surface water
- Human health, direct contact
- Human health, ingestion
- Aquatic species

RAOs are based on the findings of the remedial investigation, and guide the development and evaluation of cleanup alternatives. Potential risks used to establish RAOs include:

- Ground water – Potential risks include migration of impacted ground water to adjacent surface water
- Surface water – Potential risks associated with surface water include those from direct contact with or ingestion of water, by human and ecological receptors, and ingestion of aquatic species by humans

3 SCREENING/EVALUATION OF REMEDIAL ALTERNATIVES

Under MTCA, the development of a cleanup plan requires that technologies capable of meeting cleanup objectives are screened and then assembled into remedial alternatives. These alternatives are then evaluated, compared, and preferred alternatives identified.

This section includes review of available cleanup technologies, initial screening of the technologies, and selection of technologies to be further evaluated. The initial screening of treatment technologies is based on technical feasibility, i.e., available site data and knowledge of design parameters for potential treatment technologies. The selected cleanup technologies are then screened for overall effectiveness, implementability, and relative cost to identify a short-list of potentially applicable technologies, that are then assembled into cleanup alternatives.

The initial technologies screened include:

- In situ ground water treatment
  - Chemical oxidation
  - Chemical reduction
  - Bioremediation
  - Air sparging
  - Soil vapor extraction (SVE)

- Ground water gradient control
  - Pump, treat, and discharge
    - Carbon adsorption
    - Air stripping
    - Discharge to sanitary sewer
  - Pump, treat (using one of the above-listed methods), and recirculate

- Permeable reactive barriers
  - Zero valent iron
  - Funnel and gate with zero valent iron

- Monitored Natural attenuation

Soil cleanup methods at the Riverside Site HVOC area were not considered, because soil does not appear to be impacted by HVOCs on the Site.

MTCA regulations place a preference on the use of permanent cleanup methods such as removal, disposal, or treatment relative to those that manage contaminants in place using institutional controls, natural attenuation and/or containment. The discussion of the benefits and disadvantages of each candidate technology is described in this section.

HWA selected the following remediation alternatives as appropriate technologies to treat ground water contaminated with HVOCs.

3.1 In Situ Ground Water Treatment

In situ methods involve the injection of liquids or air into the subsurface, to treat HVOCs by a variety of means. In situ methods are more effective as soil permeability increases.

3.1.1 In Situ Chemical Oxidation

DESCRIPTION

In situ chemical oxidation involves the introduction of chemical oxidants (e.g. Fenton's reagent, permanganate, persulfate, ozone, hydrogen peroxide, etc.) into the subsurface to destroy organic contaminants.

ENGINEERING DISCUSSION

Different oxidants have varying oxidation potentials, or strengths, and applicability to different contaminants. The oxidant must be in aqueous contact with the contaminants, therefore considerations for treatment efficacy include distribution of contaminants, phase of contaminants, presence of other compounds that consume oxidant (e.g., other forms of organic carbon), and the ability to introduce and distribute the oxidant in the subsurface.

Pilot scale studies are typically performed to determine parameters for optimum performance of a full scale system (e.g., flow rates, pressures, well spacings).

APPLICABILITY

Permeable soils at the site are generally amenable to in situ methods. HVOC contaminants present are amenable to in situ chemical oxidation.

The advantages of in situ chemical oxidation include:

- Contaminants are destroyed, leaving harmless byproducts

The disadvantages of in situ chemical oxidation include:

- Not effective where other organics are present (e.g., peat) as the oxidation demand is generally too great to be practical. Alluvial soils at the Riverside Site contain organics, and are therefore not suitable for this method.
- Injected oxidants may adversely impact surface water quality in the river. Use of this technology in 2001 at the Bothell Service Center site, over 700 feet from the Sammamish

River (although attributed to "short circuiting" via footing or storm drains), resulted in a permanganate plume in the river and resulting fish kill.

- Injection permits may be required
- Multiple treatments may be required
- Inability to access lower permeability zones in mixed (heterogeneous) subsurface conditions
- May cause short term increases in concentrations due to contaminant desorption
- May mobilize naturally occurring metals in ground water, and hence in nearby surface water
- Injected material may surface, travel along utilities, or damage wells, due to high injection pressures

In situ chemical oxidation at the Site is ruled out as a potentially applicable cleanup method for further evaluation due to the numerous drawbacks in this specific application, most notably the potential impacts to surface water quality.

3.1.2 In Situ Chemical Reduction

In situ chemical reduction involves the introduction of chemical reducing agents (typically zero valent iron) into the subsurface to destroy organic contaminants. The technology and features are very similar to in situ chemical oxidation (described above).

The main disadvantage of this technology at this site is that ground water passing through the reducing area may have elevated pH, mobilized metals (e.g., iron, manganese, arsenic) and adversely impact surface water quality of the river.

In situ chemical reduction at the Riverside Site is ruled out as a potentially applicable cleanup method for further evaluation due to the drawbacks in this specific application, most notably the potential impacts to surface water quality.

3.1.3 In Situ Bioremediation

DESCRIPTION / ENGINEERING DISCUSSION

In situ bioremediation of HVOCs involves enhancing the microbial degradation of contaminants in subsurface soils and/or ground water without excavating overlying soil. Treatment systems supply nutrients (typically a carbon source such as emulsified edible oil) which create anaerobic conditions and help stimulate the natural dechlorination of halogenated organic compounds by bacteria.

Treatability studies and/or pilot tests are typically performed to determine the biological and chemical conditions in the subsurface at the site. These tests provide biodegradation rates for specific contaminants, as well as parameters for optimum performance of a full scale system (e.g., flow rates, nutrient levels, etc.).

APPLICABILITY

Permeable soils at the site would facilitate in situ treatment. HVOCs present are generally amenable to bioremediation.

Advantages of an in situ bioremediation system include:

- Low maintenance costs once in operation
- Contaminants break down into harmless byproducts
- Less site disruption than mass excavation methods

Disadvantages of an in situ bioremediation system include:

- PCE breaks down via reductive dechlorination into TCE, DCE, and vinyl chloride. Complete breakdown into harmless ethenes in not likely to be achievable given the short distance from the treatment area to the river
- Injected nutrients, bacteria, and chemically reduced ground water may adversely impact surface water quality in the river
- Inability to access lower permeability zones in mixed (heterogeneous) subsurface conditions

In situ bioremediation at the Site is ruled out as a potentially applicable cleanup method for further evaluation due to the numerous drawbacks in this specific application.

3.1.4 Air Sparging

DESCRIPTION

Air sparging involves introducing compressed air into the ground water. The introduction of air below the ground water table enhances volatilization of contaminants dissolved in ground water and sorbed onto saturated soils. Volatilized contaminants are then recovered via vapor extraction of the overlying vadose zone. Low molecular weight, volatile compounds such as PCE, TCE, DCE and vinyl chloride are generally amenable to air sparging. Air sparging would be combined with SVE to remove the contaminants, which is discussed below.

ENGINEERING DISCUSSION

The same contaminant criteria apply as for vapor extraction and air stripping (i.e., more volatile, less soluble compounds are more amenable to treatment). Well spacings are generally tighter than for ground water gradient control, as the radius of influence of air is less, typically 15 to 30 feet. The systems are often pulsed (turned on and off) to minimize channeling of air and encourage mixing of ground water in the subsurface.

APPLICABILITY

Although permeable soils exist at the Site, the presence of silt and peat layers suggests a heterogeneous subsurface environment, which may not be amenable to air sparging.

Advantages of air sparging include:

- Low capital costs
- Minimal site disruption

Disadvantages of air sparging include:

- Requires electricity and some land area for the wells and treatment system components.
- Requires pilot testing to establish design parameters (i.e., pressure, well spacings, SVE vacuum, discharge gas concentrations)
- Low injection radius of influence (more wells may be required)
- Inability to access lower permeability zones in mixed (heterogeneous) subsurface conditions, i.e., air may preferentially flow through more permeable channels
- Potential upwelling of ground water and modification of existing gradients
- Performance monitoring may be biased, as air may preferentially flow into the monitoring well filter packs, potentially biasing the results
- Potentially long restoration timeframe

Air sparging at the Site is identified as a potentially applicable cleanup method for further evaluation. For this alternative, we assumed a 150 foot long treatment / barrier area, extending roughly from RMW-6 to BC-3, with 10 sparge wells 40 feet deep, on 15 foot centers, and vapor extraction wells or trench as described in the following section.

3.1.5 Vapor Extraction

DESCRIPTION

Vapor extraction is the process of removing contaminants from the soil in the vapor phase, usually by applying a vacuum to the subsurface. This is done through the use of a series of wells or trenches which are placed throughout the area of contamination and screened above the ground water table. Some of the wells are connected to a blower which draws a vacuum. With the reduced pressure, air begins to move through the subsurface drawing out the contaminant vapors.

Other wells may be connected to a compressor that injects air into areas surrounding the extraction wells. The end effect is a flow-through system that draws out the contaminant vapors. Through proper placement of injection and withdrawal wells the flow of air can be focused on the area of contamination.

The withdrawn air may require treatment, depending on contaminant concentrations. Common processes for cleaning this air include vapor phase carbon adsorption, catalytic converters, or thermal converters (oxidizers).

ENGINEERING DISCUSSION

Vapor extraction systems are most effective remediating contaminants having fairly high vapor pressures. Low molecular weight, volatile compounds such as PCE, TCE, DCE and VC are generally amenable to vapor extraction.

Increased soil permeability facilitates vapor extraction. As the average permeability of the contaminated soil decreases, the cost of vapor extraction system increases due to the need for more wells and larger blowers. Proper spacing of injection and extraction wells requires some preliminary site work to determine the soil air permeability.

Based on the ground water concentrations present at the Site, off-gas treatment will not likely be required, although air dispersion modeling will be required as part of the permitting process. This modeling and permitting efforts should be conducted early in the project to make sure original planning and cost assumptions are valid.

APPLICABILITY

Vapor extraction may be feasible at the Site, due to volatile HVOCs and generally permeable soils.

Advantages of vapor extraction include:

- Less site disruption than mass excavation methods
- Physical removal of contaminants from the subsurface

Disadvantages of vapor extraction include:

- Site would need to be capped to maintain subsurface negative pressures
- Contaminants are not destroyed if no off-gas treatment is used
- Contaminated off-gas may require treatment
- Possible air permit requirements
- Operation and maintenance (O&M) requirements, long-term on-site equipment required
- Treatment times may be slower than other more aggressive remediation methods
- Inability to access lower permeability zones in mixed (heterogeneous) subsurface

Vapor extraction at the Site is identified as a potentially applicable cleanup method for further evaluation. For this alternative, we assumed a 150 foot long treatment / barrier area, extending roughly from RMW-6 to BC-3, with sparge wells as described above, and either a line of similarly spaced vapor extraction wells (10 feet deep), or a shallow vapor extraction trench (5-10 feet deep).

3.2 Ground Water Gradient Control

DESCRIPTION

Ground water plumes may be controlled by halting further migration, in the absence of treatment, or in addition to some form of treatment. Controlling ground water gradient may be accomplished by active (e.g., pumping wells or extraction trench) or passive (e.g., ground water cutoff) methods.

Achieving hydraulic control of the ground water involves a sufficient number, location, and spacing of wells, with pumping rates sufficient to modify the gradient such that impacted ground water flows into the wells, and not into the river.

ENGINEERING DISCUSSION

Active gradient control via pumping may be accomplished with recovery wells or trenches that are pumped to create a localized reversal of the pre-existing ground water gradient. Well spacing and pumping rates are determined after investigating the site hydrogeology and aquifer properties, typically via pumping or aquifer testing. Pumped water is treated using one of the methods described in the following sections.

HWA performed a preliminary capture zone analysis to estimate how many wells would be needed to achieve the gradient control objective. We used Visual MODFLOW (Schlumberger, 2009) to simulate ground water flow at the site. Visual MODFLOW is a package of integrated ground water flow models that simulate ground water flow and solute transport in a three-dimensional array of cells for which the user can define a variety of hydrogeologic properties. HWA used the MODPATH module in Visual MODFLOW for the capture zone analysis. The U.S. Geological Survey developed MODPATH to calculate three-dimensional particle tracking path lines for steady state and transient ground water flow simulation.

For the capture zone analysis, HWA created a simple one-layer steady state model by discretizing an area 1,680 feet west-to-east by 1,080 feet south-to-north that included the Bothell Riverside site and environs. The resulting grid consisted of 84 columns and 54 rows of 20- by 20-foot cells. We assumed a uniformly horizontal land surface elevation of 37 feet and aquifer bottom elevation of -4 feet across the model area based upon the borehole log of well RMW-10. We input the following hydrogeologic parameters into Visual MODFLOW:

MODFLOW Model Parameters

Parameter	Value
Ground surface elevation	37 feet
Aquifer bottom elevation	-4 feet
East-west hydraulic conductivity	13.1 feet/day
North-south hydraulic conductivity	13.1 feet/day
Vertical hydraulic conductivity	1.3 feet/day
Specific yield	0.3
Effective porosity	0.25
Recharge rate	4 inches/year

The 4 inches per year recharge rate for the area utilized in the model was based upon the assumption that approximately 10 percent of annual precipitation contributes to ground water recharge.

To establish a ground water gradient across the model area, we specified a constant head boundary northwest of the site having a ground water elevation of 37 feet. We also specified a constant head boundary having an elevation of 18 feet along the northern shore of the Sammamish River adjacent to the site. We then ran the model to simulate the steady state ground water gradient across the Bothell Riverside site. We next simulated the ground water capture zone created by variably spaced wells pumping at different rates. Each pumping well in the capture zone model was modeled as being screened through the entire saturated interval of the aquifer – from an elevation of +24 to -4 feet. By trial and error we optimized gradient control by using four wells spaced approximately 40 feet apart and each pumping at 5 to 10 gallons per minute (gpm). Model results and graphics are included in the *Focused Feasibility Study* (HWA, 2012) prepared for the Pump and Treat interim action implemented in 2014.

After installation of the first four extraction wells, in order to confirm plume capture by the system, HWA measured ground water levels in nearby monitoring wells during pumping in 2015. There are not enough monitoring wells near the pumping wells to create a ground water gradient map accurately depicting the capture area, although if drawdown is sufficient in wells located across and along the gradient relative to the pumping wells, then capture in all directions can be assumed. HWA performed an interference pumping test in April and May 2015 to demonstrate hydraulic capture of the pumping system. Water levels were measured in the pumping and nearby monitoring wells during rest periods (pumps off) and during pumping. Data-logging pressure transducers were installed in two pumping wells and a monitoring well located between them, with periodic manual measurements of the other wells. Drawdowns measured in the pumping and nearby wells are summarized below:

Well	Drawdown (feet)
EW-1	6.0
EW-2	11.1

EW-3	2.9
EW-4	10.7
RMW-6	3.7
RMW-10	6.9
BC-3	1.8

Based on several feet of drawdown in between and near the pumping wells, the system installed as an Interim Action in 2014 is sufficient to intercept ground water travelling to the river.

Passive gradient control via a cutoff wall may be accomplished by installing a low permeability wall or curtain around, or in front of, the ground water plume. Cutoff walls may be constructed with interlocking sheet piles (steel or PVC), or an excavated trench filled with a low permeability slurry, typically containing bentonite or polymers.

APPLICABILITY

Advantages of ground water gradient control include:

- Low capital costs
- Minimal site disruption (for pumping wells)

Disadvantages of ground water gradient control include:

- No treatment (for ground water barriers)
- Interference with underground utilities (for cutoff wall)
- Potentially long restoration timeframe

Ground water gradient control at the Site is identified as a potentially applicable cleanup method for further evaluation, in combination with treatment methods described in the following sections. For this alternative, we assumed a 150 foot long ground water capture area, extending roughly from RMW-6 to BC-3, with four recovery / pumping wells 40 feet deep.

