

DRAFT CLEANUP ACTION PLAN Jacobson Terminals

Prepared for: A&B Jacobson

Project No. 020030 · August 27, 2003 Draft

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Introduction

This Cleanup Action Plan (CAP) describes the proposed cleanup action to address occurrences of chlorinated hydrocarbons in soil and groundwater on the Jacobson Terminals property in Seattle, Washington. The Jacobson Terminals property is located on the Lake Washington Ship Canal, and is bordered by the Hiram Chittenden Locks (operated by the Army Corps of Engineers) to the west. The land to the north is owned by the City of Seattle, and north of the City property lies the Market Street property.

Historical releases of chlorinated solvents on the Market Street property led to groundwater contamination migrating southeast, toward the Lake Washington Ship Canal, onto the City of Seattle, Army Corps of Engineers property, and the Jacobson Terminals property. In 1999, a permeable reactive wall containing iron filings was installed on Jacobson and the City of Seattle property to treat chlorinated solvents in groundwater and prevent migration of solvents onto the downgradient properties (Market Street Property Cleanup Action). Subsequent groundwater monitoring indicated that groundwater exiting the iron filings wall met treatment standards, and a No Further Action letter was issued by Ecology for groundwater on the upgradient property. Groundwater monitoring on the Terminals property, however, indicated that groundwater concentrations of two chemicals – vinyl chloride and 1,4-dichlorobenzene – did not decline as quickly as expected. Additional investigations were performed and two additional source areas were identified: one located on the City of Seattle property containing chlorinated solvents, and one located on the Jacobson Terminals property containing chlorinated benzenes and PCBs. The cleanup action described herein is intended to address both of these source areas.

This CAP was prepared on behalf of A&B Jacobson LLC, who intends to conduct this Cleanup Action under the Washington State Department of Ecology (Ecology) Voluntary Cleanup Program. This document was prepared in general accordance with requirements listed in the Washington State Model Toxics Control Act (MTCA – WAC 173-340-360).

Site Description

The Jacobson Terminals (Terminals) property is located at 5355 - 28th Avenue Northwest in the Ballard District of Seattle as shown on Figure 1. The Terminals property is occupied by Pirelli Jacobson's offices and operation yard for laying marine cables and by a boat storage facility. The Terminals property is zoned industrial (IG1U/45). A site map is provided on Figure 2.

The site is bound by the Lake Washington Ship Canal (Ship Canal) to the east and south, the Seaborn property to the east, Army Corps of Engineers (Corps) property to the west, and City of Seattle (City) property to the north. The Seaborn property is used for boat moorage and office space. The Corps property contains offices, maintenance buildings,

and a tourist facility for the Ship Canal Locks. The City property consists of a former Burlington Northern Railroad right of way and contains an active railroad.

The Terminals property is generally flat. The northwest corner, which is used for parking, is approximately 5 feet above the elevation of the rest of the property, at the approximate elevation of the City property railroad. Access to the site is controlled by fencing and gates.

The property is located on a former estuarine tideflat. In the 1920's, the area was filled with sand dredged from the Lake Washington Ship Canal, wood waste, and construction debris. The property was the site of a lumber mill from approximately 1890 to the 1930s. Starting around 1940, the property was used for loading and unloading boats and for storage. Alan and Brian Jacobson (partners in A&B Jacobson LLC) purchased the property in 1975 and the property has been used as a marine support facility since that date.

Previous Studies and Cleanup Actions

Several field investigations and remedial actions have been conducted on the Terminals property, first as part of the Market Street Property Cleanup Action and later as part of the Terminals Property Interim Cleanup Action. A list of activities is provided in Table 1, and a map showing the locations of explorations and interim cleanup actions is provided on Figure 3.

Market Street CAP and Source Identification

Groundwater monitoring on the Terminals property was first performed to delineate a vinyl chloride plume originating from the upgradient Market Street property. This plume was a known component of the Market Street property cleanup and was addressed in 1999 by installing the permeable iron filings wall to treat groundwater flowing onto the Terminals property (Market Street Property Cleanup Action). As part of the Market Street Property Cleanup Action, Oxygen-Release Compound (ORC) was injected into groundwater on the Terminals property to enhance *in situ* biodegradation of vinyl chloride and 1,4-dichlorobenzene.

Following ORC injection, vinyl chloride and 1,4-dichlorobenzene concentrations at the point of compliance decreased but remained above cleanup levels. Because ORC did not adequately address occurrences of these compounds, more investigations were performed, and two source areas that were not addressed by the Market Street Property Cleanup Action were identified. One area consisted of chlorinated solvents in groundwater located in a small area on the City property that is downgradient of the wall and appears to be contributing to the vinyl chloride plume on the Terminals Property. The other area consisted of PCBs (Aroclor 1260) and chlorinated benzenes, in soil, located on the Terminals property. *In situ* oxidation, a process in which strong oxidizing agents are injected into the subsurface to destroy contaminants, was identified as a potential enhancement to ORC injections. A pilot test in February 2001 demonstrated that applying

this technology by injecting concentrated hydrogen peroxide into the subsurface reduced soil and groundwater concentrations of vinyl chloride, 1,4-dichlorobenzene and PCBs.

Interim Cleanup Action

Following the February 2001 pilot test, an aggressive *in situ* oxidation program was instituted to address the two source areas. A total of 4,500 gallons of 50 percent hydrogen peroxide were injected into 17 injection points (IP-1 through IP-17) and 2 monitoring wells (BR-1 and BR-2) between August 2001 and May 2002. The results of this program are described in the Interim Cleanup Action Summary Report (Hart Crowser 2002a). Performance monitoring indicated that although concentrations of 1,4-dichlorobenzene and vinyl chloride were significantly reduced, concentrations at the point of compliance (JT-6) for the Market Street property cleanup action still exceeded cleanup levels. Therefore, a focused feasibility study (Hart Crowser 2002b) was prepared to evaluate other potential cleanup actions.

Focused Feasibility Study

The feasibility study identified the preferred alternative to be constructing a sorptive/reactive wall to treat contaminated groundwater, pending completion of additional studies. Three studies were performed between March and August 2003 as follows:

- A hydrogeology study, to better characterize groundwater movement in and downgradient of the source area;
- A bench-scale test of the sorptive/reactive wall technology; and
- An evaluation of natural attenuation processes and contaminant fate and transport at the site.

The results of these studies are discussed in this report.

Site Conditions

Site conditions have been characterized by soil and groundwater investigations conducted on the Terminals property since 1996. Results through the completion of the interim cleanup action are compiled in the Interim Cleanup Action Summary Report (Hart Crowser 2002a). Current site conditions are summarized below.

Geology

Site soils consist generally of approximately 10 feet of fill overlying native estuarine sediments. The fill is a heterogeneous mixture of silty sand, silt, wood waste, and occasional debris. A layer of wood waste approximately 6 to 10 feet deep has been identified over much of the northern portion of the site. Below the fill layer are native sand or silty sands to a depth of 16 to 18 feet. Beneath the sand layer is a layer of silty

clay, typically 1 to 4 feet thick. Below this layer are discontinuous layers of sand and silt of increasing density. A generalized geologic cross section is provided on Figure 4.

The fill soils exhibit substantially higher organic content than the underlying native soils, with an average total organic carbon (TOC) content of 3.5 percent (excluding wood waste samples) for fill soils and 0.15 percent for the native sands and silty sands.

Hydrogeology

Shallow groundwater in the area generally flows toward the south-southeast before discharging into the Lake Washington Ship Canal. Groundwater elevations on the upgradient Market Street property are typically 12 to 14 feet whereas elevations on the Terminals property are typically 7 to 8 feet. Groundwater is typically encountered beneath Jacobson Terminals at depths between 4 to 7 feet. The groundwater elevation fluctuates approximately 2 feet seasonally and depends largely on the elevation of the Ship Canal, which is adjusted seasonally by the Corps of Engineers. A map showing groundwater elevation contours is provided on Figure 5. Historical groundwater elevations measured at Terminals, City, Corps, and Market Street property wells are in Table 2.

An upward gradient has been identified between the deeper water-bearing zone (beneath the silty clay layer) and the shallower water-bearing zone, with the hydrostatic head typically 1 to 2 feet greater at wells JT-5 and MW-8D than at adjacent shallower wells.

Hydraulic Conductivity and Groundwater Flow Rates

Saturated-zone soils at the site generally have low hydraulic conductivities. Slug tests performed in April 2003 indicated that at five of six wells tested (IP-1, JT-3, JT-6, JT-8, and BR-1), hydraulic conductivities ranged between 1.7 and 2.8 feet per day. Slug tests at the sixth well (IP-8) indicated a hydraulic conductivity of 14 feet per day. Using the average hydraulic conductivity of the five similar wells, the average hydraulic horizontal gradient of 0.02 foot per foot across the site, and assuming a porosity of 0.4, the estimated groundwater flowrate at the site is 0.1 foot per day (40 feet per year). Using the maximum calculated hydraulic conductivity, the groundwater flowrate would be 0.7 foot per day (250 feet per year). During the interim cleanup action, hydrogen peroxide was first injected in the source area in January 2001: the concentration of vinyl chloride dropped to non-detect immediately in the source area and declined to less than half its previous concentration by August 2001 at well JT-6, located 100 feet downgradient. Using vinyl chloride (a very mobile compound in groundwater) as a conservative tracer results in a calculated approximate groundwater velocity of 0.4 foot per day (150 feet per year).

Potential Sewer Line Leakage

Groundwater elevations have typically been lower than the rest of the site near the sewer line in the area around JT-9. A sewer camera survey performed in April 2003 indicated that near this point was a connection to the site side sewer. The camera noted water flowing in at the side sewer connection with significant scale buildup. The sewer line is located below the water table (see Figure 4); therefore, leakage of shallow groundwater

into the sewer at this point could cause a local depression in groundwater elevation. Groundwater elevations at surrounding properties and chemical distribution patterns in groundwater indicate that the groundwater depression is localized and that shallow groundwater flow toward the Ship Canal remains the primary discharge route.

Soil, Groundwater, and Air Quality

Two source areas, based on elevated chemical concentrations in soil and/or groundwater, have been identified at the site as follows:

- The Chlorinated Ethene Source Area, consisting of perchloroethene (PCE) and its degradation products trichloroethene (TCE), cis-1,2-dichloroethene (cis-DCE), and vinyl chloride (see Figure 6); and
- The PCB/TCB Source Area, consisting primarily of PCBs and 1,2,4-trichlorobenzene in soil with lower concentrations of other chlorinated benzene species (see Figure 7).

Soil and groundwater data collected at the site before, during, and after the interim cleanup actions is provided in Appendix A. Chemical occurrences at the site are summarized below.

Chlorinated Ethene Source Area

Concentrations of chlorinated ethenes in groundwater are shown on Figure 6. Monitoring wells BR-1 and BR-2 and direct-push exploration SP-32 define the chlorinated ethene source area, located directly beneath the railroad tracks on the City property (see Figure 5). Direct-push explorations SP-33, SP-34, and SP-35 bound the source area: concentrations of the parent compound PCE were much lower or non-detect in groundwater samples collected from these points. The depth of affected groundwater was approximately 20 to 22 feet; below this depth is a confining layer of very dense, sandy silt. The maximum detected concentrations of PCE and TCE in the source area monitoring wells are 900 and 1,500 ug/L, respectively, both detected at BR-1.

The original source of the detected occurrences is not known. Low soil concentrations of PCE and TCE (maximums of 960 and 620 ug/kg, respectively) were detected at BR-1 and BR-2, but no significant soil source of PCE or TCE has been identified. Soil occurrences were collocated with groundwater occurrences at depths below 20 feet, above the silt confining layer. The limited extent suggests a one-time historical release of a small quantity of contaminated material, which migrated down to the silt confining layer.

Downgradient of the chlorinated ethene source area on the Terminals property, PCE and TCE are typically not detected, but relatively high concentrations of vinyl chloride (maximum of 650 ug/L, at IP-6) and somewhat lower concentrations of cis-DCE have been detected in groundwater. The current estimated extent of the vinyl chloride plume is presented on Figure 6. Some of these occurrences may be residual occurrences from the Market Street Property plume before the treatment wall was installed; however, concentrations of chlorinated ethenes exiting the treatment wall have been very low or non-detect since it was installed in 1999. Vinyl chloride concentrations have declined

steadily since installing the Market Street iron wall and performing *in situ* oxidation on the Terminals property, as shown on Figure 8.

PCB/TCB Source Area

The PCB/TCB source area is located in the northern part of the Terminals property, as shown on Figure 7. It is roughly elliptical in shape, extending along the sanitary sewer line and measuring approximately 60 feet by 30 feet. The original source is not known, but PCB and trichlorobenzene mixtures were historically used as dielectric fluids in transformers. The shape and location of the contaminated area imply a historical release of product near injection point IP-1, which migrated down until reaching the silt confining layer at an approximate depth of 16 to 18 feet. Chemical occurrences in the PCB/TCB source area are highest just above the silt confining layer, while occurrences in the unsaturated zone are limited and generally at much lower concentrations. It is important to note that although the nature of occurrences implies a historical release of product, no evidence of free product has been observed in the 18 wells and injection points installed in the Source Area, and no contamination has been observed in the soil or groundwater beneath the confining silt layer.

Contaminant migration along the top of the confining layer in the direction of groundwater flow may account for the southeastern lobe of the Source Area. The elongation along the sewer line might be from either contaminant migration toward the line (see Hydrogeology Section) or from spreading of contaminated material during installation and backfilling of the sewer line in 1974, if the release occurred earlier.

Soil Occurrences

Along with PCBs and 1,2,4-trichlorobenzene, several other related chemicals have been detected in this source area, including 1,2,3-trichlorobenzene, 1,2-, 1,3-, and 1,4-dichlorobenzene, and chlorobenzene. Of these, only 1,4-dichlorobenzene has been detected at concentrations above applicable screening levels. This chemical is a biodegradation product of 1,2,4-trichlorobenzene, and may also be an impurity in the original product mixture. Occurrences of PCBs, 1,2,4-trichlorobenzene, and 1,4-dichlorobenzene in soil following the interim cleanup action (see Appendix A) are as follows:

- PCBs (Aroclor 1260) have been detected in unsaturated zone soils at concentrations up to 18 mg/kg and in saturated zone soils at concentrations up to 690 mg/kg.
- 1,2,4-Trichlorobenzene has only been detected in one sample from the unsaturated zone, at a concentration of 0.26 mg/kg, but has been detected at concentrations up to 360 mg/kg in the unsaturated zone. Occurrences of 1,2,4-trichlorobenzene are generally collocated with PCB occurrences.
- 1,4-Dichlorobenzene has been detected in unsaturated zone soils at concentrations up to 0.28 mg/kg and in saturated zone soils up to 15 mg/kg. Occurrences of 1,4-dichlorobenzene are generally collocated with 1,2,4-trichlorobenzene occurrences, but at concentrations 1 to 2 orders of magnitude lower.

Groundwater Occurrences

Groundwater monitoring data (see Appendix A) indicate the following:

- 1,2,4-Trichlorobenzene occurrences in groundwater are limited to the area immediately around the source area. In the source area, the highest concentration detected following the interim cleanup action was 4,700 ug/L at IP-2. However, 40 feet downgradient of the source area at monitoring well JT-11, 1,2,4-trichlorobenzene was not detected. 1,2,4-Trichlorobenzene was detected at downgradient well JT-6 during one monitoring round immediately following the interim cleanup action, but not in subsequent sampling events.
- 1,4-Dichlorobenzene occurrences in groundwater extend southeast from the source area toward the Ship Canal. The highest concentration detected following the interim cleanup action was 450 ug/L at JT-8 and IP-8. At downgradient well JT-6, 1,4-dichlorobenzene concentrations have steadily declined since the onset of the interim cleanup action, with a concentration of 12 ug/L detected in April 2003. The trend in 1,4-dichlorobenzene concentration at this well is shown on Figure 7.
- PCBs were not detected in downgradient wells JT-3 and JT-6 before the interim
 cleanup action. Immediately after the cleanup action, low concentrations of PCBs
 were detected in these wells (1 ug/L at JT-3, 0.2 ug/L at JT-6), but concentrations
 declined in subsequent sampling events. In June 2003, 0.083 ug/L was detected in
 well JT-6.

The greater extent of the 1,4-dichlorobenzene plume relative to the 1,2,4-trichlorobenzene plume is likely due to the greater mobility of 1,4-dichlorobenzene and because biodegradation of 1,2,4-trichlorobenzene under anaerobic conditions (which exist at the site) can produce 1,4-dichlorobenzene. Natural attenuation monitoring and modeling was performed as part of a fate and transport study (Trihydro 2003) that is included in Appendix B. This study concluded that significant attenuation of the chemicals of concern occurs at the site due to sorption, dispersion, and biodegradation of dissolved-phase compounds downgradient of the source area.

Air Quality

There are no permanent structures above the affected areas. Much of the surface above the affected areas is covered with pavement, and occurrences of chemicals of concern are typically 5 to 10 feet below the water table. In June 2002, because the sewer line runs through the contaminated groundwater plume and may potentially collect contaminants through leaking fittings, vapor samples were collected from sewer manholes hydraulically upgradient and downgradient of the affected source area and analyzed for VOCs by EPA Method 8260. No VOCs were detected. Therefore, there does not appear to be a completed air exposure pathway at the site.

Chemicals of Concern

Constituent concentrations in soil and groundwater on the City and Terminals properties were compared to screening criteria for soil and surface water. Soil and surface water screening criteria consider applicable state and federal ARARs. Soil screening levels are generally based on MTCA Method B direct contact cleanup levels for unrestricted use for

all constituents except PCBs, which is based on the MTCA Method A cleanup level for unrestricted use. Surface water screening levels are based on MTCA Method B surface water screening levels. A statistical summary of chemical detections at the site and their screening levels is provided in Table 3 for soil and Table 4 for groundwater. Chemicals that significantly exceeded screening criteria were identified as chemicals of concern for each medium, as follows:

- Soil. PCBs.
- **Groundwater.** PCBs, 1,2,4-Trichlorobenzene, 1,4-Dichlorobenzene, perchloroethene, trichloroethene, and vinyl chloride.

Benzene was also detected in groundwater at several locations above the screening level and appears to come from an upgradient source; however, benzene occurrences were evaluated in the Market Street Property Cleanup Action Plan and found to meet cleanup criteria before entering the Ship Canal. Therefore, benzene was not identified in this study as a chemical of concern.

Cleanup Objectives and Criteria

Remedial Action Objectives

The two primary objectives for addressing environmental conditions at the Terminals property are as follows:

- Protection from Direct Contact. Soil screening criteria are based on relevant and applicable state and federal standards for direct contact under unrestricted land use assumptions. The point of compliance is from ground surface to a depth of 15 feet below ground surface.
- Interception and Treatment of Contaminated Groundwater. A primary goal of the remedial action is to prevent the discharge of contaminants in groundwater above cleanup levels to sensitive surface water receptors. Groundwater screening criteria include consideration of relevant and applicable standards under state and federal laws. The conditional point of compliance for groundwater will be groundwater quality at the Terminals property boundary directly upgradient of the Ship Canal.

To achieve the Remedial Action Objective for groundwater, the cleanup action should either reduce soil concentrations to sufficiently protect groundwater or should contain and treat groundwater impacted via the soil-to-groundwater pathway.

Screening criteria for chemicals of concern based on applicable state and federal laws are presented in Table 5.

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Evaluation of Remedial Alternatives

The interim cleanup action included the following technologies:

- In situ Bioremediation using ORC; and
- *In situ* Oxidation using hydrogen peroxide.

Both of these technologies improved groundwater quality but neither was able to achieve Remedial Action Objectives.

A Focused Feasibility Study (FFS: Hart Crowser 2002b) was prepared following the interim cleanup action to identify potential remedial alternatives to achieve site closure. The FFS developed and evaluated the following 5 alternatives:

- Alternative 1—Capping and Monitored Natural Attenuation;
- Alternative 2—Capping and Enhanced Natural Attenuation using HRC;
- Alternative 3—Capping and Passive Groundwater Treatment with a Reactive/Sorptive Wall;
- Alternative 4–Hot Spot Excavation with a Reactive/Sorptive Wall; and
- Alternative 5-Full Excavation.

Alternative 1 was rejected because of the likelihood it would not meet Remedial Action Objectives. This analysis was confirmed by the Fate and Transport Study (Trihydro 2003), which concluded that although significant natural attenuation is occurring, it is not occurring quickly enough to achieve RAOs under current site conditions.

Alternative 2 was rejected because HRC would likely increase, at least in the short term, the production of degradation byproducts that are more toxic than the parent products (e.g., vinyl chloride from PCE, 1,4-dichlorobenzene from 1,24-trichlorobenzene). Also, HRC has not been proven to be effective against PCBs.

Alternatives 4 and 5 were rejected because of the disproportionate costs involved to excavate contaminated material considering the depth of contaminated material below the water table, utility concerns, and the difficulty in removing the chlorinated ethene source area from beneath the railroad tracks.

Alternative 3 – the sorptive/reactive wall – was, therefore, selected as the most effective method of achieving RAOs, pending testing of the technology under site conditions. A laboratory study performed in Germany found that treating mixtures of chlorinated ethenes and chlorinated benzenes with both mixtures of iron and GAC and sequential iron and GAC columns was effective (Koeber et. al. 2000). A copy of this study is included in Appendix C. To test the applicability of the technology at the Terminals site, a bench-scale treatability study was conducted between May and August 2003 in which site groundwater was pumped through columns of sorptive/reactive materials (granular activated carbon and iron filings). Samples from the outlets and inlets of the columns were collected and analyzed for the chemicals of concern. The results of the treatability study are included in Appendix D. A hydrogeologic study was also conducted to estimate

the rate of groundwater flow at the site. The results of these studies indicated that using conservative design criteria, a 2-foot-thick wall containing 35 percent granular activated carbon would operate at least 30 years before requiring maintenance or carbon replacement.

In the FFS, Alternative 3 was selected based on the assumption that the sorptive/reactive wall effective lifetime would be 20 years. This assumption was confirmed by subsequent testing; therefore, we have retained Alternative 3—Capping and Passive Groundwater Treatment with a Reactive/Sorptive Wall as the preferred alternative at the site.

Description of Proposed Cleanup Action

The proposed cleanup action consists of placing a permeable wall across the contaminated groundwater plume before the point of discharge to the Ship Canal. The permeable wall will contain iron filings to destroy vinyl chloride and granular activated carbon to absorb 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, and PCBs. A conceptual design plan view and cross-sectional view of the proposed wall are shown on Figures and 9, respectively. A mixture of carbon, sand, and iron will be placed within the saturated zone, and structural fill will be placed above the saturated zone. Because the entire wall will consist of materials more permeable than the surrounding formation, contaminated groundwater will flow through the wall rather than around, over, or beneath it, and there will not be groundwater mounding behind the wall as is seen with a funnel-and-gate design.

The conceptual design includes extending the wall to the northeast approximately 40 feet beyond the boundary of the contaminant plume. This is because of the potential that plume extent is influenced by the potentially leaking sewer connection. The extra wall length will ensure that even if groundwater flowpaths change in the future, the contaminant plume will still be intercepted.

Preliminary design assumptions and criteria are provided in Table 6. Based on results of the treatability and hydrogeology studies, a mixture of 30 percent by volume granular activated carbon, 40 percent by volume iron, and 30 percent by volume sand, will provide a minimum 20-year effective operating life. In addition to the available information, the following data will be needed for the final design of the wall:

- Length of the Wall. The conceptual layout of the wall is based on available chemical data and predicted groundwater flow paths. To ensure complete capture of the contaminant plume, groundwater samples will be collected using a direct-push drill rig at several locations along the proposed wall alignment. The length of the wall will be adjusted, if necessary, based on the width of the contaminant plume.
- Depth of the Wall. A direct-push drill rig will be used to advance borings at regular intervals along the proposed wall alignment. At each boring location, continuous soil samples will be collected until the confining silt layer is identified. The wall will be designed to key 6 inches into this silt layer.

Once the final design is complete, the wall will be constructed as described below.

Wall Construction

The wall will be constructed by removing the asphalt strip above the wall footprint and installing two rows of 13-inch diameter pipe piles to a depth 6 inches into the silt confining layer. The soil in the annular space of the pipe pile will be removed, free water will be pumped out of the center of the piles (which act as a casing), and the iron/sand/carbon mixture will be placed in the annular space. Imbedding the casing into the confining silt layer will prevent additional groundwater from infiltrating in to the hole. After the casing is filled with the reactive/sorptive mixture, the casing will be removed.