3.2.1 Pump and Treat

DESCRIPTION

Pump and treat methods assume a ground water pumping system capable of recovering ground water over the extent of known contaminated areas, and effectively halting further plume migration. Several treatment alternatives are described in the following sections. Treated water can be discharged to sanitary sewers, storm drains, surface waters, or reinjected into the ground, depending on project requirements and regulatory approval.

ENGINEERING DISCUSSION

For any remediation plan involving ground water pumping, an analysis of subsurface conditions should be performed which will provide information on ground water flow and soil hydrogeologic properties. At least one aquifer pumping test should be performed. This process involves pumping a well at the site for a period of time and observing water level changes in the pumped well and at several observation wells during and after pumping. The information gathered during the pumping test is then used to calculate the aquifer hydraulic conductivity, transmissivity and storage coefficient/specific yield.

The information supplied by the pumping test can be applied to ground water flow modeling. Computer flow modeling is used to predict the effects of ground water pumping and/or injection on an aquifer at a specific site. This information is then used to determine the design parameters of the ground water treatment system, such as recovery well design, locations, discharge rates, and treatment system sizing.

Treatment of ground water by pump and treat methods typically requires long treatment times. In most cases, contaminant concentrations in ground water decrease asymptotically as treatment progresses. In some cases the final concentration reached is above regulatory levels and cleanup goals. If pumping and treatment are then discontinued, contaminant concentrations frequently rebound, as contaminants are desorbed from the soil matrix into the ground water. In general, pump and treat systems are effective at achieving gradient control (halting plume migration) and removing the bulk of contaminants. These methods are generally not effective in reaching cleanup goals or achieving a lasting remediation.

APPLICABILITY

Pump and treat remediation duration is difficult to predict. Duration estimates based on the number of pore volumes recovered are generally not accurate, as dissolved phase contaminants continually release from soil sources, if source areas are not cleaned up.

Advantages of pump and treat methods include:

- Easily implementable and combined with other technologies
- Less site and vicinity disruption during cleanup
- Effective gradient control

Disadvantages of pump and treat methods include:

- Long restoration timeframe in the presence of continuing releases from soil sources
- Continuing O&M requirements and costs
- Biofouling of wells, pumps, and pipes

Pump and treat methods at the Site are identified as a potentially applicable cleanup method for further evaluation.

3.2.1.1 Carbon Adsorption

DESCRIPTION

Liquid phase carbon adsorption involves passing contaminated water through activated carbon that adsorbs the contaminants. The life of the carbon is proportional to the concentration of adsorbed species and volume of water being processed. When the carbon is no longer able to adsorb the contaminant, or when effluent concentrations exceed discharge criteria, the carbon must be replaced or regenerated. Exceedance of discharge criteria typically occurs before maximum carbon loading (i.e., breakthrough) occurs. Carbon canisters are frequently arranged in series to maximize carbon usage. Upstream carbon units are used until breakthrough, while newer downstream units serve to meet discharge criteria.

ENGINEERING DISCUSSION

Not all compounds can be adsorbed by carbon. Adsorption is favored by:

- Increased chain length (carbon will not adsorb anything smaller than isobutane)
- Increased aromaticity
- Decreased branching
- Decreasing solubility
- Decreasing degree of dissociation

Degree of adsorption also varies somewhat by carbon type. Activated carbon is available in powdered or granular form, in varying grain sizes and textures. Carbon loading rates may be calculated using known properties of the contaminants, or measured in the lab using water from the site. Carbon vendors typically perform these carbon loading studies.

Spent carbon can be disposed of by landfilling or regenerated by heating it. Carbon disposed of in a landfill must conform to the regulations of the waste that it contains.

APPLICABILITY

HVOCs in ground water at the Site are amenable to carbon adsorption. Carbon costs will decrease over time as contaminant concentrations decrease, but can be a significant cost during the initial stages and also over the long-term. O&M costs will remain the same or increase as equipment gets older.

Advantages of carbon adsorption include:

- Low capital cost (not including carbon costs)
- Minimal start-up effort
- System is fairly simple
- Contaminants are destroyed during carbon regeneration

Disadvantages of Carbon Adsorption include:

- Long/uncertain treatment duration
- High O&M costs
- Biofouling of equipment
- Used carbon disposal issues (carbon must be disposed of or regenerated, and may be designated a dangerous or hazardous waste requiring additional transportation and disposal costs)

Carbon adsorption is not identified as a potentially applicable cleanup method for further evaluation due to O&M requirements and used carbon disposal issues.

3.2.1.2 Air Stripping

DESCRIPTION

Air stripping is a mass transfer process in which contaminated water is stripped of volatile constituents after being pumped from the ground to a treatment system. This is usually accomplished by passing the water through a packed column or series of compartments in one direction while forcing air through the system from the other direction. The contaminants are transferred from the water stream to the air stream in the process. Air stripper designs utilize long columns with high surface area packing, or multiple trays with baffles to increase water turbulence, residence times, and mass transfer. The off-gas may require treatment, depending on contaminant concentrations. Common processes for cleaning this air include vapor phase carbon adsorption, catalytic converters, or thermal converters (oxidizers).

ENGINEERING DISCUSSION

Temperature and the characteristics of the contaminants affect the performance of an air stripping process. Contaminant solubility and vapor pressure are important factors in determining the applicability of air stripping. Compounds with low solubility and high vapor pressure are more amenable to stripping. Other properties of the process water, such as total suspended solids and dissolved inorganic species (e.g., iron, manganese, carbonates), can also affect system performance. Biofouling and scaling (chemical precipitation) are two common maintenance problems affecting air strippers.

The output products of an air stripper are effluent water and contaminated off-gas. Both must be analyzed for contaminant levels, and the off-gas must be captured and treated if contaminant emissions exceed allowable regulatory levels. Vapor phase carbon adsorption, catalytic oxidizers, or thermal oxidizers are common methods of treating air stripper gas discharge.

Based on the ground water concentrations present, off-gas treatment will not likely be required, although air dispersion modeling will be required as part of the permitting process. This modeling and permitting efforts should be conducted early in the project, to make sure original planning and cost assumptions are valid.

APPLICABILITY

HVOCs at the site are volatile and amenable to air stripping. The system will likely not require treatment of the off-gas.

Advantages of Air Stripping include:

- Low capital costs

Disadvantages of Air Stripping include:

- Temperature effects (cold weather decreases efficiency)
- Contaminants are not destroyed if no off-gas treatment is used
- Biofouling of equipment
- Air permit requirements

Air stripping is identified as a potentially applicable cleanup method for further evaluation. For this alternative, we assumed a shallow tray air stripper, which is smaller and easier to maintain than packed-tower designs.

3.2.1.3 Discharge to Sanitary Sewer

DESCRIPTION / ENGINEERING DISCUSSION

Pumped ground water is discharged to a sanitary sewer for treatment at a municipal wastewater treatment plant. Factors influencing feasibility include anticipated water volume, type and concentration of chemicals to be treated, and proximity to a suitable sewer discharge point.

APPLICABILITY

The City has several sanitary sewer lines in the area. HVOC contaminants at the concentrations detected are generally acceptable at wastewater treatment facilities, and are generally treated by the standard primary and secondary wastewater treatment processes (e.g., activated sludge, facultative lagoons, etc.). Many of the HVOCs would likely volatilize prior to reaching the treatment areas, in the sewer lines, manholes, treatment plant headworks, solids removal, and aeration basins.

Advantages of discharge to sanitary sewer include:

- Low capital costs
- Low O&M costs

Disadvantages of discharge to sanitary sewer include:

- Potential limits by the treatment plant on volume (i.e., 25,000 gallon per day =17 gpm during the wet season)
- Volatilization of HVOCs prior to treatment
- High sewerage disposal costs over long time periods

Discharge to sanitary sewer is identified as a potentially applicable cleanup method for further evaluation.

3.2.1.4 Discharge to Ground Water / Recirculate

DESCRIPTION / ENGINEERING DISCUSSION

For any of the treatment methods described above, treated water can be reinjected back into the ground in an upgradient position. Reinjection method(s) and rate(s) would be performed in accordance with injection permit criteria and hydraulic parameters for the aquifer collected during the RI.

APPLICABILITY

Advantages of discharge to ground water

- Maintains ground water balance, pre-existing gradient, and recharge to surface water
- Eliminates need for other discharge options (e.g., storm drain, sanitary sewer)

Disadvantages of discharge to ground water

- Permitting – Ecology may not allow reinjection of highly treated ground water if it still exceeds cleanup levels.
- Additional wells, piping, and land area are required
- Biofouling of piping and equipment, plugging of aquifer at recharge sites

Discharge to ground water is not identified as a potentially applicable cleanup method for further evaluation due to permitting and space considerations.

3.3 PERMEABLE REACTIVE BARRIERS

DESCRIPTION / ENGINEERING DISCUSSION

Permeable reactive barriers (PRBs) are zones of treatment in the subsurface, created by trenching or a line of borings or wells. These zones passively capture a plume of contaminants in the ground water as it moves past them, and removes or breaks down the contaminants via chemical processes, biological activity, sorption or precipitation, leaving the treated ground water to pass through the zone.

APPLICABILITY

Advantages of PRBs include

- Low O&M once installed
- No power requirements
- No discharge requirements
- Can build on top of the PRB after installation

Disadvantages of PRBs include

- Depth limitations
- Site disruption / footprint due to excavation
- Additional monitoring parameters may be required to evaluate potential by-products of the PRB process.

Two types of PRBs are described below.

3.3.1 Zero Valent Iron

DESCRIPTION / ENGINEERING DISCUSSION

Zero valent iron (ZVI) is a strong reducing agent and acts to destroy organic contaminants such as HVOCs. ZVI can be placed in a PRB, along with sand, to increase permeability and allow ground water to pass through. The design thickness of the ZVI wall depends on the residence times required to treat specific compounds, which in turn is dependent on the ground water velocity and contaminant concentrations.

The main disadvantage of this technology at the Site is that ground water passing through the reducing area may result in elevated pH and mobilized metals (e.g., iron, manganese, arsenic) that may adversely impact water quality in the river.

A ZVI permeable reactive barrier is ruled out as a potentially applicable cleanup method for further evaluation due to the drawbacks in this specific application.

3.3.2 Funnel and Gate with Zero Valent Iron

DESCRIPTION / ENGINEERING DISCUSSION

Funnel and gate methods involve constructing one or more subsurface hydraulic barrier walls oriented such that they direct ('funnel') ground water to a PRB (the 'gate'). Barrier walls may be sheet piles or slurry walls (a trench filled with bentonite and soil).

APPLICABILITY

Funnel and gate methods are used where large areas of ground water need to be captured, typically to reduce costs of the PRB / treatment area, as the cutoff walls may be less costly. The treatment zone will likely need to be thicker than a full PRB to achieve residence times as described above, as ground water velocities will increase in the 'gate' area. Some designs incorporate "cells" of reactive material that can be replaced as the material is depleted.

Funnel and gate methods are ruled out as a potentially applicable cleanup method for further evaluation due to the drawbacks in this specific application.

3.4 MONITORED NATURAL ATTENUATION

DESCRIPTION / ENGINEERING DISCUSSION

Monitored natural attenuation (MNA) consists of monitoring Site ground water over a long-term period to ascertain that natural attenuation is occurring. Natural attenuation refers to physical, chemical, or biological processes that can reduce mass, toxicity, mobility, volume, or concentration of organic contaminants in soil or ground water. These processes include biodegradation, dispersion, mixing, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants. Some natural bioremediation of HVOCs is already occurring, as evidenced by the presence of PCE breakdown products (TCE, DCE, VC) in some Site wells.

APPLICABILITY

Advantages of MNA include

- Less site impacts
- Reduced generation of remediation wastes

Disadvantages of MNA include

- Longer cleanup timeframe

Natural attenuation is not retained for alternatives development due to the long cleanup timeframe.

3.5 SUMMARY OF TECHNOLOGIES CARRIED FORWARD

The remedial technologies described above were screened for overall effectiveness, implementability, and relative cost, resulting in a short-list of potentially applicable technologies for further evaluation. These technologies were then combined to meet the Site RAOs and requirements of MTCA, resulting in the development of the following remedial alternatives.

- Air sparging with soil vapor extraction
- Pump and discharge to sanitary sewer
- Pump, treat with air stripping, discharge to storm/surface water

The alternatives were then evaluated to select a preferred alternative. The following sections describe each alternative, including all component cleanup technologies and costs.

4 EVALUATION OF REMEDIATION ALTERNATIVES

This section evaluates the cleanup alternatives selected in the previous section in accordance with the selection of remedy requirements under MTCA (WAC 173-340 through 370). The proposed alternatives are:

- Air sparging with soil vapor extraction
- Ground water gradient control, pump and treat via discharge to sanitary sewer
- Pump, treat with air stripping, discharge to storm/surface water

4.1 MTCA Threshold Requirements

MTCA (WAC 173-340-360(2)(a)) specifies several threshold or basic requirements that cleanup actions must meet in order to be considered. The four threshold requirements specify that the cleanup action must:

- Protect human health and the environment
- Comply with cleanup standards
- Comply with applicable state and federal laws
- Provide for compliance monitoring

Table 4 summarizes the evaluation of cleanup alternatives by MTCA requirements. The following sections evaluate the alternatives against the threshold and other criteria.

4.1.1 Protect Human Health and the Environment

The 'protection of human health and environment' criterion addresses whether a cleanup alternative will provide a minimum acceptable level of protection, i.e., a sufficiently low residual risk to human and ecological receptors. Alternatives are compared by relative degree of protection, which may include the second criterion 'compliance with cleanup standards' as well as short-term risks posed by remedial action (e.g., during construction and implementation of the cleanup action, such as mobilization of contaminants during construction or transport, or other ancillary safety risks during construction).

All the selected alternative remedies would protect human health and the environment, although the degree to which cleanup levels could be reached is less certain for air sparging with soil vapor extraction. The other two pump and treat alternatives would ensure gradient control, and be more likely to be protective of surface water quality in the river.

4.1.2 Comply with Cleanup Standards

Compliance with cleanup standards is defined by meeting the requirements of WAC 173-340-

700 through 760, i.e., meeting calculated cleanup levels at the established point of compliance. Of the three alternatives at the Site, pump and discharge to sanitary sewer would be the most likely to ensure compliance at the river, as impacted ground water would be removed from the Site for off-site treatment. The second most likely alternative to reach cleanup standards would be pump, treat via air stripping, discharge to storm/surface water. Provided the air stripper is designed and operated properly, cleanup standards should be achieved prior to discharge to surface water. The least certain option is air sparging with soil vapor extraction, which may not be able to remove all contaminants down to cleanup levels due to greater uncertainty in below-ground systems (i.e. above ground, engineered systems are easier to predict, control and operate).

4.1.3 Comply with Applicable State and Federal Laws

Compliance with State and Federal Laws includes legally applicable requirements and relevant and appropriate requirements (ARARs). ARARs for the Site include the cleanup standards listed in Table 2, as well as other regulations such as dangerous waste, health and safety, shoreline permitting, cultural resources, well construction, etc., which are not addressed in this FS. All alternative remedies meet ARARs to the same relative degree, with the exception of the cleanup standards, which are discussed above.

4.1.4 Provide for Compliance Monitoring

Compliance monitoring requirements (specified in WAC 173-340-410) include the following elements:

- Protection monitoring to confirm that human health and the environment are adequately protected during implementation of an alternative
- Performance monitoring to confirm that cleanup standards or other performance standards are met
- Confirmational monitoring to monitor the long-term effectiveness of the remedy after completion of the alternative

All alternative remedies provide compliance monitoring. Existing wells RMW-7 and RMW-13 are proposed as a compliance wells for performance monitoring, as they are located on the upper bank of the river. Wells RMW-5, RMW-6, RMW-7, and BC-3 are proposed for confirmational monitoring once cleanup is completed.