Some settlement of materials will occur after the casing is removed and materials fill in the casing void space. If the top of the reactive/sorptive mixture is below the seasonal high water table elevation (approximately 4 feet below ground surface), additional material will be placed on top. In the unsaturated zone, structural fill will be placed, compacted, and covered with asphalt pavement.

Three monitoring wells, SRW-1, SRW-2, and SRW-3, will be installed inside the wall near the downgradient edge. These wells, constructed of 1-inch diameter steel pipe and screened for 5 feet above the confining silt layer, will be placed during construction of the wall.

Material Handling

Groundwater removed during wall construction will be collected in a Baker Tank pending characterization for proper disposal.

Asphalt Cap

An existing asphalt cap, which covers the area containing soil exceeding cleanup levels, prevents direct contact with underlying soils. As part of this cleanup action, the asphalt cap will be maintained during and after construction of the treatment wall.

Compliance Monitoring

Compliance monitoring will be performed to confirm that human health and the environment are protected during the construction, operation, and maintenance of the cleanup action. Compliance monitoring will also confirm that the cleanup action has attained the remedial action objectives prescribed by the cleanup plan and confirms the long-term effectiveness of the remedial action. Compliance monitoring at the site will be performed as described below.

Protection Monitoring

Protection monitoring will be implemented during construction by ensuring that site workers are appropriately trained in health and safety, that proper personal protective equipment is worn, and that adequate air monitoring is conducted when working with potentially contaminated materials. A site-specific worker health and safety plan will be developed to address site activities.

Performance Monitoring

Performance monitoring will be conducted after construction to ensure the wall is effectively removing contaminants. Performance monitoring will consist of collecting groundwater samples from the three monitoring wells in the gate (SRW-1, SRW-2, and SRW-3), one well directly upgradient of the wall (JT-11), and two wells in the source areas (JT-8 and BR-2). In addition, groundwater elevations will be measured at a network of wells to ensure the wall continues to capture the groundwater plume. The proposed monitoring well network is shown on Figure 9. Performance monitoring will be conducted as long as the wall is in place or until constituent concentrations upgradient of the wall meet cleanup criteria.

Concentrations in groundwater exiting the gate will be compared to wall performance criteria rather than cleanup criteria. Performance criteria for 1,2,4-trichlorobenzene and 1,4-dichlorobenzene were developed in the Fate and Transport Study (Trihydro 2003) and are based on modeling the natural attenuation of contaminants between the source area and the groundwater discharge point. This study concluded that the following concentrations exiting the source area would attenuate to below cleanup criteria at the Ship Canal:

- 1,2,4-Trichlorobenzene. 95 ug/L; and
- 1,4-Dichlorobenzene. 17 ug/L.

The performance criterion for 1,2,4-trichlorobenzene is lower than the cleanup level because this study takes into account production of 1,4-dichlorobenzene from 1,2,4-trichlorobenzene.

The performance criteria for other chemicals of concern in groundwater are:

- Vinyl Chloride. 5 ug/L, based on the Market Street property natural attenuation modeling, adjusted for the closer proximity of this wall to the discharge point; and
- PCBs. 0.02 ug/L, based on the current PQL for PCBs in groundwater. If the PQL for this analyte is lowered, the performance criteria may be adjusted accordingly.

Confirmation Monitoring

Confirmation monitoring will be implemented to ensure the long-term effectiveness of the cleanup action to protect human health and the environment. The proposed point of compliance is well JT-6, located just upgradient of the nearest discharge point of groundwater to the Ship Canal. After wall construction is complete, confirmation sampling will be performed at well JT-6. We expect a slight lag time between installation of the wall and achievement of cleanup levels at JT-6 due to the slow rate of groundwater flow: clean groundwater exiting the treatment wall may not reach the JT-6 until 6 to 12 months after the wall is installed. Confirmation monitoring will be performed until four consecutive quarters of data meet cleanup levels.

In addition to monitoring at the conditional point of compliance, well JT-3 and JT-7 will be monitored periodically to ensure that the contaminant plume continues to be intercepted. Increasing concentrations in JT-3 could indicate a shift of the plume to the north, and increasing concentrations at JT-6 could indicate a shift of the plume to the

9 3,7,11

north. If concentrations at the three monitoring wells directly upgradient of the wall meet cleanup levels for four consecutive quarters, than the wall performance monitoring program will end.

Contingency Plans

If either wall performance or compliance standards are exceeded in two consecutive monitoring events and a downward trend in constituent concentrations is not evident, additional action will need to be considered. This could occur under the following circumstances:

- Wall Performance Criteria are Exceeded but Compliance Standards are Met. In
 this case, additional natural attenuation investigation and modeling may be
 appropriate if required by Ecology. If updated natural attenuation modeling indicates
 that measured wall performance is adequate and compliance standards continue to be
 met, wall performance standards may be adjusted.
- Wall Performance Criteria are Met but Compliance Standards are Exceeded. In
 this case, downgradient treatment via ORC injection or other appropriate technology
 may be required by Ecology until compliance standards are met. Constituent
 concentrations at the point of compliance may drop gradually because the slow rate
 of groundwater flow will slowly flush out contaminants present downgradient of the
 wall.
- Both Wall Performance and Compliance Standards are Exceeded. In this case, Ecology may require downgradient treatment as an interim action while wall maintenance is performed. Wall maintenance may involve mixing or replacing the iron and carbon, widening the wall near the center of the plume, or a supplemental source area action to lower the concentrations entering the reactive/sorptive wall.

Schedule

Implementing the Cleanup Action

The key milestones for the cleanup action are:

• Complete design of treatment wall September 23, 2003

Begin construction of wall
 October 1, 2003

• Finish construction of wall October 21, 2003

• First Groundwater Monitoring Event January 2004

Site Closure

We propose obtaining a No Further Action (NFA) determination from Ecology for the Terminals and City properties under the following scenarios:

- City Property. An NFA letter will be issued after one year of quarterly monitoring data indicate wall performance criteria are being met.
- Jacobson Property. An NFA letter will be issued after one year of quarterly monitoring data indicate cleanup levels at the conditional point of compliance are met without supplemental treatment between the wall and the point of compliance.

Groundwater Monitoring Schedule

The groundwater monitoring program will provide periodic monitoring of chemicals of concern upgradient of the treatment wall, within the treatment wall, and downgradient of the wall at the conditional point of compliance by the Ship Canal. In addition, the monitoring program will include monitoring of groundwater elevations at 14 wells.

A proposed monitoring schedule is provided in Table 6. This schedule provides for quarterly chemical monitoring of 7 wells (2 wells in the source areas, 1 well immediately upgradient of the wall in the center of the plume, 3 wells in the wall, and 1 well at the conditional point of compliance) during the first two years following wall construction, followed by semi-annual monitoring at 6 wells and quarterly monitoring at the conditional point of compliance until NFA letters are received for both properties. Two additional wells near the plume edges will be periodically monitored to ensure the plume is completely intercepted by the wall. After NFA letters are received, annual monitoring of the 7 wells will continue, with 5-year reviews by Ecology.

We expect that PCB concentrations downgradient of the treatment wall will decline more slowly than VOCs and change very little seasonally because of their much lower mobility and greater recalcitrance. Therefore, we will analyze for PCBs on a semi-annual basis at the conditional point of compliance and in the wall at the center of the plume until the applicable criteria are achieved.

After NFA letters are received for both properties, monitoring will be performed on an annual basis until 10 years after wall installation. After 10 years, the monitoring program will be re-evaluated.

References

Hart Crowser 2001. Interim Cleanup Action Plan, PCB and Trichlorobenzene Occurrences. Letter to Chuck Findley, US EPA, and Gail Colburn, Washington State Department of Ecology. August 2, 2001.

Hart Crowser 2002a. Interim Cleanup Action Summary Report. Prepared for A&B Jacobson LLC. July 18, 2002.

Hart Crowser 2002b. Focused feasibility Study. Prepared for A&B Jacobson LLC. October 1, 2002.

Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of A&B Jacobson LLC for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

Table 1 - Summary of Site Activities

Activity	Date
Market Street Property Cleanup Action and Source Area Investigations	
Market Street Property Cleanup Action	
Limited Groundwater Assessment	March 1996
Follow-up Groundwater Study	March 1999
First ORC Injection Round	June 1999
Second ORC Injection Round	December 1999
Third ORC Injection Round	July 2000
Cleanup Action Groundwater Monitoring	July 1999 to Presen
No Further Action Letter Issued for Market Street Property	March 13, 200
1,4-Dichlorobenzene Investigation	
Soil and Groundwater Sampling and Analysis	October 24, 2000
Issue 'Occurrence and Proposed Remediation of p-Dichlorobenzene' Memo (Hart Crowser)	December 14, 2000
Hydrogen Peroxide Injection Pilot Test	
Install Injection Points IP-1, IP-2, and IP-3	January 2001
First Pilot Injection Round	January 2001
Performance Monitoring - Groundwater	February 20, 2001
Second Pilot Injection Round	March 2001
Performance Monitoring - Groundwater	April 10 and 11, 2001
Issue 'Occurrence of Chlorinated Benzenes and PCBs' Memo (Hart Crowser)	May 7, 2001
PCB and Trichlorobenzene Assessment	
Soil and Groundwater Sampling and Analysis	May 21, 22, 23, and June 6, 2001
Issue 'PCB and Trichlorobenzene Assessment Results' Memo (Hart Crowser)	June 20, 2001
Interim Cleanup Action	
Issue Interim Cleanup Action Plan (Hart Crowser)	August 2, 2001
Interim Cleanup Action	
Install Injection Points IP-4 through IP-13	August 21 to 24, 2001
First Full Injection Round	August 27 to September 21, 2001
Performance Monitoring - Groundwater	October 22, 2001
Second Full Injection Round	November 5 to 20, 2001
Performance Monitoring - Groundwater	December 17, 2001
Performance Monitoring - Soil	January 15 and 29, 2001
Issue 'Interim Cleanup Action Status Report' Memo (Hart Crowser)	March 6, 2002
Install Injection Points IP-14 through IP-17	March 2002
Third Full Injection Round	
Performance Monitoring - Groundwater	March 25 to May 10, 2002
	June 3 and 4, 2002
Performance Monitoring - Soil	June 5, 2002
Issue 'Interim Cleanup Action Summary Report' (Hart Crowser)	July 18, 2002
Chlorinated Solvent Assessment	45 400 0000
Railroad Track Investigation - Soil and Groundwater Issue 'Chlorinated Solvent Assessment' Memo (Hart Crowser)	January 15 and 30, 2002 March 28, 2002
Focused Feasibility Study Issue 'Focused Feasibility Study' Report (Hart Crowser)	October 1, 2002
issue Focused Feasibility Study Report (Hart Crowser)	October 1, 2002
Slug Testing	March 2003
Soil and Groundwater Investigation	March and May 2003
Slug Testing Soil and Groundwater Investigation Issue 'Fate and Transport/Remedial Action Objectives Evaluation' Report (Trihydro)	March and May 2003
Slug Testing Soil and Groundwater Investigation Issue 'Fate and Transport/Remedial Action Objectives Evaluation' Report (Trihydro) Bench-Scale Treatability Study	March and May 2003 July 25, 2003
Slug Testing Soil and Groundwater Investigation	March and May 2003

Table 2 - Statistical Summary of Soil Data Compared to Screening Criteria Detected Constituents Only

			Maximun	n Detected C		
		Detection Frequency above Screening			Concentration in	Soil Screening Level i
Chemical Constituent	Detection Frequency	Level	Date	Location	mg/kg	mg/kg ^A
Chlorinated Ethenes						
Vinyl Chloride	1/96	1/97	6/5/2002	SP-47	0.83	0.667
1,1-Dichloroethene	0/96	0/97	na	na	na	1.67
trans-1,2-Dichloroethene	0/96	0/97	na	na	na	1,600
cis-1,2-Dichloroethene	6/96	0/97	6/5/2002	SP-47	4.3	800
Trichloroethene	3/96	0/97	4/11/2002	BR-2	0.62	90.9
Perchloroethene	3/96	0/97	4/11/2002	BR-2	0.96	19.6
Chlorinated Benzenes						
Chlorobenzene	35/96	0/96	6/5/2002	SP-43	22	1,600
1,2-Dichlorobenzene	27/96	0/97	10/24/2000	HC-31	4	7,200
1,3-Dichlorobenzene	45/96	0/97	1/29/2002	SP-38	13	na
1,4-Dichlorobenzene	52/96	0/97	6/5/2002	SP-41	15	41.7
1,2,3-Trichlorobenzene	36/92	0/95	6/502	SP-44	26	na
1,2,4-Trichlorobenzene	48/92	0/95	4/11/2001	IP-2	560	800
Other VOCs						
Benzene	1/96	0/97	5/23/2001	SP-19	0.45	18.2
1,3,5-Trimethylbenzene	1/92	na	5/21/2001	SP-18	0.1	na
1,24-Trimethylbenzene	4/92	na	5/22/2001	SP-5	0.36	na
n-Butylbenzene	1/92	na	5/21/2001	SP-18	0.25	na
Hexachlorobutadiene	2/92	0/95	1/15/2002	SP-2(B)	0.5	700
Naphthalene	12/92	0/95	5/21/2001	SP-18	0.82	7,000
Polychlorinated Biphenyls						
Aroclor 1260	52/100	37/100	1/29/2002	SP-38	880	1 ^B

Notes

A Soil screening level based on MTCA Method B Direct Contact Cleanup Levels

B Soil screening level based on MTCA Method A Unrestricted Use Cleanup Level na not applicable

Table 3 - Statistical Summary of Groundwater Data from Monitoring Wells Compared to Screening Criteria Detected Constituents Only

		•	Maximun	n Detected C		
Chemical Constituent	Detection Frequency	Detection Frequency above Screening Level	Date	Location	Concentration in ug/L	Groundwater Screening Level in ug/L ^A
				-		
Chlorinated Ethenes						
Vinyl Chloride	70/120	69/120	6/3/2002	IP-6	650	2.92
1,1-Dichloroethene	3/120	3/120	4/15/2002	BR-2	8.9	1.93
trans-1,2-Dichloroethene	7/120	0/120	7/7/2000	JT-6	12	32,800
cis-1,2-Dichloroethene	58/120	na	3/13/2003	BR-1	2,200	na
Trichloroethene	13/120	4/120	3/13/2003	BR-1	900	55.6
Perchloroethene	14/120	10/120	3/13/2003	BR-1	1,500	4.15
Chlorinated Benzenes						
Chlorobenzene	95/115	0/115	1/16/2001	JT-6	1,100	5.030
1,2-Dichlorobenzene	96/120	0/120	4/10/2001	JT-8	660	4,200
1,3-Dichlorobenzene	77/120	na	2/20/2001	IP-1	670	na
1,4-Dichlorobenzene	97/120	91/120	2/20/2001	IP-1	1,300	4.86
1,2,3-Trichlorobenzene	35/66	na	12/17/2001	IP-1	2,500	na
1,2,4-Trichlorobenzene	48/66	26/66	12/17/2001	IP-1	11,000	227
Other VOCs						
Chloromethane	7/119	0/106	12/17/2001	IP-11	32	133
1,1,2-Trichloroethane	1/119	1/119	1/16/2001	JT-6	41	25.3
Benzene	65/120	24/120	4/15/2002	BR-2	89	22.7
Toluene	27/120	0/120	7/17/2001	JT-6	2.9	48,500
Ethylbenzene	7/120	0/120	6/4/2002	BR-1	3.7	6,910
Xylenes	16/120	0/120	4/15/2002	BR-2	8.7	na
Naphthalene	2/67	0/67	5/1/2003	JT-6	63	12,300
1,2,4-Trimethylbenzene	2/67	0/67	3/13/2003	JT-6	2.6	na
Polychlorinated Biphenyls						
Aroclor 1260	2/8	2/8	6/4/2002	JT-3	1.5	0.00017 B

Notes

Groundwater screening level based on MTCA Method B Surface Water Cleanup Levels

B Groundwater screening level based on MTCA Method B Surface Water Cleanup Levels using 40 CFR Part 131 as an ARAR

Table 4 - Screening Levels for Chemicals of Concern in Soil and Groundwater

Chemical Constituent	Soil Screening Level for Direct Contact in mg/kg ^A	Groundwater Screening Level in ug/L ^B
Chlorinated Ethenes		
Vinyl Chloride	0.667	2.92
Trichloroethene	90.9	55.6
Perchloroethene	19.6	4.15
Chlorinated Benzenes		
1,4-Dichlorobenzene	41.7	4.86
1,2,4-Trichlorobenzene	800	227
Polychlorinated Biphenyls	# J	
Aroclor 1260	1 ^C	0.00017 ^D

Notes

A Soil screening level based on MTCA Method B Cleanup Levels for Unrestricted Use unless otherwise indicated

B Groundwater screening level based on MTCA Method B Surface Water Cleanup Levels unless otherwise noted

^C Based on MTCA Method A Cleanup Level for Unrestricted Use.

Based on MTCA Method B surface water cleanup level using 40 CFR Part 131 as an ARAR.

Table 5 - Preliminary Design Criteria Sorptive/Reactive Wall

Parameter	Value	Units
Plume Dimensions		
Width	120	ft
Vertical Thickness	14	
Cross-Sectional Area	1680	
Cross-Sectional Area	1080	11
Treatment Wall		
Reactive Media	Zero-valent Iron Filings	
Sorptive Media	Liquid-phase Granular Activated Carbon	
Porosity	0.4	
Minimum Width	2	ft
Length	120	ft
Treatment Depth	14	ft
Maximum Groundwater Velocity	0.4	ft/day
Iron Composition Calculations		
Wall Residence Time	5	days
Half-life of Vinyl Chloride with Iron	2.8	hr
Maximum Vinyl Chloride Concentration	650	ug/L
Target Vinyl Chloride Concentration		ug/L
Required Residence Time (100% Iron)	19.7	
Iron Safety Factor	2	
Percentage of Iron		percent
Carbon Compositions Calculations		
Carbon Usage Rate (Treatability Study)	0.00035	ft ³ GAC/ft ³ wate
Site Groundwater Velocity		ft/day
Porosity	0.40	loddy
Site Groundwater Flowrate		ft ³ /ft ² /day
Wall Width		ft
GAC Composition		percent
		ft ³ /ft ²
Volume of GAC in Wall		
Time to Breakthrough		years
Target Lifetime		years
Design GAC Composition	30	percent
Earthwork Calculations		
Average Width	2.2	ft
Total Depth	18	
Volume of Soil Excavated	176	су
Volume Iron	45	
Volume GAC	41	
Volume Sand	51	
Volume Structural Fill	39	
Mass of Soil Excavated		tons
Mass Iron		tons
Mass GAC		tons
Mass Sand		tons
Mass Structural Fill		tons
		A-miT

Table 6 - Proposed Long-Term Monitoring Plan

Well	Location	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Wall Performan	ce										
BR-2	Chlorinated Ethene Source Area	Quarterly	Quarterly	Biannually	Annually	Annually 1	Annually	Annually	Annually	Annually	Annually 1
JT-8	PCB/TCB Source Area	Quarterly	Quarterly	Biannually	Annually	Annually 1	Annually	Annually	Annually	Annually	Annually 1
JT-11	upgradient of wall - center of plume	Quarterly	Quarterly	Biannually	Annually	Annually 1	Annually	Annually	Annually	Annually	Annually 1
SRW-1	in wall - northeast	Quarterly	Quarterly	Biannually	Annually	Annually 1	Annually	Annually	Annually	Annually	Annually 1
SRW-2	in wall - center	Quarterly	Quarterly	Biannually	Annually	Annually 1	Annually	Annually	Annually	Annually	Annually 1
SRW-3	in wall - southwest	Quarterly	Quarterly	Biannually	Annually	Annually 1	Annually	Annually	Annually	Annually	Annually 1
Compliance											
JT-6	conditional point of compliance	Quarterly	Quarterly	Biannually	Annually	Annually 1	Annually	Annually	Annually	Annually	Annually 1
JT-3	monitor southern extent of plume	Quarterly	Biannually	Annually	,	Annually 1		Annually			Annually 1
JT-7	monitor northern extent of plume	Quarterly	Biannually	Annually		Annually 1		Annually			Annually 1

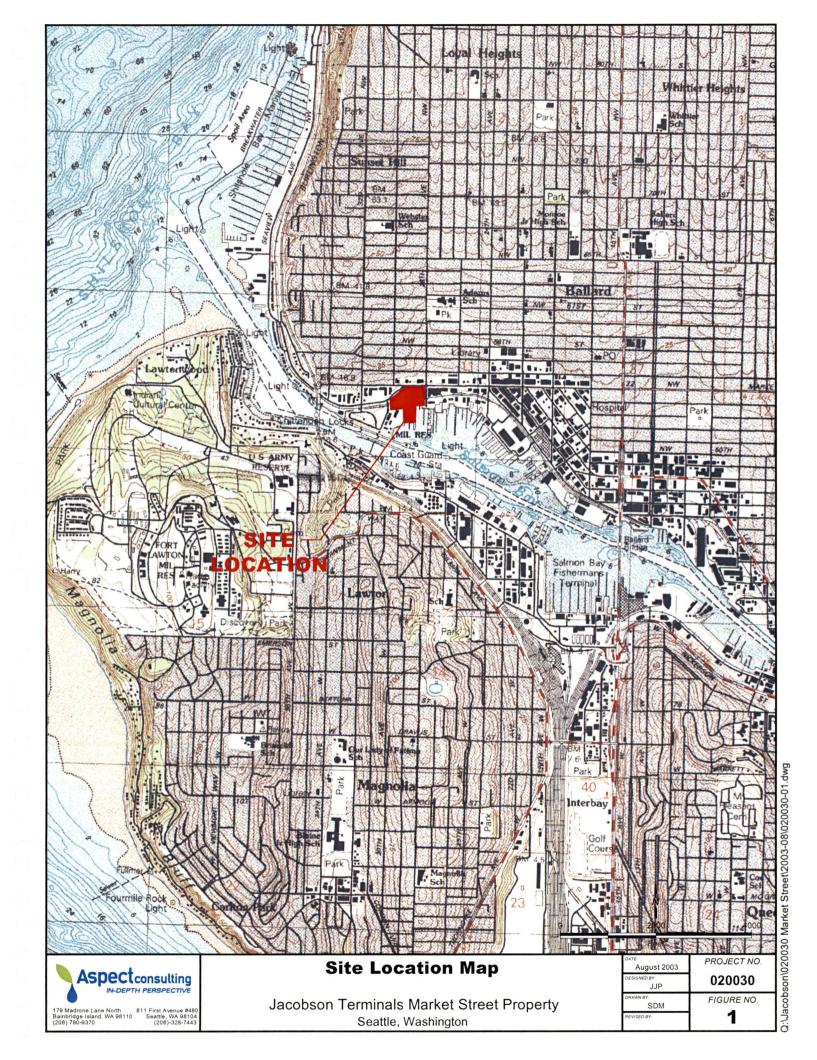
Notes:

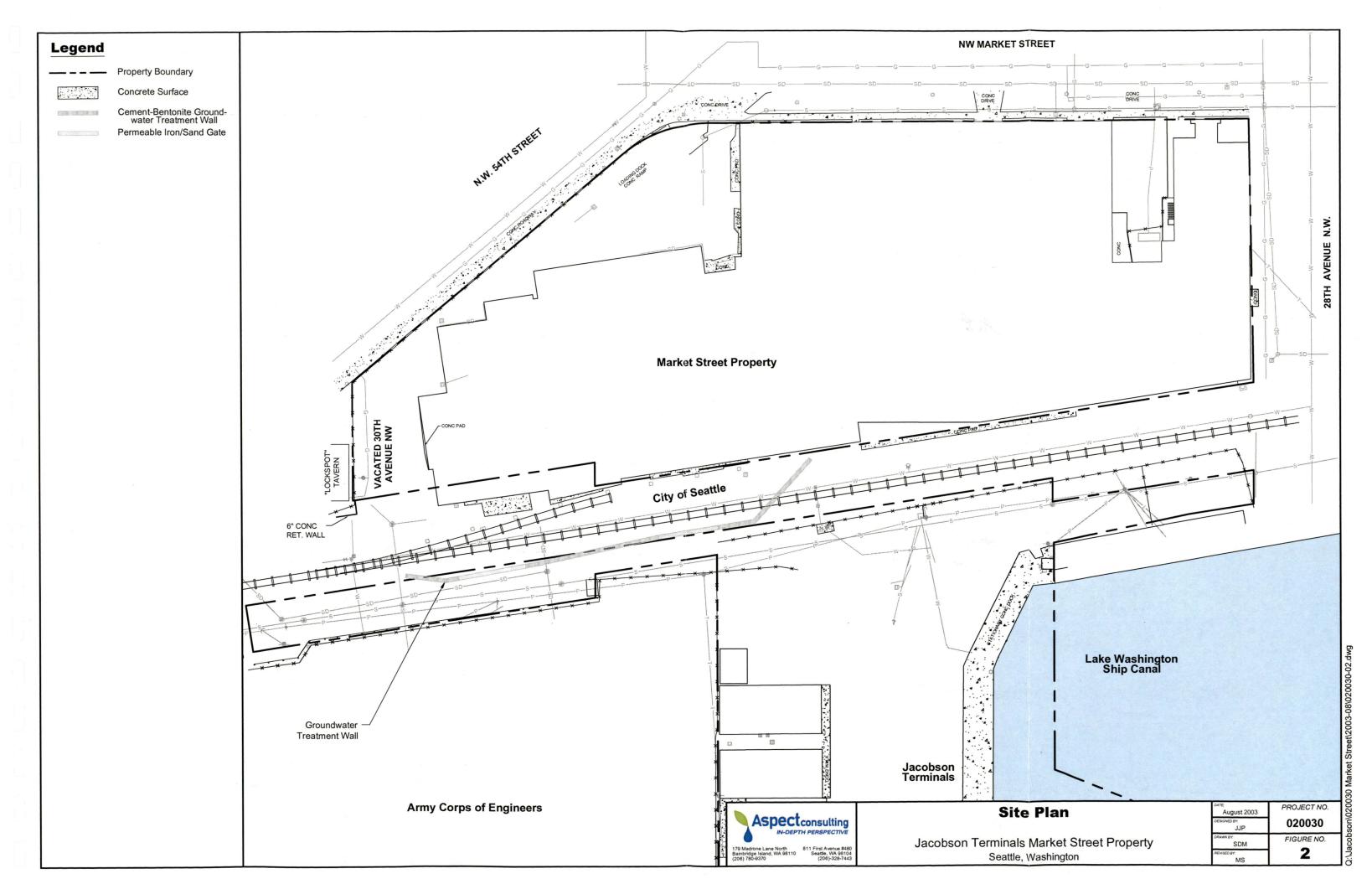
Biannual referes to twice per year.

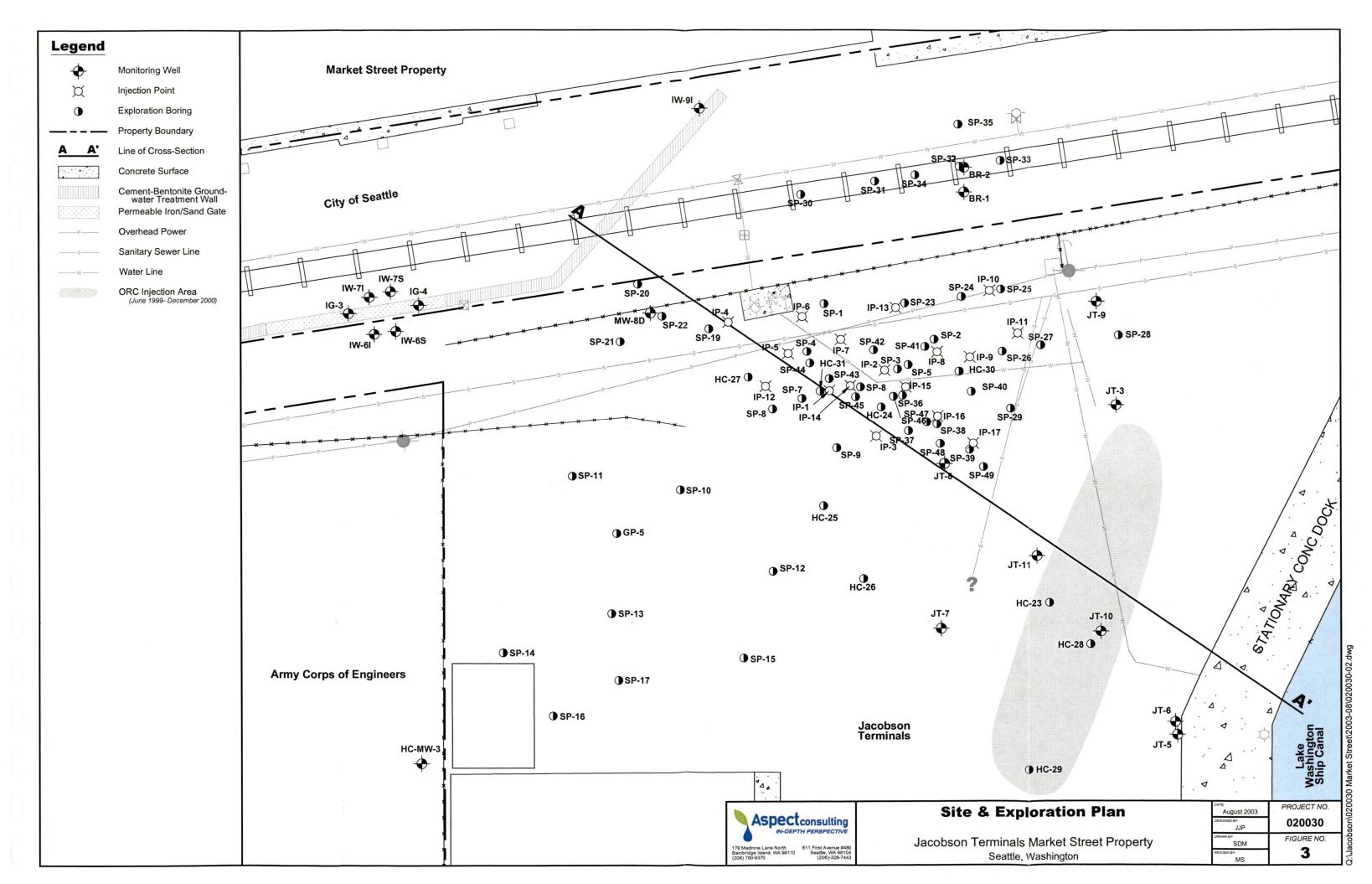
Schedule assumes NFAs for the City and Terminals Property will be issued during 2006.

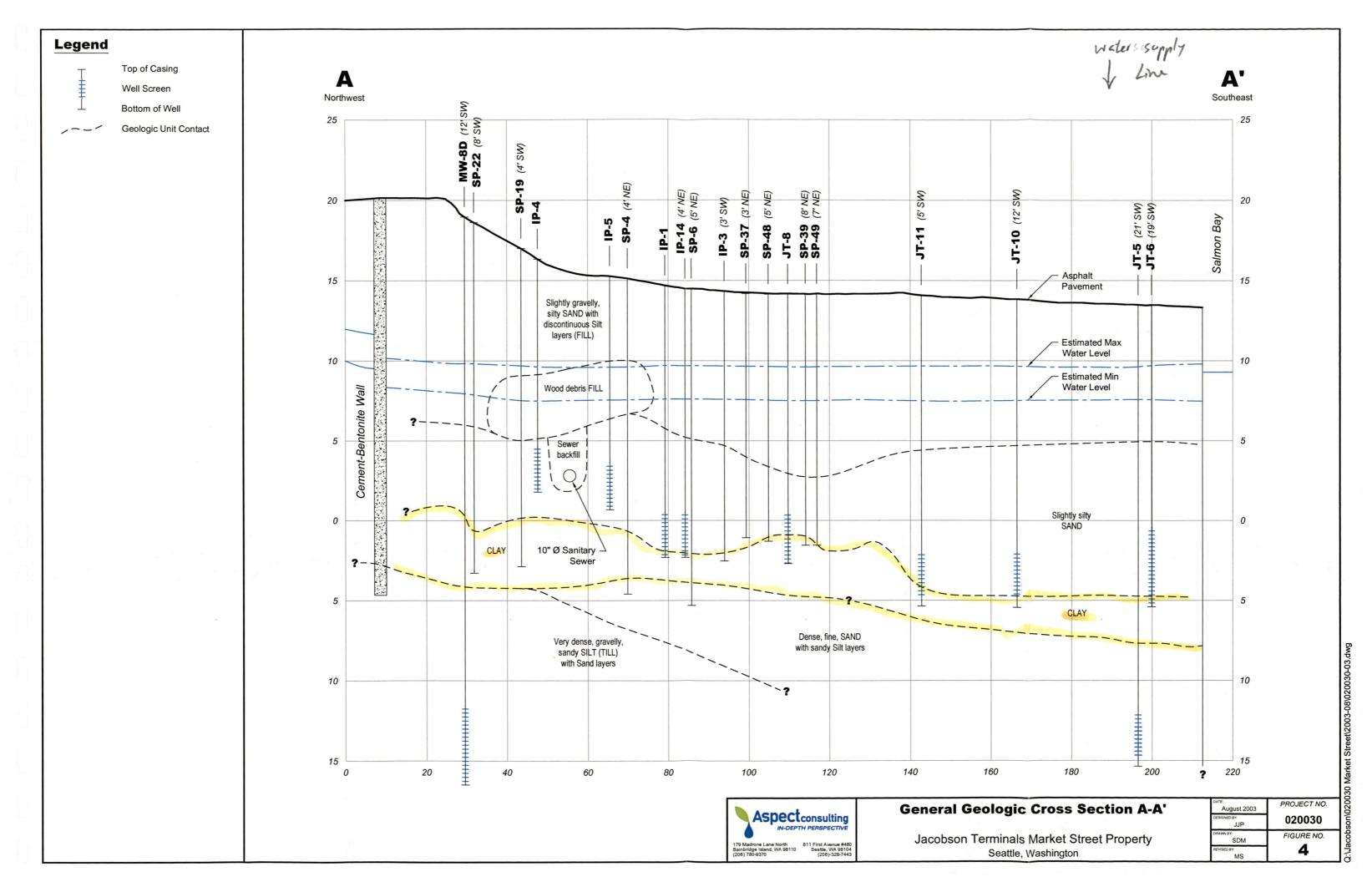
Monitoring will include measurement of groundwater elevation and collection of a groundwater sample for analysis by EPA Method 8260B.