4.2 MTCA Other Requirements

Other requirements specified in MTCA include:

- **Use permanent solutions to the maximum extent practicable** – The requirement to use permanent solutions to the maximum extent practicable includes a preference hierarchy to evaluate alternatives and cost effectiveness. Cleanup technologies in order of decreasing preference include reuse / recycling, destruction, detoxification, and separation / volume reduction. Under MTCA these preferences may be weighed against costs and benefits using a "disproportionate cost analysis" (WAC 173-340-360(3)(e)).

- **Provide for a reasonable restoration time frame** – alternatives that can be implemented in less time (while equivalent in other respects) are preferred under MTCA
- **Consider public concerns –** MTCA specifies public notice and participation requirements for cleanups conducted by Ecology, conducted under an order or decree, where site-specific risk assessment is used to establish cleanup levels, or where cleanup would restrict future site use

4.3 EVALUATION OF ALTERNATIVES

Of the alternatives carried forward for evaluation, pump and discharge to sanitary sewer is selected as the preferred alternative. All alternatives ranked similarly based on remedial action objectives and MTCA threshold and other requirements (Table 4), however pump and discharge to sanitary sewer is the most permanent, shortest timeframe, and most protective, with respect to site wide HVOCs.

5 RECOMMENDED REMEDIAL ALTERNATIVE

This section presents proposed remedial actions to be conducted at the Site.

5.1 Description of Recommended Remedial Alternative

Based on the results of the remedial investigation and feasibility study conducted under MTCA and the application of the selection of remedy criteria, the preferred cleanup alternative at the Site (developed in accordance with WAC 173-340-350 through 173-340-390) is ground water gradient control, via pump and treat, via discharge to sanitary sewer. This cleanup action has already been imitated as in interim action in 2014, therefore the proposed final cleanup action is to continue the ongoing pump and treat system.

Based on discussions with Ecology in October 2017, if, at the end of the fourth year of monitoring (February 2018 quarterly report) sampling results indicate that the interim action is reducing concentrations in ground water, the current interim action can be continued as a final cleanup action. The point of compliance monitoring well RMW-7 which has shown steadily decreasing concentrations.

A detailed description of the system is presented in Section 3.2. The ground water extraction and treatment system began operation in December 2013, with four original extraction wells, and is still operating. Extraction wells EW-5 and EW-6 were installed in October 2016, with Ecology's input and approval. Monitoring results are detailed in quarterly ground water monitoring reports (HWA, 2018a).

5.1.1 Ground Water Monitoring

Ground water monitoring will be continued per the existing monitoring plan, which is summarized below.

Sample Type	Sampling Location	Sampling Frequency / Rationale
Point of Compliance	RMW-7 RMW-13	Quarterly for one year, then modify based on results and consultation with Ecology (e.g. move to semi-annual if concentrations stabilize)
Extraction wells	Extraction well 1 Extraction well 2 Extraction well 3 Extraction well 4 Extraction well 5 Extraction well 6	Quarterly
Combined discharge	Combined discharge at sewer manhole or manifold	As required by KCIWD permit

Nearby wells	BC-3 RMW-4 RMW-5 RMW-6 RMW-8 RMW-9 RMW-10 RMW-12	Semi-annual for one year, then modify based on results and consultation with Ecology

5.1.2 Restoration Timeframe

Because the cleanup method selected is mainly a barrier approach, i.e., designed to prevent migration and discharge of HVOCs from ground water into the Sammamish River, the cleanup timeframe may be on the order of 15 years. Figures 6 and 7 show linear regression plots of HVOC data from point of compliance well RMW-7, which show a general decreasing trend over the last few years of pumping, although with a seasonal trend of increased concentrations in the fall and winter months. Projecting trend lines for average and peak seasonal HVOC concentrations indicates a restoration timeframe of 7 to 15 years, as follows:

- PCE - already in compliance at RMW-7
- TCE - 10 years
- DCE - 7 years
- VC - 15 years

5.2 Rationale for Selecting Proposed Alternative

The proposed alternative was selected in accordance with remedy selection requirements under MTCA, and meet all threshold and other requirements specified in WAC 173-340-360. This rationale is detailed in Section 4 above.

5.3 Other Alternatives Evaluated

A range of other cleanup alternatives was evaluated, as detailed in Section 4, and includes:

- Air sparging with soil vapor extraction
- Pump and discharge to sanitary sewer
- Pump, treat with air stripping, discharge to storm/surface water

5.4 Cleanup Standards

Determination of cleanup standards is detailed in Section 2.8 and included the following process, per MTCA:

- Evaluate beneficial use of land, ground water, and surface water
- Develop conceptual site model (i.e., contaminant source, affected media, exposure pathways, and receptors)
- Select COCs
- Select ARARs
- Choose cleanup levels
- Identify points of compliance

The cleanup standards are then based on the calculated cleanup levels measured at the points of compliance. Cleanup levels for soil are the MTCA Method A Soil Cleanup Levels for Unrestricted Land Uses (WAC 173-340-900, Table 740-1), and MTCA Method B Direct Contact values (if no Method A value). Cleanup levels for ground water are MTCA Method B surface water cleanup levels, MTCA Method B ground water cleanup levels if there is no surface water cleanup level, and PQL (practical quantitation limit) if the PQL is higher than MTCA cleanup levels (see Section 2.8.2 and Table 3).

Points of compliance are as follows:

- Soil
  - Standard point of compliance (throughout the Site) based on protection of ground water
  - From the ground surface to 15 feet below ground surface based on direct contact exposure
- Ground water
  - For this Site (HVOC area), a conditional point of compliance is proposed as near as practicable to the river, i.e., at RMW-7 and RMW-13 located on the north bank of the river.

Another component of the cleanup standard is a reasonable restoration timeframe. Per Section 5.1.2, the restoration timeframe is estimated up to 15 years.

5.5 SCHEDULE FOR IMPLEMENTATION

Because the proposed cleanup is already in progress as an interim action, the schedule for implementation is immediate and ongoing. The final cleanup would continue under a cleanup Agreed Order for Riverside Site HVOC area to be negotiated with Ecology.

5.6 Applicable State and Federal Laws

All applicable state and federal laws, if any, for the proposed cleanup action will be followed. Regulatory compliance will be addressed during the permitting phase of the project and may include grading, storm water, and other permitting issues.

5.7 Compliance With Threshold and Other MTCA Requirements

As stated in Section 8, the proposed cleanup action complies with threshold and other MTCA requirements specified in WAC 173-340-360.

6 SUMMARY & CONCLUSIONS

RI activities at the Riverside Site HVOC area have defined the nature and extent of soil and ground water impacts, which include PCE and its breakdown products TCE, DCE, and VC.

Cleanup levels for soil are the MTCA Method A Soil Cleanup Levels for Unrestricted Land Uses (WAC 173-340-900, Table 740-1), and MTCA Method B Direct Contact values (if no Method A value). Cleanup levels for ground water are MTCA Method B surface water cleanup levels, MTCA Method B ground water cleanup levels if there is no surface water cleanup level, and PQL (practical quantitation limit) if the PQL is higher than MTCA cleanup levels (see Section 2.8.2 and Table 3).

Points of compliance are as follows:

- Soil
  - ➢ Standard point of compliance (throughout the Site) based on protection of ground water
  - ➢ From the ground surface to 15 feet below ground surface based on direct contact exposure
- Ground water
  - ➢ For this Site (HVOC area), a conditional point of compliance is proposed as near as practicable to the river, i.e., at RMW-7 and RMW-13 located on the north bank of the river.

Based on the results of the remedial investigation and feasibility study conducted under MTCA and the application of the selection of remedy criteria, the preferred cleanup alternative at the Riverside Site HVOC area (developed in accordance with WAC 173-340-350 through 173-340-390) for HVOC contaminated ground water is ground water gradient control, pump and treat via discharge to sanitary sewer. This alternative is already in progress as an interim action, therefore would be continued as the final cleanup (dCAP, Feb 7 2018, HWA) under a cleanup Agreed Order for Riverside HVOC site to be negotiated with Ecology.

7 REFERENCES

HWA GeoSciences, 2009, *Remedial Investigation And Feasibility Study Work Plan Riverside Property Bothell, Washington,* August 26, 2009.

HWA GeoSciences, 2011, *Documentation of Interim Action At Bothell Riverside Site Bothell, Washington,* February 2, 2011.

HWA GeoSciences, 2012, *Focused Feasibility Study Bothell Riverside Site Bothell, Washington,* September 5, 2012.

HWA GeoSciences, 2013, *Interim Action Work Plan Bothell Riverside Site Bothell, Washington,* January 7, 2013.

HWA, 2016a. Soil Gas Survey/ Source Investigation, Riverside HVOC Site, Bothell, Washington February 26, 2016

HWA, 2016b. Ground Water Monitoring and New Well Results Year 3, Quarter 2 – June/July 2016, Riverside Site, September 2, 2016

HWA, 2017, *Final Remedial Investigation Report, Bothell Riverside Site, Bothell, Washington,* December 18, 2017.

HWA. 2018a, *Ground Water Monitoring Results Year 4, Quarter 4 – January 2018, Riverside HVOC Site,* January 29, 2018. (Letter Report dated February 7, 2018)

HWA. 2018b, *draft Cleanup Action Plan, Bothell Riverside Site HVOC Area, Bothell, Washington,* February 7, 2018.

Parametrix, 2009a, *Bothell Riverside Remedial Investigation/Feasibility Study*, Revision No. 0, Prepared by Parametrix, Bellevue, Washington, November 2009.

Parametrix, 2009b. *Bothell Riverside Draft Cleanup Action Plan*, Revision No. 1. Prepared by Parametrix, Bellevue, Washington, December 2009.

Washington State Department of Ecology, 2007, *Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC*, Publication No. 94-06, dated October 12.

Washington Department of Ecology, 2009, *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action*, Washington State Department of Ecology, Toxics Cleanup Program, Publication no. 09-09-047, Review DRAFT, October 2009.

Table 1
Bothell Riverside Site
Ground Water Analytical Results

			FIELD PARAMETERS							HVOCs					NOTES
Monitoring Well Identification	Screened Interval (ft bgs)	Date Sampled	Depth to Water (ft below MP)	pH (units)	Conductivity (µS)	Temp (^oC)	Dissolved Oxygen (mg/L)	Oxygen Reduction Potential (ORP)	Settable Solids (mg/L)	Tetrachloro-ethene (µg/L)	Trichloro-ethene (µg/L)	(cis) 1,2-Dichloro-ethene (µg/L)	(trans) 1,2-Dichloro-ethene (µg/L)	Vinyl chloride (µg/L)	
Cleanup Levels*										0.69	2.5	16 (B)	100 (B)	0.2	
KCIWD Limits									7.00	240	500	Total <2000		12	
RMW-4	15-25	6/24/14													Wellhead buried under new landscaping
		12/19/14	12.2	6.59	1183	14.6	1.70			0.79	0.33	<0.20	<0.20	<0.20	
		6/23/15	13.09	5.76	987	17.67	0.00	-125.70		0.52	0.72	<0.20	<0.20	<0.20	
		12/8/15	11.95	5.99	510	14.9	0.00	-69.90		2.2	0.56	<0.20	<0.20	<0.2	
		6/29/16	12.22	5.17	400	15.31	4.22	91.50		3.6	0.46	<0.20	<0.20	<0.20	
		12/21/16	11.48	6.2	293.5	14.5	0.43	0.00		4.3	0.51	<0.20	<0.20	<0.20	
		6/28/17	11.48	6.41	225	14.65	1.57	65.3		3.9	0.49	<0.20	<0.20	<0.20	
		1/2/18	11.01	6.35	231	13.8	3.46	35.8		6.2	0.94	<0.20	<0.20	<0.20	
RMW-5	12-22	5/24/13	11.51	6.70	932	13.9	1.00			1.7	<0.2	<0.2		<0.20	
		6/24/14	14.51	6.48	740	14.5	0.15			1.4	0.40	<0.20	<0.20	<0.20	
		12/19/14	13.61	6.28	1226	13.3	0.55			1.3	0.32	0.22	<0.20	<0.20	
		6/23/15	14.26	6.28	953	16.1	0.00	-127.10		0.66	0.36	<0.20	<0.20	<0.20	
		12/8/15	13.29	5.83	318	14.54	18.61	-90.40		1.6	<0.20	<0.20	<0.20	<0.2	
		6/29/16	13.41	6.18	356	14.43	1.71	-2.00		1.1	0.31	<0.20	<0.20	<0.20	
		12/22/16	13.01	6.48	483.9	13.7	0.27	-106.2		1.0	<0.20	0.23	<0.20	<0.20	
		6/29/17	13.26	6.65	438	13.85	0.46	-89.3		2.0	<0.20	<0.20	<0.20	<0.20	
		1/2/18	12.38	6.59	524	14.08	0.69	-80.3		5.1	0.28	0.23	<0.20	<0.20	
RMW-6	15-25	9/14/09								<0.2	0.27	3.6		5.3	
		5/24/13	10.42	6.68	467	14.3	1.40			<0.2	<0.2	2.7		3.4	
		6/24/14	14.79	6.47	407	14.2	0.13			0.34	0.60	0.42	<0.20	<0.20	
		12/19/14	13.31	6.09	294	14.3	0.82			0.47	<0.20	<0.20	<0.20	<0.20	
		6/23/15	13.65	6.12	283	15.2	0.00	8.00		<0.20	1.4	0.88	<0.20	<0.20	
		12/8/15	12.46	6.00	232	14.99	0.00	-40.10		<0.2	2.7	1.0	<0.20	<0.20	
		6/29/16	13.14	6.39	194	15.34	1.64	35.50		<0.20	2.5	1.3	<0.20	<0.20	
		12/21/16	12.21	6.47	179.8	14.8	0.57	88.20		<0.20	0.39	0.5	<0.20	<0.20	
		6/28/17	12.68	6.60	171	14.21	1.11	140.50		<0.20	0.41	0.3	<0.20	<0.20	
		1/2/18	11.45	6.59	257	14.05	0.63	37.00		<0.20	0.44	1.9	<0.20	<0.20	
RMW-7	15-25	9/14/09								50	120	190		22	
		5/24/13	16.31	6.80	447	16.2	0.30			9	33	65		9.3	
		4/4/14	16.65	6.50	1969	12.9	0.55			0.75	3.8	35	0.54	8.3	
		6/25/14	16.55	6.48	865	15.2	0.03			5.2	24	80	1.1	9.9	
		9/22/14	17.54	6.96	386	18.2	5.25			<1.0	3.2	170	1.6	47	
		12/19/14	17.49	6.06	683	15.4	0.73			2.9	8.9	150	1.4	34	
		3/18/15	16.66	6.35	1127	14.9	1.87			<0.40	1.5	57	0.64	20	
		6/23/15	17.41	5.97	508	17.96	0	-70.3		<0.40	3.1	95	1.2	9.6	
		9/11/15	18.50	6.22	464	21.54	3.23			4.2	23	110	1.4	14	
		12/8/15	15.97	5.96	274	15.92	0.00	-12.3		3.5	8.7	85	0.87	9.0	
		3/31/16	16.94	6.40	403	14.63	2	38.9		1.5	6.8	84	0.91	35	
		6/29/16	17.11	6.28	297	16.57	1.2	30.3		2.3	14	65	0.68	12	
		9/30/16	18.28	6.12	419	16.81	0.69	31.3		2.4	7.8	89	<1.0	13	
		12/22/16	15.89	6.34	368.4	15.8	0.19	-34.1		1.1	4.1	88	0.93	24	