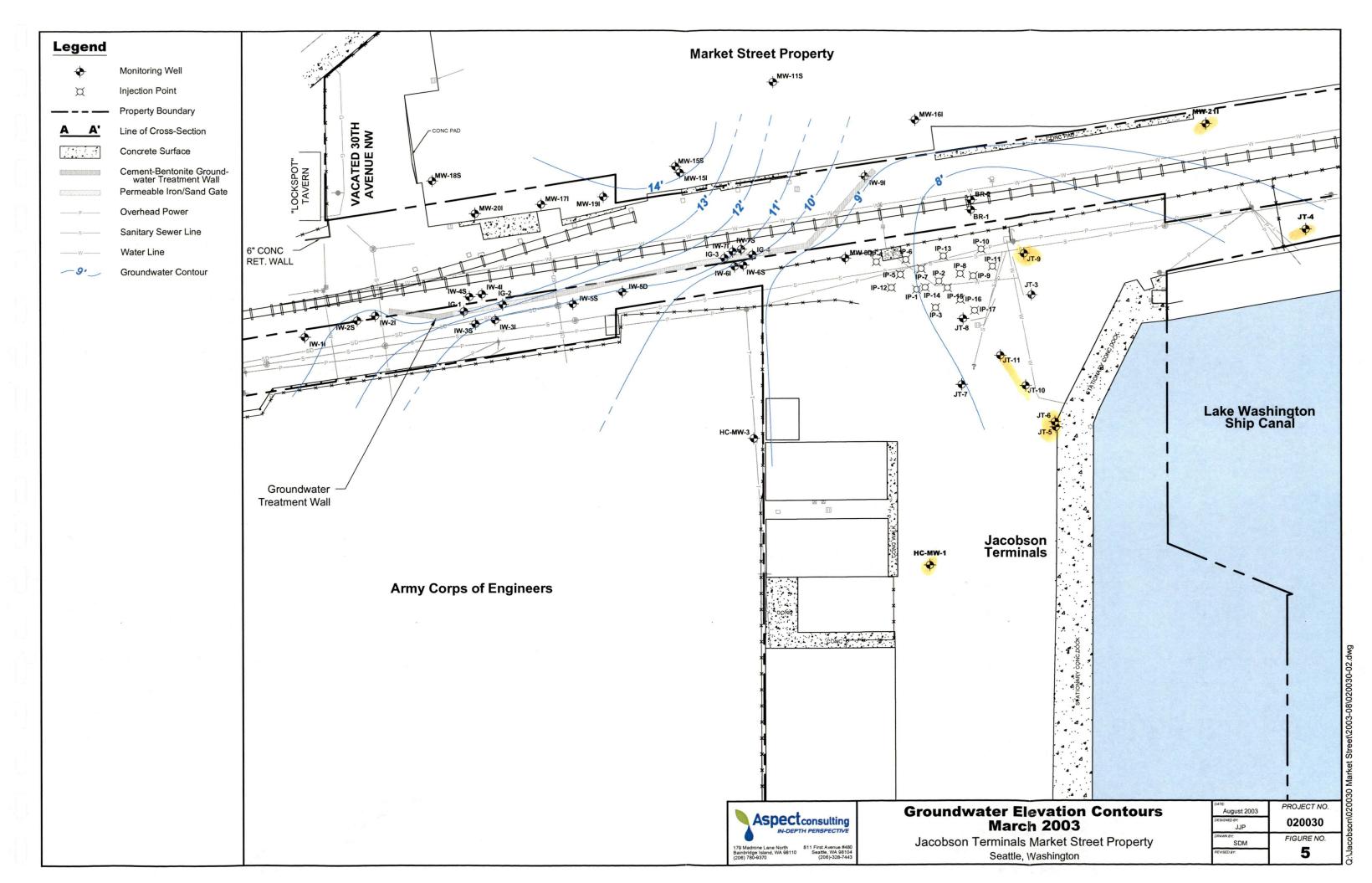
¹ Projected 5-Year Review by Ecology

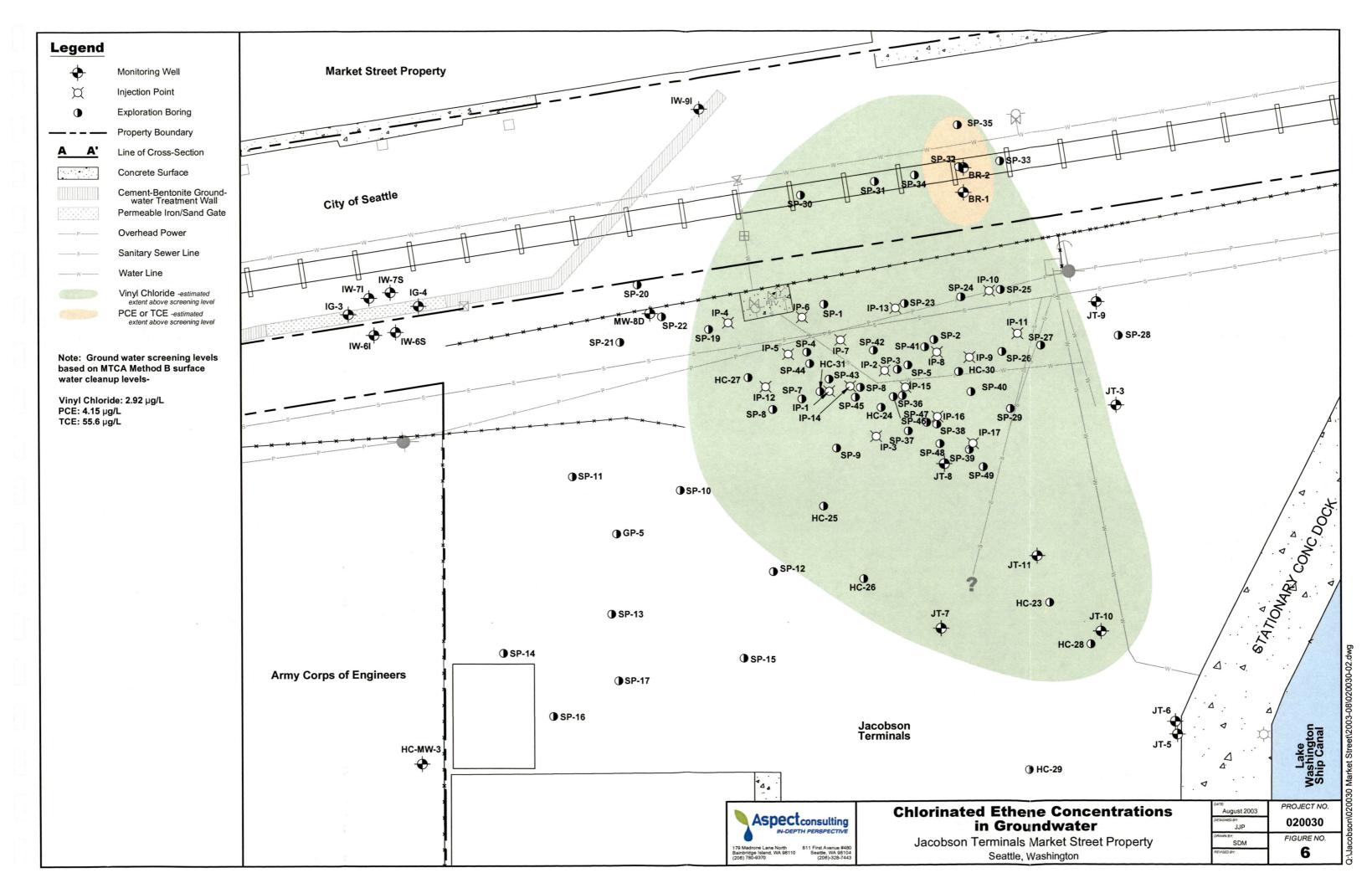