Table 1
Bothell Riverside Site
Ground Water Analytical Results

			FIELD PARAMETERS							HVOCs					NOTES
Monitoring Well Identification	Screened Interval (ft bgs)	Date Sampled	Depth to Water (ft below MP)	pH (units)	Conductivity (µS)	Temp (°C)	Dissolved Oxygen (mg/L)	Oxygen Reduction Potential (ORP)	Settable Solids (mg/L)	Tetrachloro-ethene (µg/L)	Trichloro-ethene (µg/L)	(cis) 1,2-Dichloro-ethene (µg/L)	(trans) 1,2-Dichloro-ethene (µg/L)	Vinyl chloride (µg/L)	
							Cleanup Levels*			**0.69**	**2.5**	**16 (B)**	**100 (B)**	**0.2**	
							KCIWD Limits		**7.00**	**240**	**500**	**Total <2000**		**12**	
RMW-7	**15-25**	4/5/17	16.43	6.26	318.9	13	0.3	19.5		**1.2**	**2.4**	**12**	<0.20	**0.86**	
		6/28/17	16.65	6.50	283	15.49	0.78	5.9		**1.3**	**1.9**	**33**	**0.5**	**1.9**	
		10/10/17	18.26	6.33	438	17.38	3.18	176.6		**1.0**	**2.3**	**47**	**0.67**	**25**	
		1/4/18	17.26	6.43	386	15.14	0.6	-5.2		**1.1**	**4.4**	**53**	**0.65**	**20**	
RMW-8	**20-30**	9/15/09								**0.46**	**2.6**	**1.3**		<0.2	
		5/24/13	18.81	6.42	494	16.4	0.10			**0.5**	**0.85**	**0.44**		<0.2	
		6/25/14	19.62	6.27	650	15.7	0.20			<0.20	<0.20	<0.20	<0.20	<0.20	
		12/19/14	20.63	6.18	431	14.5	0.84			**0.7**	<0.20	<0.20	<0.20	<0.20	
		6/23/15	20.87	5.74	333	26.9	0.27	-61.20		<0.20	<0.20	<0.20	<0.20	<0.20	
		12/8/15	19.42	5.83	344	15.15	1.51	44.30		<0.2	**0.39**	**0.47**	<0.20	<0.2	
		6/29/16	20.5	6.27	216	17.47	2.05	32.00		<0.20	<0.20	<0.20	<0.20	<0.20	
		12/22/16	20.58	6.13	297.3	14.6	0.31	32.80		**0.31**	**0.66**	**0.37**	<0.20	<0.20	
		6/28/17	19.73	6.21	213	16.03	0.84	120.90		<0.20	<0.20	<0.20	<0.20	<0.20	
		1/4/18	20.21	6.45	305	13.51	0.85	21.10		**0.27**	**0.74**	**0.53**	<0.20	<0.20	
RMW-9	**20-30**	9/15/09								<0.20	<0.20	<0.20		<0.20	
		5/24/13	13.65	6.38	247	15.7	4.00			<0.20	<0.20	<0.20		<0.20	
		6/24/14											<0.20		Well abandoned during SR 522 construction
RMW-9R		12/19/14	15.31	6.16	182	15.7	2.92			**0.79**	<0.20	<0.20	<0.20	<0.20	
		6/23/15	4.00	5.93	139	18.7	4.20	70.40		<0.20	<0.20	<0.20	<0.20	<0.20	
		12/8/15	15.92	5.75	163	15.61	3.29	94.30		<0.2	<0.2	<0.2	<0.20	<0.2	
		6/29/16	15.31	6.53	132	15.91	11.2	94.90		<0.20	<0.20	<0.20	<0.20	<0.20	
		12/22/16	14.78	6.19	151	16	7.68	85.30		<0.20	<0.20	<0.20	<0.20	<0.20	
		6/29/17	13.55	6.06	0.103	16.75	7.95	122.10		<0.20	<0.20	<0.20	<0.20	<0.20	
		1/4/18	14.92	6.37	108	15.6	6.12	110.30		<0.20	<0.20	<0.20	<0.20	<0.20	
RMW-10	**32-42**	5/24/13	11.85	6.52	247	13.3	6.60			<0.20	<0.20	<0.20		<0.20	
		6/24/14	15.00	6.19	361	15.4	1.08			<0.20	<0.20	<0.20	<0.20	<0.20	
		12/19/14	14.80	6.08	284	15.0	2.03			**0.69**	<0.20	<0.20	<0.20	<0.20	
		6/23/15	20.40	6.43	233	17.3	7.28	37.00		<0.20	<0.20	<0.20	<0.20	<0.20	
		12/8/15	19.69	5.94	134	14.69	5.41	50.00		<0.2	<0.2	<0.2	<0.20	<0.2	
		6/29/16	13.6	6.68	166	15.83	8.35	29.20		<0.20	<0.20	<0.20	<0.20	<0.20	
		12/21/16	13.63	6.31	152.4	14.3	3.25	133.8		<0.20	<0.20	<0.20	<0.20	<0.20	
		6/28/17	14.05	6.6	207	15.4	2.83	112.6		<0.20	<0.20	<0.20	<0.20	<0.20	
		1/4/18	13.81	6.65	154	13.35	2.33	67.0		<0.20	<0.20	<0.20	<0.20	<0.20	
RMW-12	15-25	7/25/16	16.25	6.3	0.442	17.68	1.53	21.7		**120**	**19**	**14**	<1.0	<1.0	
		12/21/16	13.1	5.9	305	15	0.25	103.3		**61**	**14**	**21**	**0.34**	**1.6**	
		6/28/17	13.1	6.09	368	14.54	1.87	144.8		**130**	**27**	**29**	<1.0	<1.0	
		1/4/18	13.03	6.14	272	14.67	1.27	158.6		**21**	**4.7**	**8.8**	<0.20	**2.6**	
RMW-13	15-25	7/25/16	14.95	5.19	0.333	17.4	2.5	183.5		<0.20	<0.20	**1.8**	<0.20	**0.24**	
		12/22/16	16.61	6.36	351.4	16.0	0.16	-8.2		<0.20	<0.20	**1.2**	<0.20	<0.20	
		6/28/17	15.23	6.42	448.0	14.73	0.71	25.3		<0.20	<0.20	**0.5**	<0.20	<0.20	
		1/4/18	16.03	6.51	353.0	14.68	0.77	17.7		<0.20	<0.20	**1.4**	<0.20	<0.20	

Table 1
Bothell Riverside Site
Ground Water Analytical Results

			FIELD PARAMETERS							HVOCs					NOTES
Monitoring Well Identification	Screened Interval (ft bgs)	Date Sampled	Depth to Water (ft below MP)	pH (units)	Conductivity (µS)	Temp (^oC)	Dissolved Oxygen (mg/L)	Oxygen Reduction Potential (ORP)	Settable Solids (mg/L)	Tetrachloro-ethene (µg/L)	Trichloro-ethene (µg/L)	(cis) 1,2-Dichloro-ethene (µg/L)	(trans) 1,2-Dichloro-ethene (µg/L)	Vinyl chloride (µg/L)	
							Cleanup Levels*			**0.69**	**2.5**	**16 (B)**	**100 (B)**	**0.2**	
							KCIWD Limits		**7.00**	**240**	**500**	**Total <2000**		**12**	
BC-3	**15-25**	9/5/08								**110**	**120**	**46**		<1	
		5/24/13	12.95	6.55	342	15.1	4.00			**25**	**11**	**4**		<0.20	
		6/24/14	14.41	6.06	426	14.8	2.40			**11**	**4.0**	**0.75**	<0.20	<0.20	
		12/19/14	15.61	6.07	298	14.8	1.82			**7.7**	**2.1**	**0.44**	<0.20	<0.20	
		6/23/15	18.30	5.68	161	21.2	364.00	123.40		**3.8**	**0.9**	<0.20	<0.20	<0.20	
		12/8/15	15.3	5.59	248	15.17	6.05	120.80		**5.3**	**1.3**	**0.29**	<0.20	<0.20	
		6/29/16	16.95	5.9	167	15.84	6.97	52.20		**3.7**	**0.93**	<0.20	<0.20	<0.20	
		12/21/16	14.25	5.9	245.6	14.6	1.48	175.8		**5.9**	**1.5**	**0.57**	<0.20	<0.20	
		6/28/17	16.43	6.04	265	14.86	3.67	147.6		**6.8**	**1.9**	**0.8**	<0.20	<0.20	
		1/4/18	14.45	6.16	195	14.06	3.1	96.4		**8.9**	**2.0**	**0.59**	<0.20	<0.20	
EW-1	**12.5-32.5**	4/4/14	27.90							**17**	**3**	**1.2**		<0.20	
		6/25/14	14.78	6.61	0.10	18.3	5.68			**27**	**8.1**	**6.5**	<0.20	<0.20	
		9/22/14													Pump not working
		12/19/14		6.42	107	17.3	4.99			**21**	**2.6**	**0.82**	<0.20	<0.20	
		3/18/15		7.01	167	15.9	3.65			**2.8**	**0.27**	<0.20	<0.20	<0.20	
		6/23/15								**22**	**2**	**0.95**	<0.20	<0.20	
		9/11/15	15.86	6.01	160	19.54	2.99	-49.88		**41**	**2.2**	**0.79**	<0.20	<0.20	
		12/8/15													Pump not working
		3/31/16		6,27	227	15.94	6.55	80.2		**22**	**2.8**	**2.5**	<0.20	<0.20	
		6/29/16		6.37	192	16.7	8.1	47.5		**24**	**4.2**	**4.5**	<0.20	<0.20	
		9/30/16		5.63	193	14.21	4.1	90.1		**20**	**2.0**	**2.3**	<0.20	<0.20	
		1/5/17		6.64	315	12.05	4.6	47.3		**1.1**	<0.20	<0.20	<0.20	<0.20	
		4/5/17		5.89	368.2	15.9	2.34	136		**13**	**1.2**	**0.85**	<0.20	<0.20	
		6/29/17		6.44	192	18.11	3.17	128.3		**8.9**	**0.77**	**0.7**	<0.20	<0.20	
		10/10/17		6.49	226	15.28	7.34	298.8		**15**	**0.81**	**0.5**	<0.20	<0.20	
		1/4/18		6.56	199	13.65	2.58	120.4		**34**	**5.7**	**2**	<0.20	<0.20	
EW-2	**15-35**	4/4/14	23.70							**13**	**2.8**	**1.5**		<0.20	
		6/25/14	17.10	6.58	143	16.5	2.21			**28**	**3.8**	**1.5**	<0.20	<0.20	
		9/22/14								**66**	**16**	**12**	<0.40	<0.40	
		12/19/14		7.01	204	15.8	2.31			**44**	**12**	**12**	<0.40	<0.40	
		3/18/15		6.87	251	15.0	2.16			**22**	**6.5**	**4.3**	<0.20	<0.20	
		6/23/15								**8.6**	**2.4**	**1.8**	<0.20	<0.20	
		9/11/15	19.89	6.11	235	19.9	2.84	-56.8		**6.5**	**0.62**	<0.20	<0.20	<0.20	
		12/8/15		5.92	201	15.12	2.43	595.1		**16**	**2.6**	**2.4**	<0.20	<0.20	
		3/31/16		5.75	218	15,21	8.58	129.9		**16**	**4.0**	**3.7**	<0.20	<0.20	
		6/29/16		6.46	185	15.75	6.85	48.3		**17**	**4.1**	**3.2**	<0.20	<0.20	
		9/30/16		5.94	191	14.24	3.97	73.9		**21**	**6.2**	**5.6**	<0.20	<0.20	
		1/5/17		6.67	192	12.08	3.8	31.3		**24**	**3.6**	**1.7**	<0.20	<0.20	
		4/5/17		6.38	258.7	16.2	5.08	123.4		**11**	**3.2**	**2.2**	<0.20	<0.20	
		6/29/17		6.51	185	19.5	2.5	125.6		**16**	**4.8**	**3.6**	<0.20	<0.20	
		10/10/17		6.73	215	16.35	6.2	300.9		**3.0**	**0.45**	**0.23**	<0.20	<0.20	
		1/4/18		6.5	190	13.05	2	130.6		**1.5**	**0.32**	<0.20	<0.20	<0.20	

Table 1
Bothell Riverside Site
Ground Water Analytical Results

			FIELD PARAMETERS							HVOCs					NOTES
Monitoring Well Identification	Screened Interval (ft bgs)	Date Sampled	Depth to Water (ft below MP)	pH (units)	Conductivity (µS)	Temp (^oC)	Dissolved Oxygen (mg/L)	Oxygen Reduction Potential (ORP)	Settable Solids (mg/L)	Tetrachloro-ethene (µg/L)	Trichloro-ethene (µg/L)	(cis) 1,2-Dichloro-ethene (µg/L)	(trans) 1,2-Dichloro-ethene (µg/L)	Vinyl chloride (µg/L)	
							Cleanup Levels*			**0.69**	**2.5**	**16 (B)**	**100 (B)**	**0.2**	
							KCIWD Limits		**7.00**	**240**	**500**	**Total <2000**		**12**	
EW-3	**14-34**	4/4/14	23.80							**49**	**14**	**7.2**		**0.61**	
		6/25/14	19.00	6.58	182	16.4	6.34			**41**	**14**	**12**	<0.40	<0.40	
		9/22/14								**190**	**59**	**33**	<1.0	**1.10**	
		12/19/14		6.82	275	15.9	6.02			**21**	**6.4**	**6**	<0.20	<0.20	
		3/18/15		6.78	322	15.4	5.47			**140**	**46**	**29**	<1.0	<1.0	
		6/23/15								**87**	**24**	**9**			
		9/11/15	20.86	6.56	354	19.89	2.53	-65.78		**81**	**28**	**14**	<0.40	<0.40	
		12/8/15		5.82	247	16.59	2.36	160		**33**	**11**	**7.8**	<0.20	**0.38**	
		3/31/16		6.20	358	19.57	2.28	87.5		**72**	**21**	**16**	<0.20	**0.64**	
		6/29/16		6.28	304	19.37	6.51	45.9		**79**	**24**	**14**	<0.40	**0.43**	
		9/30/16		5.84	386	18.59	1.11	51.7		**50**	**18**	**10**	<0.20	**0.63**	
		1/5/17		6.37	319	13.32	2.6	27.5		**95**	**30**	**20**	<0.40	**0.46**	
		4/5/17		5.99	434.8	18.7	1.21	105.6		**150**	**57**	**30**	<1.0	**1.3**	
		6/29/17		6.27	330	26.59	2.65	133		**270**	**79**	**59**	<1.0	**1.4**	
		10/10/17		6.38	305	18.4	6.17	221.5		**69**	**25**	**16**	<0.40	**0.41**	
		1/4/18		6.40	256	15.01	2.33	135		**150**	**57**	**35**	**0.47**	**1.7**	
EW-4	**11-31**	4/4/14	12.50												Pump not working
		6/25/14	17.30	6.46	0.22	16.0	1.73			**1.7**	**1.8**	**1.1**	<0.20	**0.38**	
		9/22/14								**45**	**10**	**7.4**	<0.20	**0.87**	
		12/19/14		6.68	105	16.6	1.99			**1.2**	**1.6**	**1.1**	<0.20	**0.27**	
		3/18/15								**15**	**4.8**	**3.2**	<0.20	<0.20	
		6/23/15								**0.85**	**2.8**	**1.7**	<0.20	**0.37**	
		9/11/15	18.84	6.23	125	19.22	2.55	-65.32		**1.8**	**2.1**	**0.92**	<0.20	**0.28**	
		12/8/15		5.84	424	22.04	0	214		<0.20	**1.6**	**2.9**	<0.20	**0.85**	
		3/31/16		6.61	354	15.91	1.47	2.0		<0.20	**2.5**	**2.0**	<0.20	**0.31**	
		6/29/16		6.54	344	19.19	6.99	33.0		<0.20	**1.2**	**3.5**	<0.20	**0.61**	
		9/30/16		8.14	373	17.05	0.95	12.0		<0.20	**0.88**	**4.0**	<0.20	**0.75**	
		1/5/17		6.67	325	12.21	1.8	-67.9		**0.33**	**3.2**	**1.8**	<0.20	**0.29**	
		4/5/17		6.37	409.2	15.9	0.82	-12.2		**0.2**	**3**	**1.7**	<0.20	**0.25**	
		6/29/17		6.73	343	19.88	1.12	-47.6		<0.20	**0.9**	**2.6**	<0.20	**0.24**	
		10/10/17													Pump not working
		1/4/18		6.75	298	14.55	3.5	-35.6		<0.20	<0.20	**2.3**	<0.20	**0.5**	
EW-5	**15-35**	1/5/17		6.61	270	12.71	1.29	-45.1		**5.0**	**4.0**	**9.4**	<0.20	**2.5**	
		4/5/17		6.27	511.9	14.8	1.22	23.9		**6.9**	**5.2**	**15.0**	**0.28**	**3.8**	
		6/29/17		6.58	239	18.98	4.41	66.7		**8.6**	**3.8**	**10**	<0.20	**0.49**	
		10/10/17		6.58	350	18.81	2.65	262.6		**0.36**	**0.94**	**8.6**	<0.20	**1.8**	
		1/4/18		6.78	312	14.15	3.55	35.6		**0.71**	**1.1**	**10**	**0.21**	**3.3**	

Table 1
Bothell Riverside Site
Ground Water Analytical Results

			FIELD PARAMETERS							HVOCs					NOTES
Monitoring Well Identification	Screened Interval (ft bgs)	Date Sampled	Depth to Water (ft below MP)	pH (units)	Conductivity (µS)	Temp (^{o}C)	Dissolved Oxygen (mg/L)	Oxygen Reduction Potential (ORP)	Settable Solids (mg/L)	Tetrachloro-ethene (µg/L)	Trichloro-ethene (µg/L)	(cis) 1,2-Dichloro-ethene (µg/L)	(trans) 1,2-Dichloro-ethene (µg/L)	Vinyl chloride (µg/L)	
							Cleanup Levels*			**0.69**	**2.5**	**16 (B)**	**100 (B)**	**0.2**	
							KCIWD Limits		**7.00**	**240**	**500**	**Total <2000**		**12**	
EW-6	**15-35**	1/5/17		6.62	166	4.13	5.65	-17.8		**2.4**	**0.54**	<0.20	<0.20	<0.20	
		4/5/17		6.2	252.7	15.2	2.47	60.2		**2.1**	**0.94**	**1.2**	<0.20	<0.20	
		6/29/17		6.67	280	20.23	4.05	29.5		**0.56**	**0.63**	**2.0**	<0.20	**0.31**	
		10/10/17		6.56	274	17.42	2.68	289.3		**20**	**7.2**	**18**	**0.2**	**0.46**	
		1/4/18		6.5	350	14.11	3.56	78.1		**41**	**17**	**14**	**0.24**	**2.2**	
DISCH	**NA**	4/4/14	NA	6.48	443	15.3				**25**	**6.3**	**3**	<0.20	<0.20	
		6/25/14	NA	6.40	200	16.4	1.43		0.0	**30**	**8.4**	**5.9**	<0.20	**0.38**	
		9/22/14	NA						0.2	**79**	**18**	**13**	<0.40	<0.40	
		12/18/14	NA							**11**	**2.7**	**2.5**	<0.20	<0.20	
		3/18/15	NA	6.54	230	15.1	1.89		0.1	**25**	**7.4**	**4.7**	<0.20	<0.20	
		6/23/15	NA							**11**	**2.3**	**1.5**	<0.20	<0.20	
		9/11/15	NA	6.23	245	20.55	2.68	-65.3	0	**7.9**	**1.5**	**0.77**	<0.20	<0.20	
		12/8/15	NA	6.15	267	17.2	3.9	18		**68**	**21**	**15**	**0.23**	**0.91**	
		3/31/16	NA	6.57	261	16.26	6.78	50.6		**21**	**5.5**	**4.4**	<0.20	<0.20	
		6/29/16	NA	6.71	214	16.83	6.14	13.7		**24**	**5.7**	**4.6**	<0.20	<0.20	
		9/30/16	NA	6.39	219	14.52	2.9	20.6		**16**	**4.4**	**3.6**	<0.20	**0.22**	
		1/5/17	NA							**27**	**8.6**	**5.3**	<0.20	**0.23**	
		4/5/17	NA							**5.4**	**2.3**	**2.4**	<0.20	**0.32**	
		6/29/17	NA	6.49	235	19.32	2.9	57.6		**15**	**4.6**	**6.5**	<0.20	**0.3**	
		10/10/17	NA	6.52	260	16.75	2.25	302.6		**11**	**3.3**	**6.8**	<0.20	**0.21**	
		1/4/18	NA	6.58	305	13.58	2.95	60.3		**5.7**	**0.47**	**0.4**	<0.20	<0.20	
QC Samples			**FIELD PARAMETERS**							**HVOCs**					**NOTES**
DUP 6/25/14		6/25/14								**28**	**8.4**	**6.4**	<0.20	**0.37**	Duplicate of DISCH 6/25/14
DUP 12/19/14		12/19/14								**0.92**	<0.20	<0.20	<0.20	<0.20	Duplicate of RMW-8 12/19/2014
Trip Blank		6/25/14								<0.20	<0.20	<0.20	<0.20	<0.20	
DUP 9/22/14		9/22/14								**66**	**16**	<0.40	<0.40	<0.40	Duplicate of EX2 9/22/2014
Trip Blank		3/18/15								<0.20	<0.20	<0.20	<0.20	<0.20	
DUP		3/18/15								<0.40	**1.0**	**54**	**0.65**	**19**	Duplicate of RMW-7 3/18/2015
Trip Blank		9/11/15								<0.20	<0.20	<0.20	<0.20	<0.20	
DUP		9/11/15								**23**	1.7	**0.62**	<0.20	<0.20	
Trip Blank		12/8/15								<0.2	<0.2	<0.2	<0.20	<0.2	
DUP		12/8/15								**2.8**	**0.6**	<0.2	<0.2	<0.2	Duplicate of RMW-4 12/8/15
Trip Blank		12/22/16								<0.20	<0.20	<0.20	<0.20	<0.20	
DUP		12/22/16								<0.20	<0.20	**1.2**	<0.20	<0.20	
Trip Blank		6/28/17								<0.20	<0.20	<0.20	<0.20	<0.20	
DUP		6/28/17								**1.2**	**2**	**35**	**0.53**	**1.8**	Duplicate of RMW-7 6/28/17
Trip Blank		10/10/17								<0.20	<0.20	<0.20	<0.20	<0.20	
DUP		10/10/17								**2.6**	**0.37**	**0.22**	<0.20	<0.20	Duplicate of EW-2 10/10/17
Trip Blank															
DUP		1/4/18								**1.2**	**4.7**	**51**	**0.66**	**20**	Duplicate of RMW-7 1/4/18

Table 1
Bothell Riverside Site
Ground Water Analytical Results

			FIELD PARAMETERS							HVOCs					NOTES
Monitoring Well Identification	Screened Interval (ft bgs)	Date Sampled	Depth to Water (ft below MP)	pH (units)	Conductivity (µS)	Temp (^{o}C)	Dissolved Oxygen (mg/L)	Oxygen Reduction Potential (ORP)	Settable Solids (mg/L)	Tetrachloro-ethene (µg/L)	Trichloro-ethene (µg/L)	(cis) 1,2-Dichloro-ethene (µg/L)	(trans) 1,2-Dichloro-ethene (µg/L)	Vinyl chloride (µg/L)	
Cleanup Levels*										**0.69**	**2.5**	**16 (B)**	**100 (B)**	**0.2**	
KCIWD Limits									**7.00**	**240**	**500**	**Total <2000**		**12**	

Bold indicates analyte detected at a concentration greater than the laboratory reporing limit

Yellow highlight indicates analyte exceeds MTCA cleanup level

*Cleanup Levels:

Tetrachloroethene: Surface Water Applicable or Relevant and Appropriate Requirements (ARARs)- Human Health - Fresh Water - Clean Water Act § 304

Trichloroethene: Surface Water ARARs- Human Health - Fresh Water - Clean Water Act § 304

1,1- Dichloroethene:

(cis) 1,2- Dichloroethene: Ground Water, Method B, Non-carcinogen, Standard Formula Value

(trans) 1,2- Dichloroethene: Ground Water ARAR - State Primary Maximum Contaminant Level

Vinyl chloride: Practical Quantitation Limits / Reporting Limits Achievable by Local Accredited Labs

KCIWD = King County Industrial Waste Discharge limit

Blank – Not analyzed

NA – Not applicable

TABLE 2
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

ARAR	Applicability
Soil	
Model Toxics Control Act (WAC 173-340-740, -747)	MTCA cleanup levels are applicable to Site soil.
Groundwater	
Model Toxics Control Act (WAC 173-340-720)	MTCA cleanup levels are applicable to Site groundwater.
Surface Water	
Model Toxics Control Act (WAC 173-340-730)	MTCA cleanup levels are applicable to the Site if remedial activities cause a release to surface water.
Air	
Washington Clean Air Act and Implementing Regulations (WAC 173-400; WAC 173-460; WAC 173-490)	Applicable for excavation activities.
Model Toxics Control Act (WAC 173-340-750)	MTCA cleanup levels are applicable to the Site if remedial activities cause a release to air.
Miscellaneous	
Protection of Wetlands, Executive Order 11990 (40 CFR Part 6, Appendix A)	This Act would be potentially applicable to remedial activities at the Site.
Native American Graves Protection and Repatriation Act (43 CFR Part 10)	This Act is 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 subsurface excavations at the Site. Such materials are not known to be present at the Site, but could be inadvertently uncovered during soil removal.
National Historic Preservation Act (36 CFR Parts 60, 63, and 800)	This Act is applicable to subsurface work at the Site. No such Sites are known to be present in the area.
Washington Hazardous Waste Management Act (WAC 173-303)	This regulation is applicable to handling of contaminated media at the Site. The contamination policy allows contaminated media to be consolidated within the same area of a site without triggering Resource Conservation and Recovery Act or Washington dangerous waste regulations.
Department of Transportation of Hazardous Wastes (49 CFR 105 – 180)	Applicable to remedial activities that involve the off-site transportation of hazardous waste.
Washington Solid Waste Handling Standards (WAC 173-350)	These regulations are applicable to solid nonhazardous wastes and are relevant and appropriate to on-site remedial actions governing contaminated media management.
Washington Water Well Construction Act Regulations (WAC 173-160)	These regulations are applicable to the installation, operation, or closure of monitoring and treatment wells at the Site.

Table 3
Site Cleanup Level Summary (µg/L)

	PCE	TCE	1,2-DCE (mixed isomers)	cis-1,2-DCE	trans-1,2-DCE	VC
Ground Water Standards						
Ground Water ARAR - State Primary Maximum Contaminant Level (MCL)	5	5	NR	70	**100**	2
Ground Water, Method A, Table Value	5	5	RND	RND	RND	0.2
Ground Water, Method B, Carcinogen, Standard Formula Value	5*	4*	NR	NR	NR	**
Ground Water, Method B, Non-carcinogen, Standard Formula Value	80	**	**72**	**16**	160	24
Surface Water Standards						
Surface Water, Method B, Carcinogen, Standard Formula Value	**	6.7	NR	NR	NR	0.025
Surface Water, Method B, Non-Carcinogen, Standard Formula Value	840	**	NR	NR	33000	6.60E+03
Surface Water ARAR - Aquatic Life - Fresh/Acute - Ch. 173-201A WAC	NR	NR	NR	NR	NR	NR
Surface Water ARAR - Aquatic Life - Fresh/Chronic - Ch. 173-201A WAC	NR	NR	NR	NR	NR	NR
Surface Water ARAR - Aquatic Life - Fresh/Chronic - Clean Water Act §304	NR	NR	NR	NR	NR	NR
Surface Water ARAR - Human Health - Fresh Water - Clean Water Act §304	**0.69**	**2.50**	NR	NR	140000	0.03
Surface Water ARAR - Aquatic Life - Fresh/Acute - Clean Water Act §304	NR	NR	NR	NR	NR	NR
Surface Water ARAR - Human Health - Fresh Water - National Toxics Rule, 40 CFR 131	0.80	2.70	NR	NR	RND	2.00
Surface Water ARAR - Aquatic Life - Fresh/Acute - National Toxics Rule - 40 CFR 131	NR	NR	NR	NR	NR	NR
Surface Water ARAR - Aquatic Life - Fresh/Chronic - National Toxics Rule, 40 CFR 131	NR	NR	NR	NR	NR	NR
PQL / RL achievable by local accredited labs	0.2	0.2	0.2	0.2	0.2	**0.2**