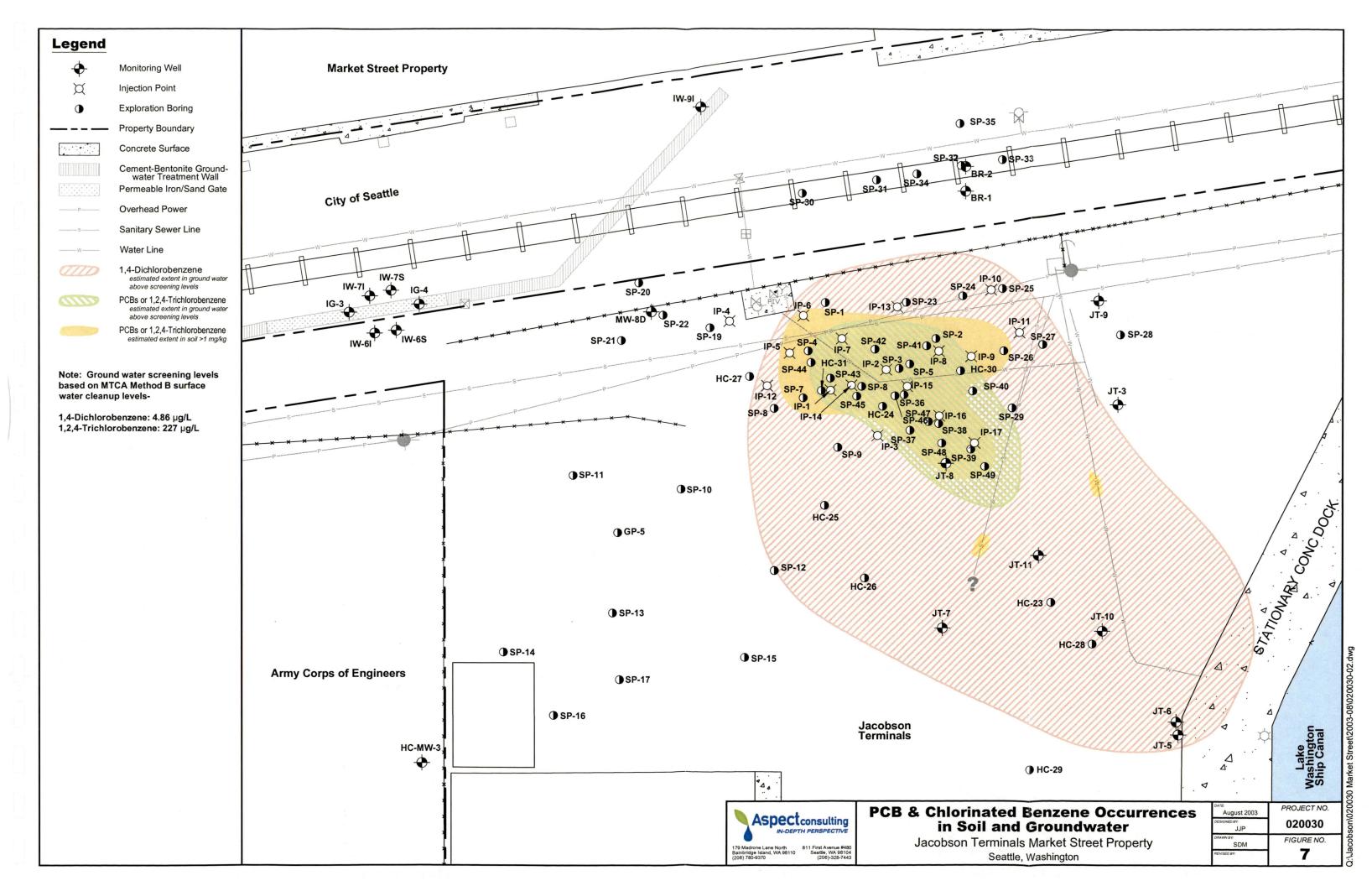
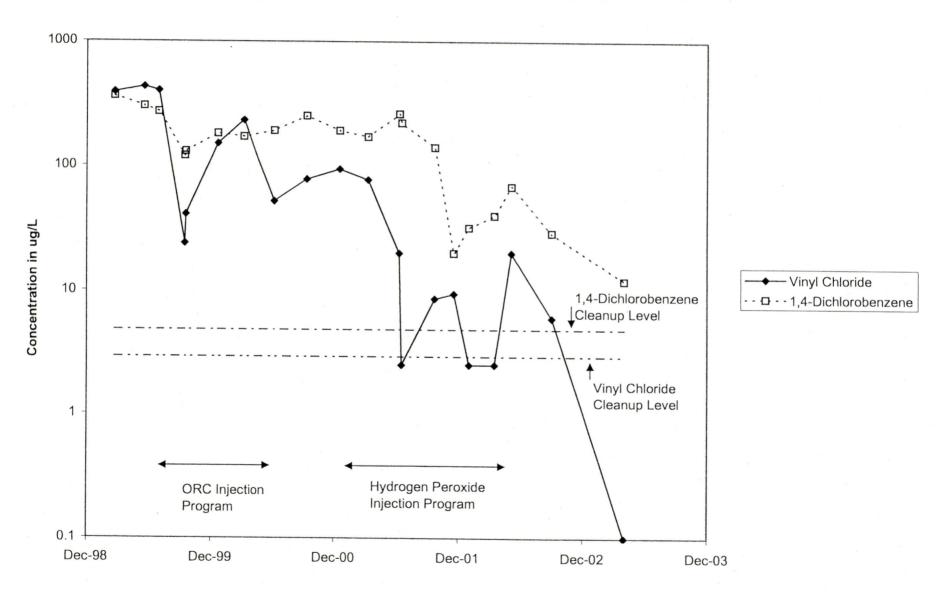
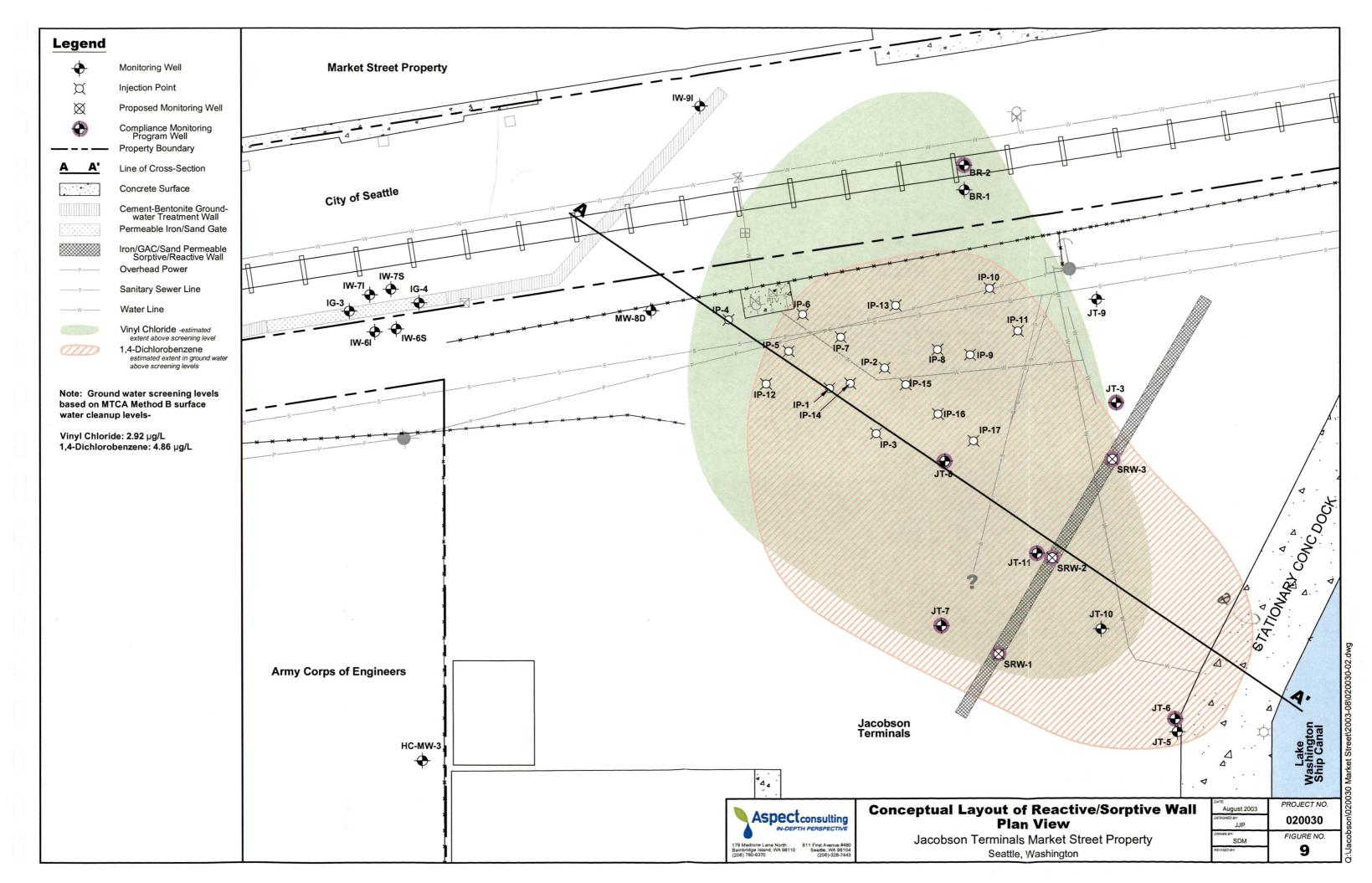
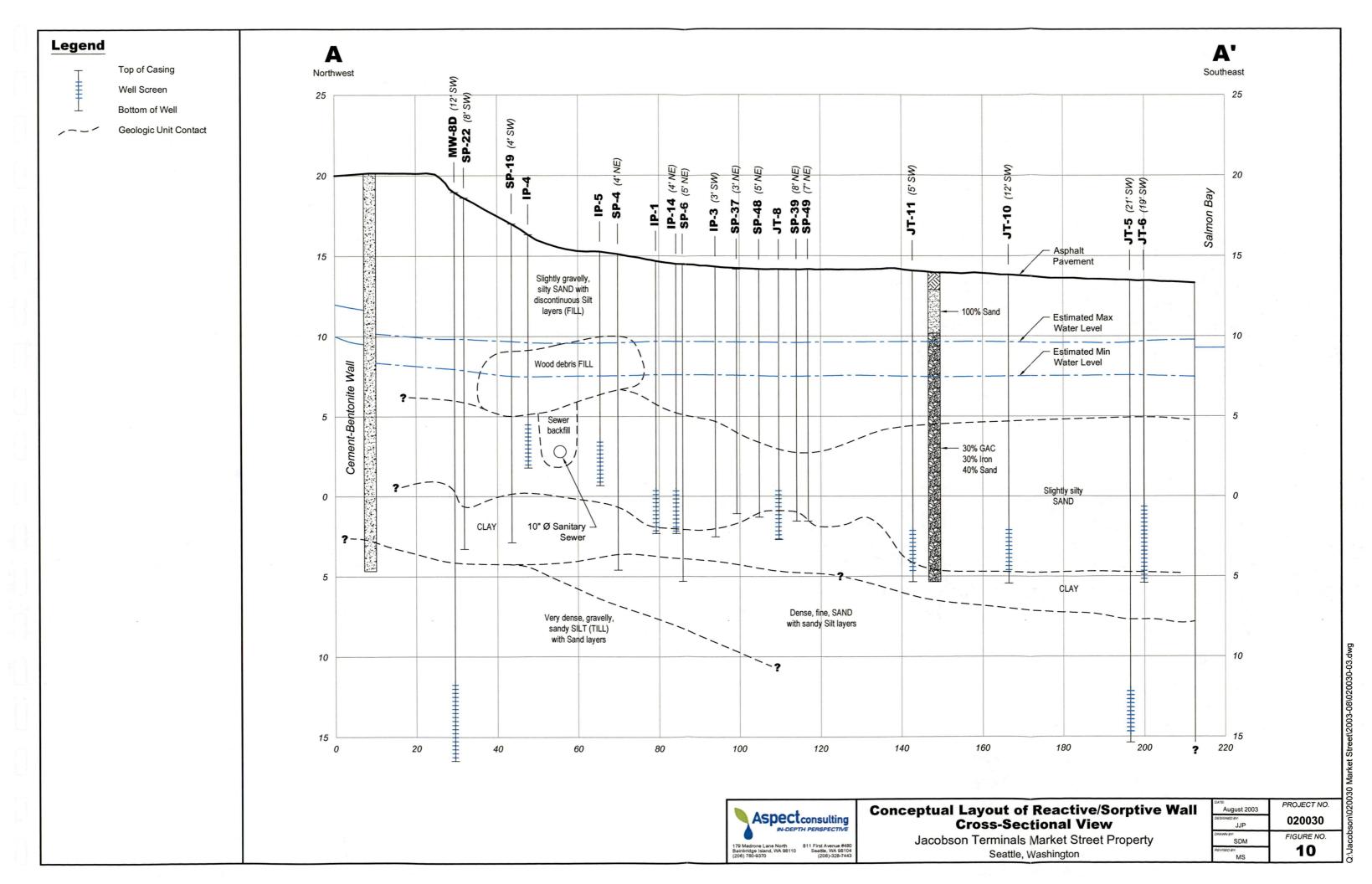