NR – Not researched

RND – Researched-No Data

* Per Sunny Becker at Ecology

** See additional information per CLARC

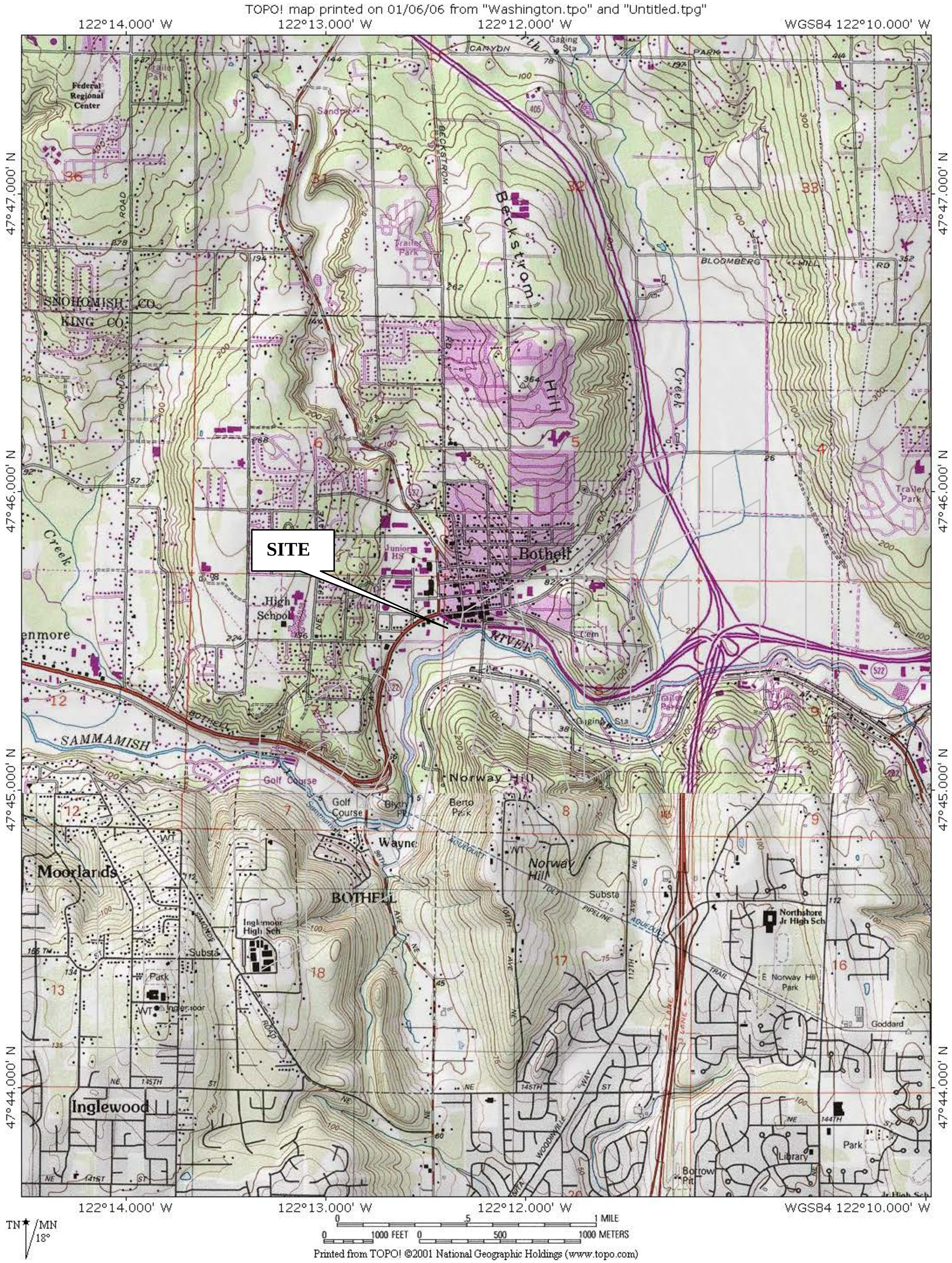
Highlighted – lowest value

Bold Highlighted – selected value

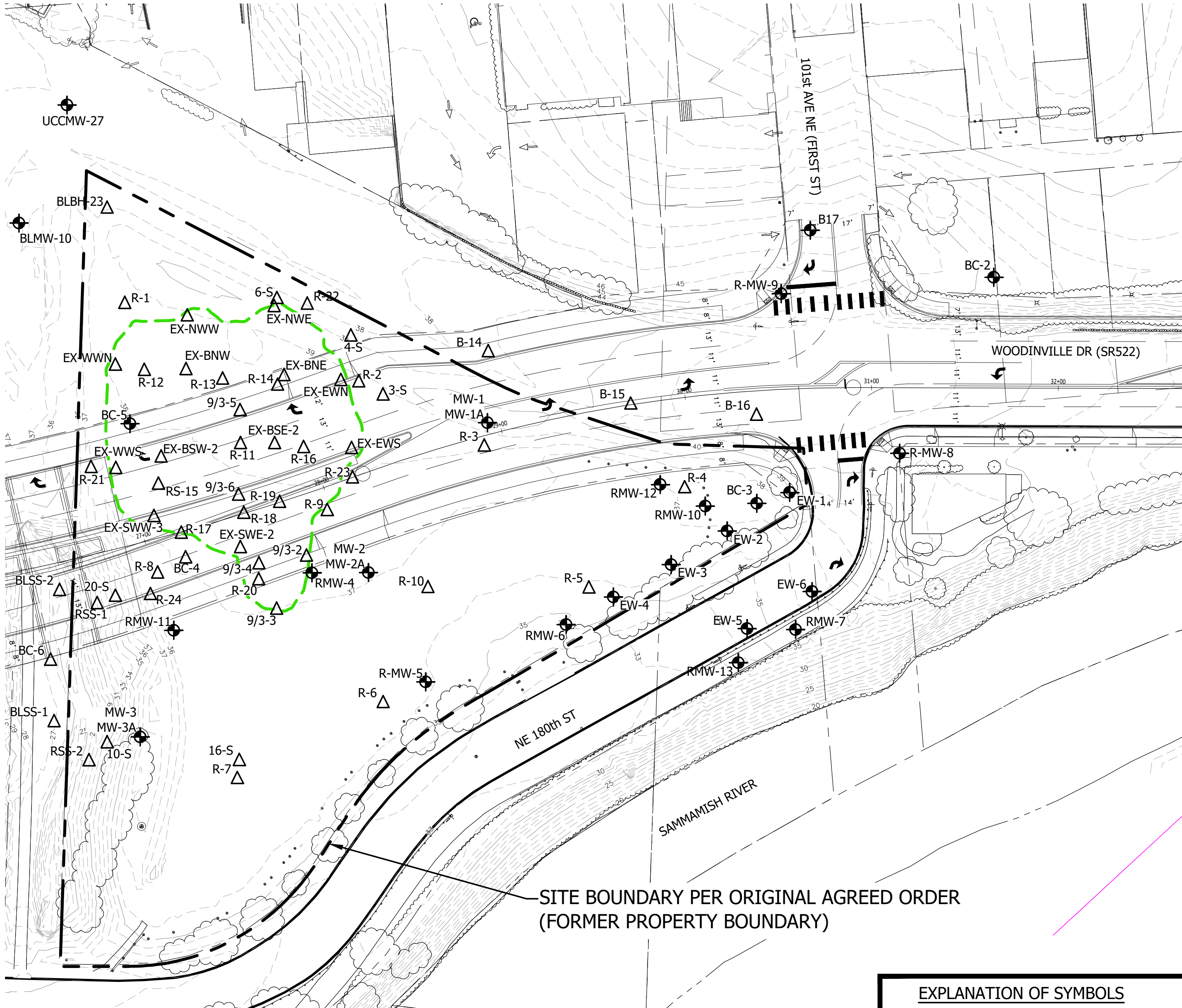
PQL – practical quantitation limit

Table 4
Cleanup Alternatives Evaluation

	Air sparging with soil vapor extraction	Pump and discharge to sanitary sewer	Pump, treat with air stripping, discharge to storm/surface water
Threshold requirements			
Protect human health and the environment	These three alternatives would reduce HVOC discharge to the river		
Comply with cleanup standards	Not as certain	Yes	Yes
Complies with applicable state and federal laws	All alternatives would comply with applicable state and federal laws		
Provide for compliance monitoring	All alternatives would include ground water monitoring		
Other requirements			
Use permanent solutions to maximum extent practicable	HVOCs discharged to air, not destroyed	Some HVOCs treated at waste water treatment plant, some volatilized to air	HVOCs discharged to air, not destroyed
Provide for a reasonable restoration time frame	These three alternatives would have similar restoration timeframes.		
Consider public concerns	Possible concern for off-gas	Limited potential public concerns	Possible concern for off-gas

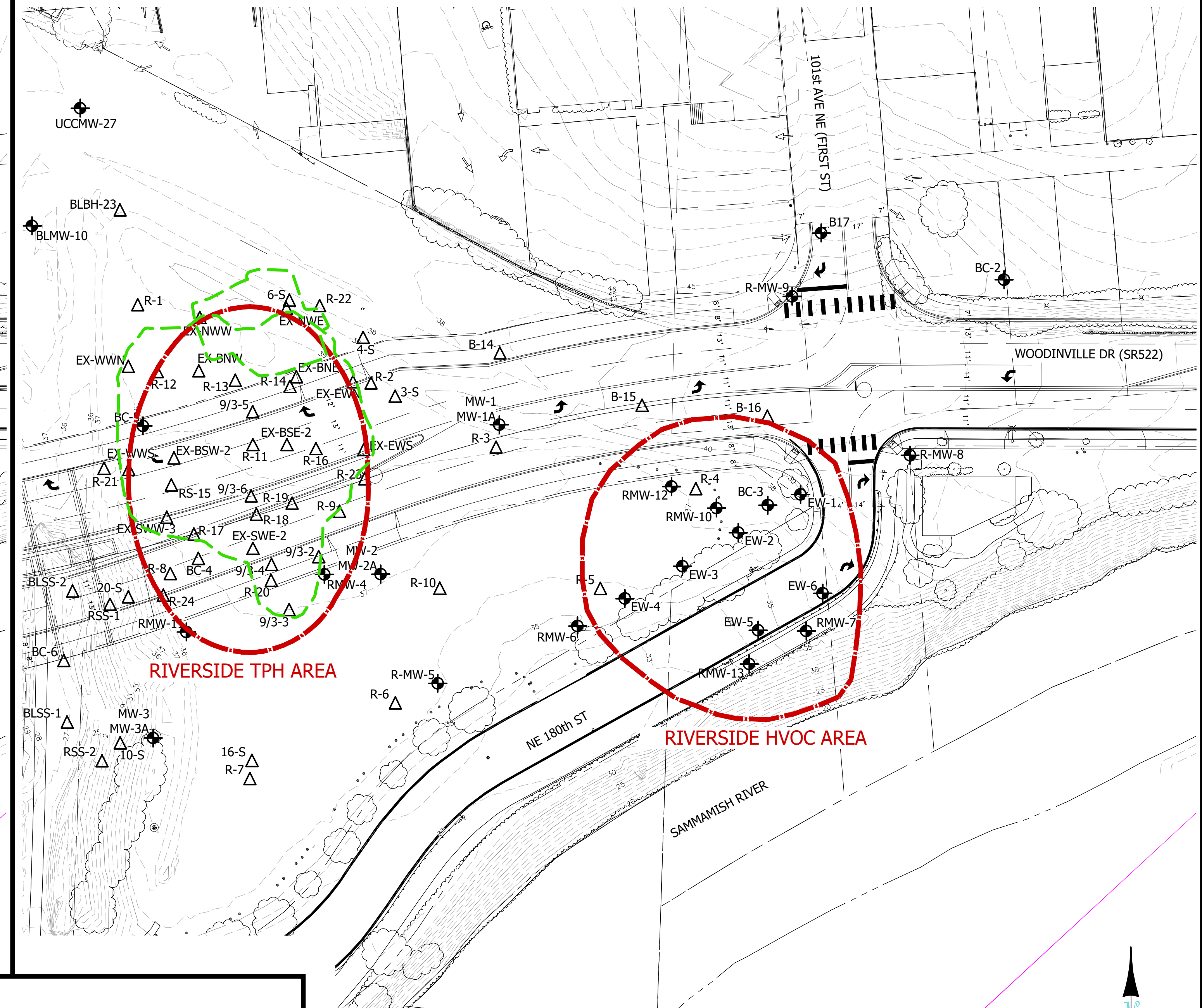


	SITE VICINITY	FIGURE NO. 1
HWA GEOSCIENCES INC.	BOTHELL RIVERSIDE HVOC AREA BOTHELL, WASHINGTON	PROJECT NO. 2007-098



ORIGINAL SITE BOUNDARIES

(AS DEPICTED IN THE AGREED ORDER)



FINIAL SITE BOUNDARIES

(AS DEFINED IN THE RI REPORT)

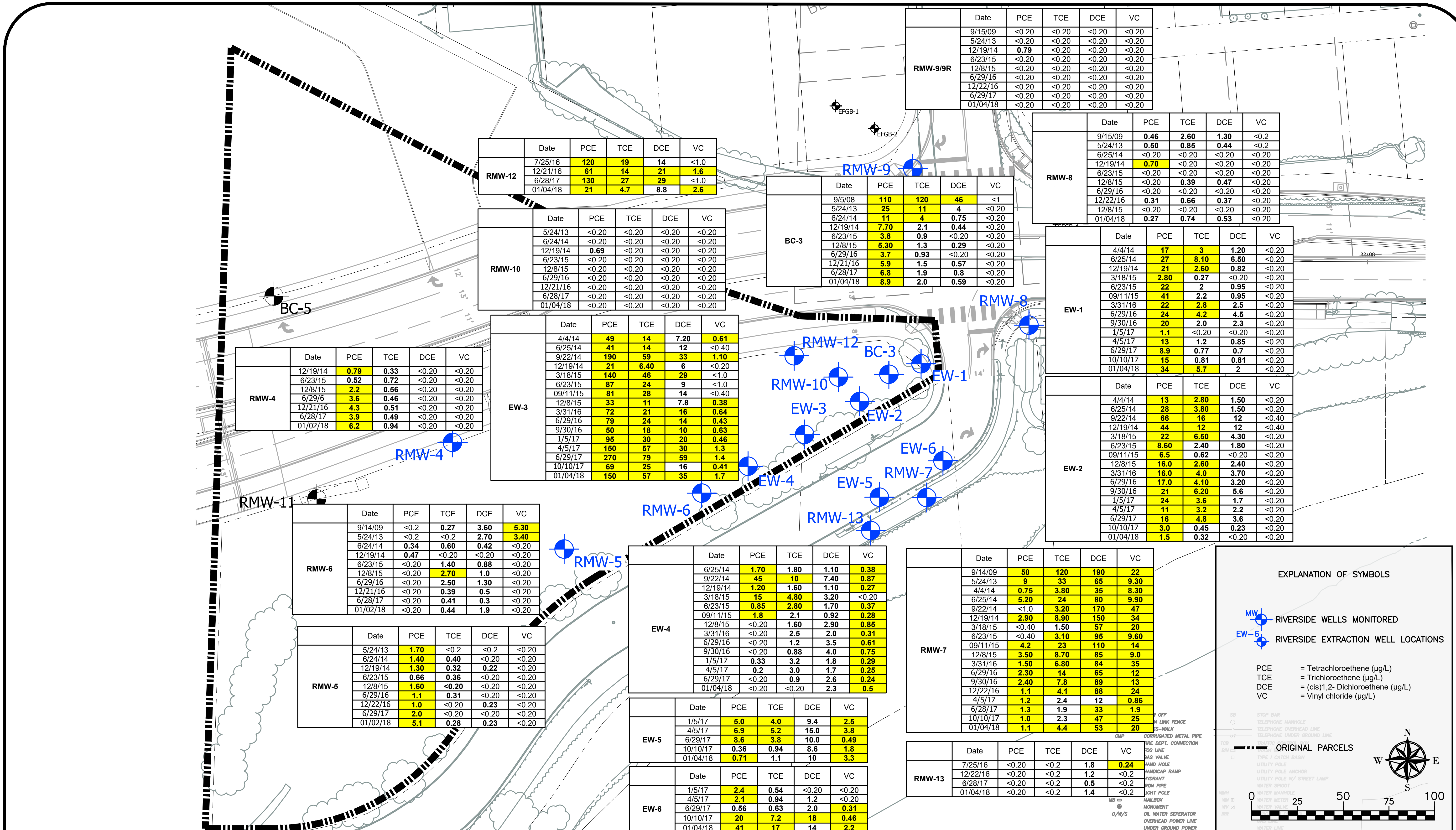
EXPLANATION OF SYMBOLS

- APPROXIMATE EXTENT OF 2010-2017 CLEANUP EXCAVATION
- APPROXIMATE PROPERTY BOUNDARY
- SITE BOUNDARY
- R-8 SOIL BORING OR TEST PIT LOCATIONS
- R-MW-10 MONITORING WELL LOCATIONS

0' 30' 60' 120'
SCALE: 1"=60'

HWA GEOSCIENCES INC.	BOTHELL RIVERSIDE HVOC AREA BOTHELL, WASHINGTON	SITE BOUNDARIES	DRAWN BY BFM CHECK BY AS DATE 09.23.15	FIGURE NO. 2 PROJECT NO. 2007-098 T2018

S:\2007-098 BOTHELL CROSSROADS\CAD 2007-098\12.15.2017\HWA 2007-098-21 T2018 (FIG 3A).DWG <Riverside HVOC Fig 3A> Plotted: 2/2/2018 6:59 AM



RMW-9/9R	Date	PCE	TCE	DCE	VC
	9/15/09	<0.20	<0.20	<0.20	<0.20
	5/24/13	<0.20	<0.20	<0.20	<0.20
	12/19/14	0.79	<0.20	<0.20	<0.20
	6/23/15	<0.20	<0.20	<0.20	<0.20
	12/8/15	<0.20	<0.20	<0.20	<0.20
	6/29/16	<0.20	<0.20	<0.20	<0.20
	12/22/16	<0.20	<0.20	<0.20	<0.20
	6/29/17	<0.20	<0.20	<0.20	<0.20
	01/04/18	<0.20	<0.20	<0.20	<0.20

RMW-8	Date	PCE	TCE	DCE	VC
	9/15/09	0.46	2.60	1.30	<0.2
	5/24/13	0.50	0.85	0.44	<0.2
	6/25/14	<0.20	<0.20	<0.20	<0.20
	12/19/14	0.70	<0.20	<0.20	<0.20
	6/23/15	<0.20	<0.20	<0.20	<0.20
	12/8/15	<0.20	0.39	0.47	<0.20
	6/29/16	<0.20	<0.20	<0.20	<0.20
	12/22/16	0.31	0.66	0.37	<0.20
	12/8/15	<0.20	<0.20	<0.20	<0.20
	01/04/18	0.27	0.74	0.53	<0.20

RMW-12	Date	PCE	TCE	DCE	VC
	7/25/16	120	19	14	<1.0
	12/21/16	61	14	21	1.6
	6/28/17	130	27	29	<1.0
	01/04/18	21	4.7	8.8	2.6

BC-3	Date	PCE	TCE	DCE	VC
	9/5/08	110	120	46	<1
	5/24/13	25	11	4	<0.20
	6/24/14	11	4	0.75	<0.20
	12/19/14	7.70	2.1	0.44	<0.20
	6/23/15	3.8	0.9	<0.20	<0.20
	12/8/15	5.30	1.3	0.29	<0.20
	6/29/16	3.7	0.93	<0.20	<0.20
	12/21/16	5.9	1.5	0.57	<0.20
	6/28/17	6.8	1.9	0.8	<0.20
	01/04/18	8.9	2.0	0.59	<0.20

RMW-10	Date	PCE	TCE	DCE	VC
	5/24/13	<0.20	<0.20	<0.20	<0.20
	6/24/14	<0.20	<0.20	<0.20	<0.20
	12/19/14	0.69	<0.20	<0.20	<0.20
	6/23/15	<0.20	<0.20	<0.20	<0.20
	12/8/15	<0.20	<0.20	<0.20	<0.20
	6/29/16	<0.20	<0.20	<0.20	<0.20
	12/21/16	<0.20	<0.20	<0.20	<0.20
	6/28/17	<0.20	<0.20	<0.20	<0.20
	01/04/18	<0.20	<0.20	<0.20	<0.20

EW-1	Date	PCE	TCE	DCE	VC
	4/4/14	17	3	1.20	<0.20
	6/25/14	27	8.10	6.50	<0.20
	12/19/14	21	2.60	0.82	<0.20
	3/18/15	2.80	0.27	<0.20	<0.20
	6/23/15	22	2	0.95	<0.20
	09/11/15	41	2.2	0.95	<0.20
	3/31/16	22	2.8	2.5	<0.20
	6/29/16	24	4.2	4.5	<0.20
	9/30/16	20	2.0	2.3	<0.20
	1/5/17	1.1	<0.20	<0.20	<0.20
	4/5/17	13	1.2	0.85	<0.20
	6/29/17	8.9	0.77	0.7	<0.20
	10/10/17	15	0.81	0.81	<0.20
	01/04/18	34	5.7	2	<0.20

RMW-4	Date	PCE	TCE	DCE	VC
	12/19/14	0.79	0.33	<0.20	<0.20
	6/23/15	0.52	0.72	<0.20	<0.20
	12/8/15	2.2	0.56	<0.20	<0.20
	6/29/6	3.6	0.46	<0.20	<0.20
	12/21/16	4.3	0.51	<0.20	<0.20
	6/28/17	3.9	0.49	<0.20	<0.20
	01/02/18	6.2	0.94	<0.20	<0.20

EW-3	Date	PCE	TCE	DCE	VC
	4/4/14	49	14	7.20	0.61
	6/25/14	41	14	12	<0.40
	9/22/14	190	59	33	1.10
	12/19/14	21	6.40	6	<0.20
	3/18/15	140	46	29	<1.0
	6/23/15	87	24	9	<1.0
	09/11/15	81	28	14	<0.40
	12/8/15	33	11	7.8	0.38
	3/31/16	72	21	16	0.64
	6/29/16	79	24	14	0.43
	9/30/16	50	18	10	0.63
	1/5/17	95	30	20	0.46
	4/5/17	150	57	30	1.3
	6/29/17	270	79	59	1.4
	10/10/17	69	25	16	0.41
	01/04/18	150	57	35	1.7

EW-2	Date	PCE	TCE	DCE	VC
	4/4/14	13	2.80	1.50	<0.20
	6/25/14	28	3.80	1.50	<0.20
	9/22/14	66	16	12	<0.40
	12/19/14	44	12	12	<0.40
	3/18/15	22	6.50	4.30	<0.20
	6/23/15	8.60	2.40	1.80	<0.20
	09/11/15	6.5	0.62	<0.20	<0.20
	12/8/15	16.0	2.60	2.40	<0.20
	3/31/16	16.0	4.0	3.70	<0.20
	6/29/16	17.0	4.10	3.20	<0.20
	9/30/16	21	6.20	5.6	<0.20
	1/5/17	24	3.6	1.7	<0.20
	4/5/17	11	3.2	2.2	<0.20
	6/29/17	16	4.8	3.6	<0.20
	10/10/17	3.0	0.45	0.23	<0.20
	01/04/18	1.5	0.32	<0.20	<0.20

RMW-6	Date	PCE	TCE	DCE	VC
	9/14/09	<0.2	0.27	3.60	5.30
	5/24/13	<0.2	<0.2	2.70	3.40
	6/24/14	0.34	0.60	0.42	<0.20
	12/19/14	0.47	<0.20	<0.20	<0.20
	6/23/15	<0.20	1.40	0.88	<0.20
	12/8/15	<0.20	2.70	1.0	<0.20
	6/29/16	<0.20	2.50	1.30	<0.20
	12/21/16	<0.20	0.39	0.5	<0.20
	6/28/17	<0.20	0.41	0.3	<0.20
	01/02/18	<0.20	0.44	1.9	<0.20

EW-4	Date	PCE	TCE	DCE	VC
	6/25/14	1.70	1.80	1.10	0.38
	9/22/14	45	10	7.40	0.87
	12/19/14	1.20	1.60	1.10	0.27
	3/18/15	15	4.80	3.20	<0.20
	6/23/15	0.85	2.80	1.70	0.37
	09/11/15	1.8	2.1	0.92	0.28
	12/8/15	<0.20	1.60	2.90	0.85
	3/31/16	<0.20	2.5	2.0	0.31
	6/29/16	<0.20	1.2	3.5	0.61
	9/30/16	<0.20	0.88	4.0	0.75
	1/5/17	0.33	3.2	1.8	0.29
	4/5/17	0.2	3.0	1.7	0.25
	6/29/17	<0.20	0.9	2.6	0.24
	01/04/18	<0.20	<0.20	2.3	0.5

RMW-7	Date	PCE	TCE	DCE	VC
	9/14/09	50	120	190	22
	5/24/13	9	33	65	9.30
	4/4/14	0.75	3.80	35	8.30
	6/25/14	5.20	24	80	9.90
	9/22/14	<1.0	3.20	170	47
	12/19/14	2.90	8.90	150	34
	3/18/15	<0.40	1.50	57	20
	6/23/15	<0.40	3.10	95	9.60
	09/11/15	4.2	23	110	14
	12/8/15	3.50	8.70	85	9.0
	3/31/16	1.50	6.80	84	35
	6/29/16	2.30	14	65	12
	9/30/16	2.40	7.8	89	13
	12/22/16	1.1	4.1	88	24
	4/5/17	1.2	2.4	12	0.86
	6/28/17	1.3	1.9	33	1.9
	10/10/17	1.0	2.3	47	25
	01/04/18	1.1	4.4	53	20

RMW-5	Date	PCE	TCE	DCE	VC
	5/24/13	1.70	<0.2	<0.2	<0.20
	6/24/14	1.40	0.40	<0.20	<0.20
	12/19/14	1.30	0.32	0.22	<0.20
	6/23/15	0.66	0.36	<0.20	<0.20
	12/8/15	1.60	<0.20	<0.20	<0.20
	6/29/16	1.1	0.31	<0.20	<0.20
	12/22/16	1.0	<0.20	0.23	<0.20
	6/29/17	2.0	<0.20	<0.20	<0.20
	01/02/18	5.1	0.28	0.23	<0.20

EW-5	Date	PCE	TCE	DCE	VC
	1/5/17	5.0	4.0	9.4	2.5
	4/5/17	6.9	5.2	15.0	3.8
	6/29/17	8.6	3.8	10.0	0.49
	10/10/17	0.36	0.94	8.6	1.8
	01/04/18	0.71	1.1	10	3.3

RMW-13	Date	PCE	TCE	DCE	VC
	7/25/16	<0.20	<0.2	1.8	0.24
	12/22/16	<0.20	<0.2	1.2	<0.2
	6/28/17	<0.20	<0.2	0.5	<0.2
	01/04/18	<0.20	<0.2	1.4	<0.2

EW-6	Date	PCE	TCE	DCE	VC
	1/5/17	2.4	0.54	<0.20	<0.20
	4/5/17	2.1	0.94	1.2	<0.20
	6/29/17	0.56	0.63	2.0	0.31
	10/10/17	20	7.2	18	0.46
	01/04/18	41	17	14	2.2

HWA GEOSCIENCES INC.

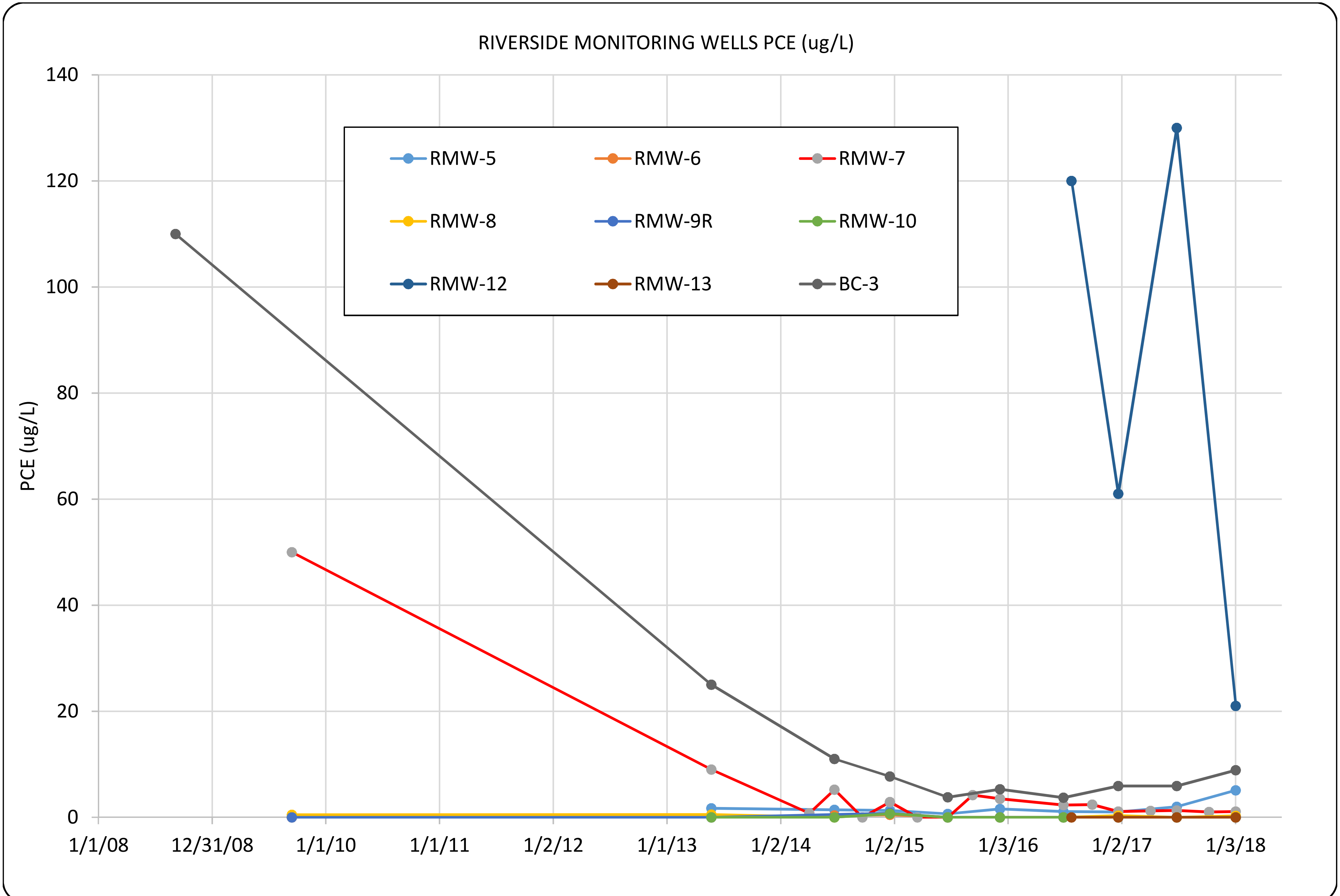
BOTHELL RIVERSIDE HVOC AREA
BOTHELL WASHINGTON

HVOCs MONITORING
GROUND WATER

DRAWN BY EFK
CHECK BY NK
11.07.16

FIGURE NO.
3
PROJECT NO.
2007-098 T2012

S:\2007 PROJECTS\2007-098-22 BOTHELL CROSSROADS\CAD 2007-098\HWA 2007-098-21 T2012.DWG <11x17 T2012 Fig 1> Plotted: 2/2/2018 2:16 PM



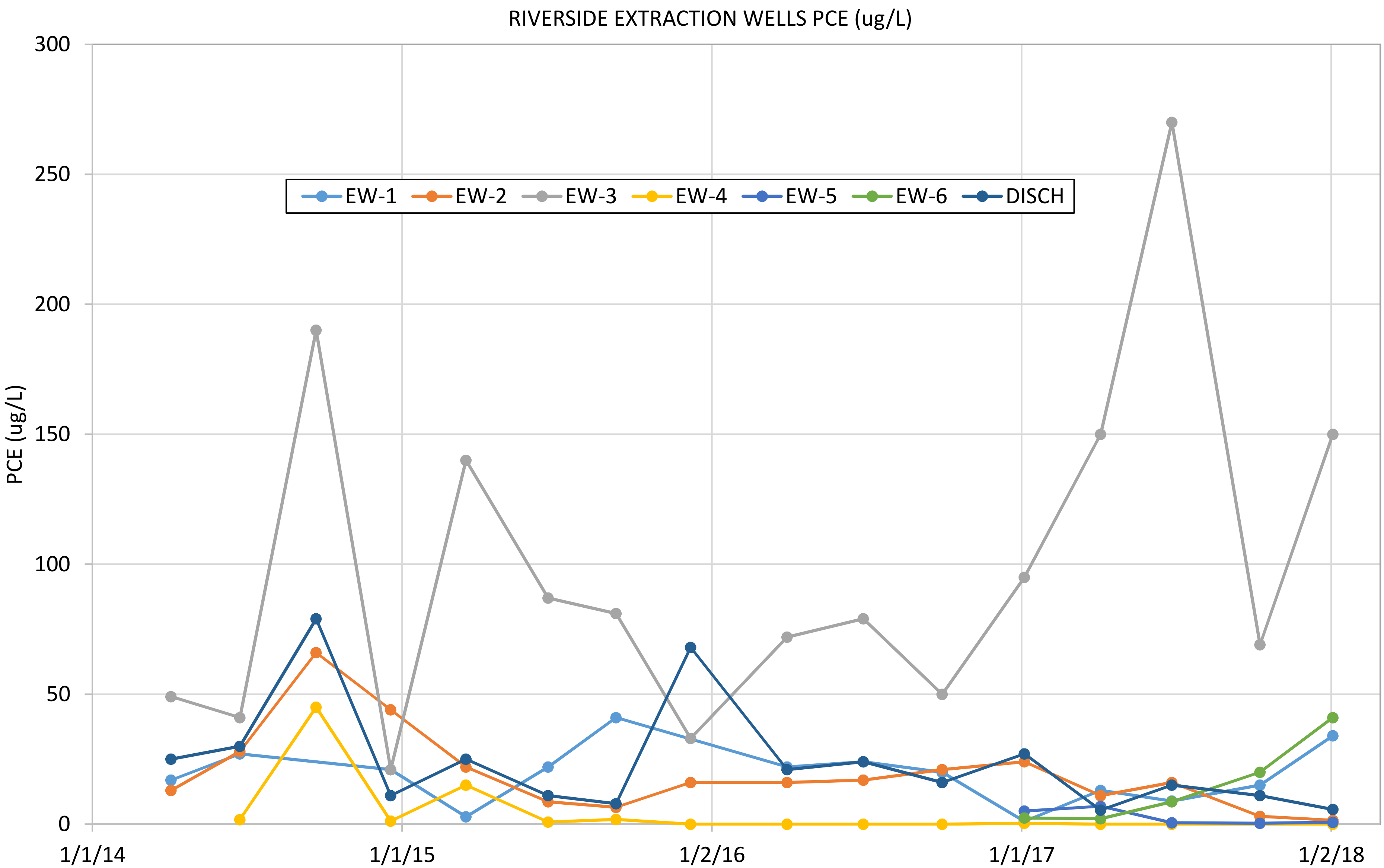
HWA GEOSCIENCES INC.

MONITORING WELLS PCE (ug/L)

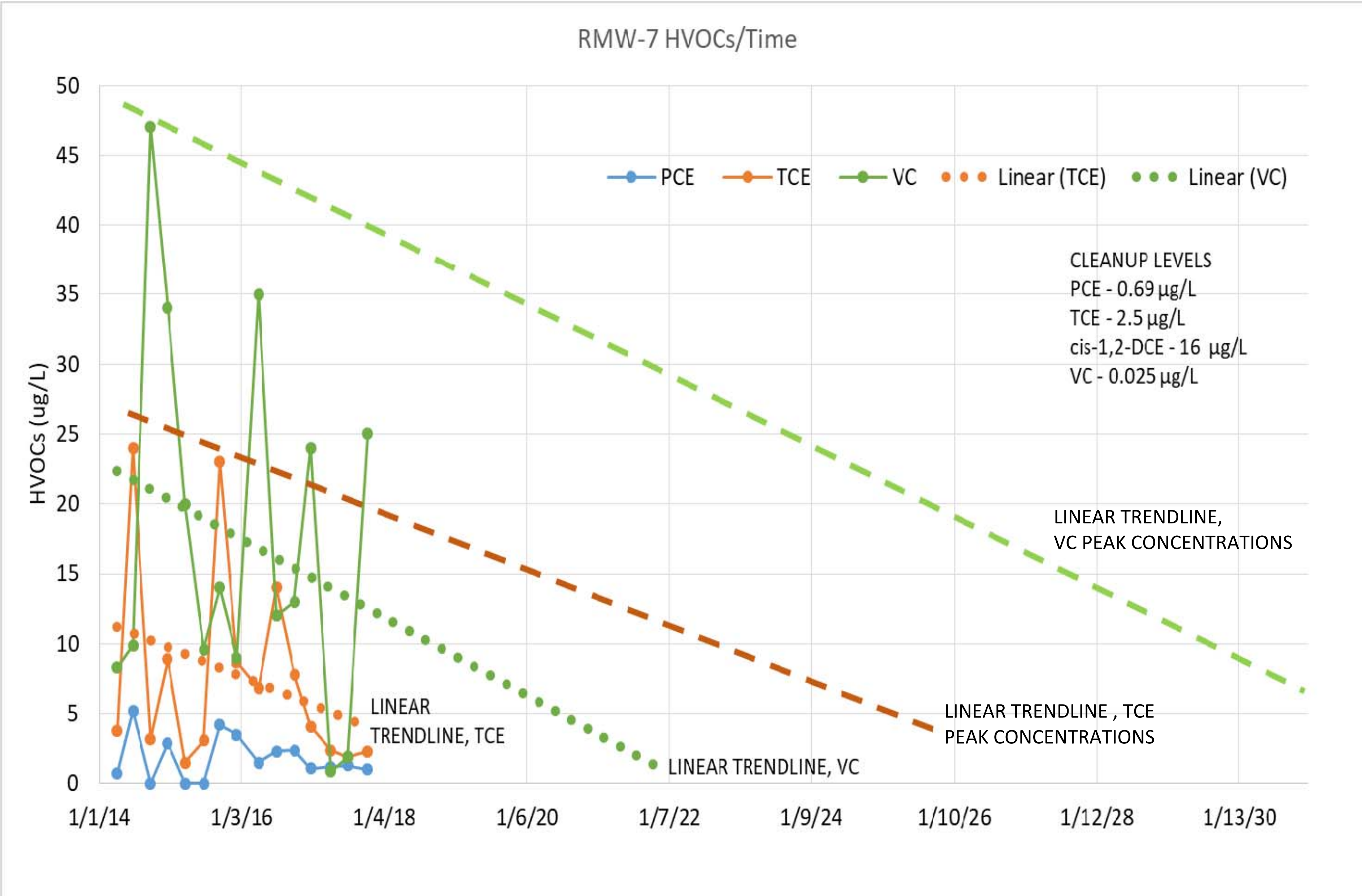
BOTHELL RIVERSIDE SITE, HVOC AREA
BOTHELL, WASHINGTON

FIGURE NO.
4

PROJECT NO.
2007-098



HWA GEOSCIENCES INC.	EXTRACTION WELLS PCE (ug/L)	FIGURE NO. 5
	BOTHELL RIVERSIDE SITE, HVOC AREA BOTHELL, WASHINGTON	PROJECT NO. 2007-098



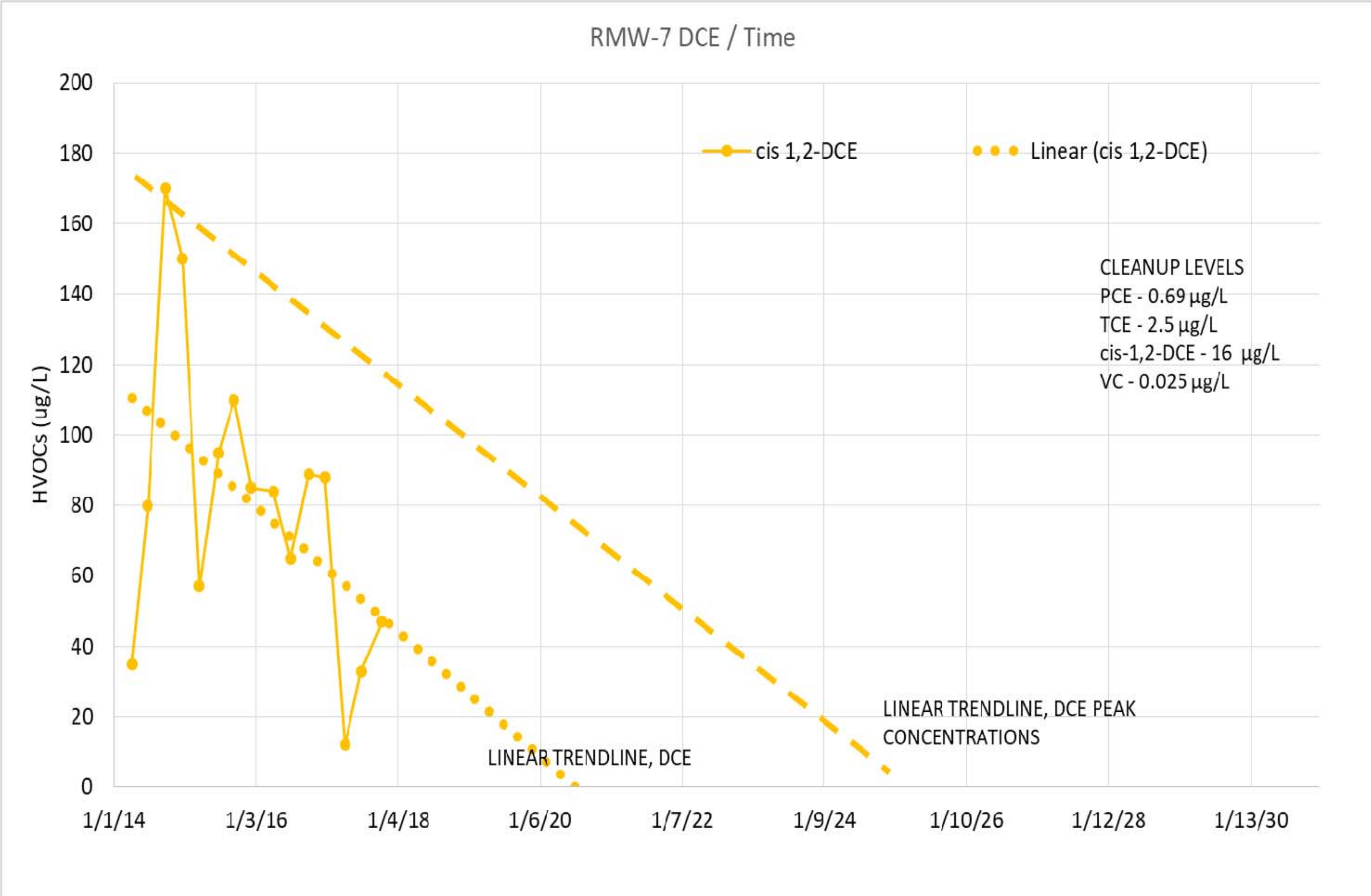
HWA GEOSCIENCES INC.

HVOCS / TIME

BOTHELL RIVERSIDE SITE HVOC AREA
BOTHELL, WASHINGTON

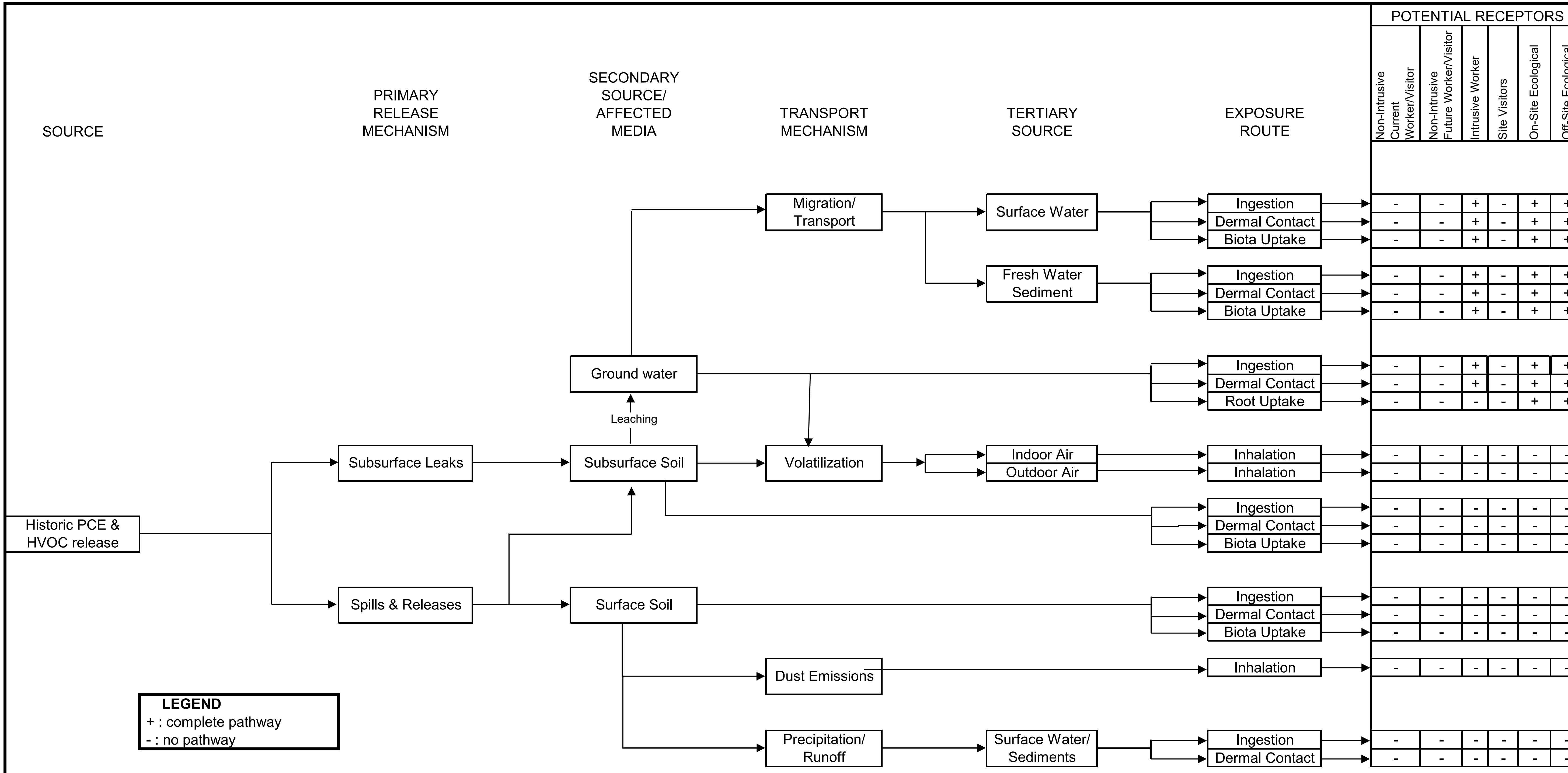
FIGURE NO. 6

PROJECT NO. 2007-098



HWA GEOSCIENCES INC.

RMW-7 DCE / TIME	FIGURE NO. 7
BOTHELL RIVERSIDE SITE HVOC AREA BOTHELL, WASHINGTON	PROJECT NO. 2007-098



Tertiary Source / Media	Exposure Route	Non-Intrusive Current Worker/Visitor	Non-Intrusive Future Worker/Visitor	Intrusive Worker	Site Visitors	On-Site Ecological	Off-Site Ecological
Surface Water	Ingestion	-	-	+	-	+	+
	Dermal Contact	-	-	+	-	+	+
	Biota Uptake	-	-	+	-	+	+
Fresh Water Sediment	Ingestion	-	-	+	-	+	+
	Dermal Contact	-	-	+	-	+	+
	Biota Uptake	-	-	+	-	+	+
Ground water	Ingestion	-	-	+	-	+	+
	Dermal Contact	-	-	+	-	+	+
	Root Uptake	-	-	-	-	+	+
Indoor Air	Inhalation	-	-	-	-	-	-
Outdoor Air	Inhalation	-	-	-	-	-	-
Subsurface Soil	Ingestion	-	-	-	-	-	-
	Dermal Contact	-	-	-	-	-	-
	Biota Uptake	-	-	-	-	-	-
Surface Soil	Ingestion	-	-	-	-	-	-
	Dermal Contact	-	-	-	-	-	-
	Biota Uptake	-	-	-	-	-	-
Dust Emissions	Inhalation	-	-	-	-	-	-
Surface Water/ Sediments	Ingestion	-	-	-	-	-	-
	Dermal Contact	-	-	-	-	-	-

HWA GEOSCIENCES INC.

CONCEPTUAL SITE MODEL

BOTHELL RIVERSIDE HVOC AREA
FS REPORT
BOTHELL, WASHINGTON

FIGURE
8

PROJECT
2007-
098-