Figure 8 - Concentrations of Chemicals of Concern at JT-6







APPENDIX A

Soil and Groundwater Data City and Terminals Properties

APPENDIX A

Soil and Groundwater Data City and Terminals Properties

																			Sheet 1012						
Well	TOC Elevation in Feet	1/22/2000	3/7/2000	4/4/2000	5/5/2000	6/7/2000	7/6/2000	8/2/2000	9/7/2000	10/11/2000	11/10/2000		Water in Fee 1/15/2001		7/9/2001	8/6/2001	9/6/2001	10/11/2001	3/10/2002	4/15/2002	5/16/2002	6/4/2002	6/11/2002	10/1/2002	3/1//2002
Intermediate \	Nater-Bearing Zo	ne									2.2000			5.5.2001		5,0,2001	5/5/2001	10/11/2001	Jr 1312002	4/10/2002	3/10/2002	0/4/2002	0/11/2002	10/1/2002	3/ 14/2003
IW-11	20.76	7.78	7.45	8.02	8.46	8.57	8.79	9.01	9.31	9.56	9.14	9.06		8.55	8.57	8.87	8.85	9.15	_	7.66	8.28	9.4	8.48	9.48	7.43
IW-21	20.64	8.09	7.82	8.38	8.84	8.97	9.21	9.4	9.67	9.94	9.6	9.48	9.11	8.92	8.96	9.25	9.25	9.55		8.19	8.61	9.81	8.89	9.46	7.43
IW-31	19.24	9.06	8.85	9.36	9.68	9.7	9.74	9.93	9.96	10.1	9.75	9.8	9.25	9.33	8.88	9.38	9.71	9.44			8.44	9.1	8.97		
IW-41	19.64	5.9	5.67	6.16	6.66	6.83	7.25	7.39	7.6	8.11	7.82	7.65	7.21	7.15	7.04	7.36	7.41	7.67		9.07	4.72			9.84	8.27
IW-61	19.04	10.09	9.78	9.86	10.18	9.96	10.29	10.36	10.67	10.98	10.6	10.5	10.59	10	10.17	10.55	10.45	10.74	0.74	6.34	9.95	6.73	6.8	7.55	5.88
IW-71	19.84	8.63	8.36	8.79	9.19	9.29	9.44	9.73	10.11	10.21	9.49	9.33	8.84	8.84	8.91	9.41	9.22		9.74	9.95		9.93		11.12	9.75
IW-91	19.18	11.37	11.04	11.12	11.14	11.15	11.29	11.43	11.74	11.93	11.8	11.82	11.79	11.1	11.18	11.44		9.61	7.72	8.15	8.48	8.83	8.92	10.08	8.31
MW-15I	19.92	7.9	7.62	7.84	8.1	8.14	8.32	8.53	8.8	9.11	8.73	8.69			8.18	8.53	11.15	11.2	10.95	10.55	10.42	10.6	10.61	11.8	11.01
MW-161	20.04	10.97	10.57	10.36	10.65	10.65	10.79	10.95		11.46	11.33	11.39	_				8.5	8.75		7.63	7.85	-	8.02	9.19	4.32
MW-17I	20.43	5.6	5.35	5.86	6.34	6.47	6.65	6.87	7	7.2	6.72	6.67		n/a 6.52	11.27 6.41	11.26 6.69	11.18	11.08		10.74	10.35	-			
MW-19I	20.15	6.65	6	6.14	6.5	6.55	7.68	6.79	7.05	6.88	6.56	6.38			6.49		6.73	n/a		5.76	6.1		6.32	7.3	
MW-20I	21.89	NM	6.97	8.54	8.03	8.12	8.36	8.59	8.81	9.2	8.88	8.66		6.75		6.58	6.6	6.73		5.13	5.43		5.88	6.81	6.56
MW-211	19.06	9.63	9.17	9.7	9.65	9.7	10.84	10.16	10.62	10.84	10.73	10.89		8.25	8.16	8.55	8.54	n/a		abandon		-		-	
RW-8	16.74	NM	5.18	5.5	5.7	NM	6	7.28	Abandon		-		_	9.38	9.8	10.15	10.19	10.46		8.88	9.19	9.3	9.37	_	8.87
Downgradient	Shallow/Interme	diate Water-	Bearing Zon	e																					
HC-MW-3	16.94	7.7	7.45	7.48	7.3	7.26	7.38	7.57	7.88	8.08	0	0							7.64	0.57	7.00	7.00	7.0		
JT-3	13.42	6.5	5.93	5.63	5.39	5.3	5.95	5.7	6.11	6.3	8 N/A	8		E 40					7.64	6.57	7.23	7.33	7.3	-	-
JT-4	13.35	5.52	4.84	4.33	4	4.02	4.15				N/A 5.32	6.65	6.62	5.48	5.6	5.82	5.35	5.85	5.64	5.54	4.81	4.92	4.95	6.49	5.81
JT-6	12.75	5.3	3.15	4.05	3.71	3.74	3.85	4.32	4.83	5.05	5.32	5.58		3.94	4.16	4.33	4.52	4.96	4.8	n/a	-	3.99	4	5.32	4.56
JT-7	13.47	6.25	5.46	5.1	4.8	4.81		4.06	4.48	4.75	4.99	5.3	5.41	3.72	3.9	4.14	4.17	4.74	4.56	3.97	3.56	3.68	3.67	5.2	4.46
JT-8	13.31	0.25	5.46	5.1			4.98	5.13	5.5	5.79	5.99	6.21	6.27	4.89	4.95	5.27	5.05	5.59	5.36	4.9	4.47	4.6	4.6	6.08	5.4
JT-9	13.22	-		_	-				-								-		5.13		4.52	4.64	4.68	5.85	5.46
IG-1	19.68	6.55	5.65	6 22	£ 70	6.00	7.40	7.40	774	0.00	7.70					_		101					g		7.05
IG-2	19.36	6.31	5.65	6.23 5.9	6.78	6.92	7.12	7.42	7.71	8.08	7.79	7.59	-	7.13	n/a	7.41	7.44	n/a	-	n/a	6.47		6.83	7.98	
IG-3	19.38	8.1	5.88 NM	8.31	6.27 8.75	6.41	6.82	7.12	7.42	7.78	7.52	7.35	7.04	n/a	6.65	6.99	n/a	7.26		5.75	5.89	6.3	6.3	7.5	
IG-4	19.19					8.83	9.03	9.29	9.64	9.86	9.09	8.8	8.42	8.46	8.62	n/a	8.86	9.29	7.5	7.95	8.29	8.51	8.61	9.8	8.14
BR-1	18.74	8.16	7.74	8.16	8.57	8.63	8.8	9.12	9.46	9.65	8.9	8.63	8.3	8.26	8.36	8.86	n/a	n/a	7.23	7.8	8.06	8.3		9.59	
BR-2	19.4	-		-		-	-		-	-	-		-							11.13	10.9	11.03	11.02	11.98	11.85
		-			-		-	-	-	-								-	-	11.58	11.39	11.58	11.49	12.17	12.1
	-Bearing Zone	7.00	7.00	7.0	0.40		_																		
IW-2S	20.72	7.69	7.38	7.9	8.49	8.69	9	9.35	9.68	9.94	9.56	9.49		8.77	8.77	9.16	9.17	9.52	-	7.72	8.32	8.58	8.68	9.9	7.39
IW-3S	19.32	8.97	8.78	9.37	9.7	9.75	9.85	10,03	10.15	10.3	9.97	9.96	9.72	9.51	9.5	9.75	9.7	9.89	-	8.93	9.43	9.56	9.6	10.27	8.73
IW-4S	19.82	5.87	5.6	6.19	6.79	6.95	7.21	7.6	7.8	8.06	7.9	7.73	7.28	7.21	7.13	7.48	7.5	7.81	-	6.91	6.3	6.82	6.88	8.03	5.85
IW-5S	18.48	7.85	6.72	7.11	7.39	7.54	7.67	7.92	9.12	8.41	9.05	8.43	7.9	7.98	7.79	8.12	8.09	8.17		6.8	8.61	7.73	7.73	8.35	7.93
IW-6S	19.08	9.9	9.55	10.08	9.96	10.17	10.18	10.8	10.9	10.88	10.73	10.61	10.31	10.15	10.02	10.4	10.3	10.6	10.25	9.79	9.81	10.06	9.97	10.99	9.83
IW-7S	19.36	7.98	7.68	8.13	8.64	8.71	8.92	9.19	9.5	9.71	8.79	8.49	8.03	8.15	8.23	8.75	8.5	8.96	7.48	6.5	7.55	8.1	8.26	9.44	7.88
MW-1S	22.8	6.11	5.68	6.15	6.73	6.78	6.96	7.19	7.43	7.63	7.3	7.1	-	-			-		-	-					
MW-4	21.96	7.28	7.08	6.69	7.86	7.89	8.23	8.46	8.78	8.97	8.53	8.6						-							
MW-11S	20.31	7.57	7.45	7.43	7.58	7.71	7.81	7.95	8.18	8.44	8.44	8.38	_	7.87	7.74	7.89	7.83	8	-		6.4			7.63	
MW-15S	20.01	5.84	5.7	5.63	6.14	6.21	6.36	6.58	6.77	5.99	4.52	5.64			6.06	6.35	6.18	6.27	_	4.88	5.7		5.85	6.6	5.83
MW-18S	22.08	4.72	9.4	5.09	5.45	5.53	5.7	5.92	6.1	6.29	5.95	5.78		5.43	5.47	n/a	5.7	5.98		n/a	5.09		5.33	6.15	4.41
TT-1	21.54	6.01	5.69	5.72	6.42	6.44	6.73	6.97	7.12	7.19	7.02	6.88		-				-						_	
TT-2	21.36	5.71	5.43	5.8	6.23	6.24	6.48	6.45	6.79	6.86	6.64	6.6											_	-	
TT-3	23.16	7.59	7.32	7.67	8.09	8.1	8.45	8.6	8.96	9.8	8.83	8.75			-								_	_	
TT-MW-7	22.88	5.51	5.24	5.83	6.27	6.31	6.73	7.03	7.42	6.43	7	6.82							_						
Deep Water-Be																									
IW-5D	19.02	9.3	9.12	9.04	9.1	9.11	9.23	9.41	9.67	9.93	10.15	9.85	9.74	9.26	9.15	9.47	9.46	9.68		9.13	8.5		8.93	9.9	9
IW-8D	15.68	6.82	6.7	6.58	6.35	6.42	6.59	6.76	7.09	7.32	7.2	7.2	7.26	6.71	6.5	6.83	6.8	7.04	6.42	6.45	6.14			7.53	6.48
MW-1D	22.16	5.44	5.14	5.53	5.94	5.98	6.19	6.35	6.67	6.89	6.58	6.4			_	-	-	-		-			- 0.02		J. 40
JT-5	12.32	3.45	4.6	2.9	2.59	2.32	2.51	2.86	3.15	3.22	3.3	3.33	3.48	2.58	2.79	2.95	2.94	_	2.98	n/a	2.67	-	2.7	3.35	3.04
_ake	12.16	_	-	-	-	, -	-	'			-	_	_					-	-	3.28	2.96	2.94	2.95	4.51	3.7
njection Point	s																								
IP-1	13.9	-	_			_				_	_	-							5.62		1 07	5	E 00	F 0	5.70
IP-2	13.37	-				_	_		_	_	_	-			_		-		5.63		4.87	5	5.02	5.9	5.76
IP-3	13.62	-				_	-	_			_	_		_	_	-		-	5.37	_	4.65	4.82		6.01	5.64
IP-4	14.86	_	_	_	_	_	_	_	-		_			-	-		-		5.6		4.8	4.98	4.97	-	-
IP-5	12.81	_		_		-	_	_		-	_	-	-			-	-		6.73		6.11	6.3	6.3	7.62	6.97
IP-6	13.26		-	_		-	-				-	-		-	_		_		5.2	_	4.5	4.67	4.67	5.8	5.38
IP-7	13.26	_				_	-				-			-	-				5.14		4.42	4.7		5.81	5.35
IP-8	13.02	-	_				_	_			_	-			-		-		5.03	-	4.27	4.44		5.79	
IP-9			-	-	_		-	-	_		-	-		-			-		5.22		4.42	4.6	4.59		5.45
	13.28			-		-	-				-		-	-	-		-	-	5.45	-	4.62	4.78		6.15	5.62
IP-10	13.12			-	_		-	_					-						5.45	-	4.81	5.03		6.28	6.07
IP-11	12.96	-	-				-	-			-								5.63		5	5.2		6.23	6.41
IP-12	13.46				-						-	-	-		-				5.32	-	_	4.77		6.16	5.49
IP-13	13.3	,		-	-														5.33	-	4.66	4.85		6.17	5.63
IP-14	13.43				,		_	_		-					-				5.47		4.62	4.77	4.83	6.2	5.62
IP-15	13.38				-		-				_					_			5.46		4.68	4.79		5.98	5.61
IP-16	13.06	-					-	-			_	_			-			-	5.15	_	4.3	4.73		5.78	5.28
IP-17	13.1			-			-	_							_		_		5.2		4.45	4.12		5.76	
										eroppi)	***************************************	_						_	0.2		7.75	7.12	4.5	3.70	5.3

Sheet 2 of 2

	TOC	T T																	Sheet 2 of 2						
Well	Elevation																								
Weil		1/22/2000	2/7/2000	4/4/2000	E 14 10000	07/0000	71010000	0.10.10.00					Elevati	on in Feet											
	in Feet	1/22/2000	3/7/2000	4/4/2000	5/1/2000	6/7/2000	7/6/2000	8/2/2000	9/7/2000	10/11/2000	11/10/2000	12/7/2000	1/15/2001	6/6/2001	7/9/2001	8/6/2001	9/6/2001	10/11/2001	3/19/2002	4/15/2002	5/16/2002	6/4/2002	6/11/2002	10/1/2002	3/14/2003
Intermediate	e Water-Bear	ing Zone																							07.112000
IW-11	20.76	12.98	13.31	12.74	12.3	12.19	11.97	11.75	11.45	11.2	11.62	11.7		. 12.21	12.19	11.89	11.91	11.61		12.1	10.40	14.00	40.00	44.00	40.00
IW-21	20.64	12.55	12.82	12.26	11.8	11.67	11.43	11.24	10.97	10.7	11.04	11.16	11.53	11.72	11.68	11.39				13:1	12.48	11.36	12.28	11.28	13.33
IW-31	19.24	10.18	10.39	9.88	9.56	9.54	9.5	9.31	9.28	9.14	9.49	9.44	9.99				11.39	11.09	-	12.45	12.03	10.83	11.75	10.79	12.82
IW-41	19.64	13.74	13.97	13.48	12.98	12.81	12.39	12.25						9.91	10.36	9.86	9.53	9.8		10.17	10.8	10.14	10.27	9.4	10.97
IW-61		200000000000000000000000000000000000000							12.04	11.53	11.82	11.99	12.43	12.49	12.6	12.28	12.23	11.97		13.3	14.92	12.91	12.84	12.09	13.76
	19.04	8.95	9.26	9.18	8.86	9.08	8.75	8.68	8.37	8.06	8.44	8.54	8.45	9.04	8.87	8.49	8.59	8.3	9.3	9.09	9.09	9.11	8.95	7.92	9.29
IW-71	19.84	11.21	11.48	11.05	10.65	10.55	10.4	10.11	9.73	9.63	10.35	10.51	11	11	10.93	10.43	10.62	10.23	12.12	11.69	11.36	11.01	10.92	9.76	11.53
IW-91	19.18	7.81	8.14	8.06	8.04	8.03	7.89	7.75	7.44	7.25	7.38	7.36	7.39	8.08	8	7.74	8.03	7.98	8.23	8.63	8.76	8.58	8.57	7.38	8.17
MW-151	19.92	12.02	12.3	12.08	11.82	11.78	11.6	11.39	11.12	10.81	11.19	11.23			11.74	11.39	11.42	11.17	_	12.29	12.07	-	11.9	10.73	15.6
MW-161	20.04	9.07	9.47	9.68	9.39	9.39	9.25	9.09		8.58	8.71	8.65			8.77	8.78	8.86	8.96		9.3	9.69				15.0
MW-171	20.43	14.83	15.08	14.57	14.09	13.96	13.78	13.56	13.43	13.23	13.71	13.76		13.91	14.02	13.74	13.7					_			
MW-19I	20.15	13.5	14.15	14.01	13.65	13.6	12.47	13.36	13.1	13.27	13.59	13.77		13.4	13.66	13.74		12.42	-	14.67	14.33	-	14.11	13.13	
MW-201	21.89	_	14.92	13.35	13.86	13.77	13.53	13.3	13.08	12.69	13.01	13.23					13.55	13.42	-	15.02	14.72		14.27	13.34	13.59
MW-211	19.06	9.43	9.89	9.36	9.41	9.36	8.22	8.9	8.44				-	13.64	13.73	13.34	13.35	_		-			_		
RW-8	16.74	-	11.56	11.24	11.04		10.74			8.22	8.33	8.17		9.68	9.26	8.91	8.87	8.6	-	10.18	9.87	9.76	9.69	-	10.19
	10.74		11.50	11.24	11.04		10.74	9.46	-		_			-					_	_					-
lp	-4 Ch - 11 - 11			_																					
Downgradie			_											-											
HC-MW-3	16.94	9.24	9.49	9.46	9.64	9.68	9.56	9.37	9.06	8.86	8.94	8.94							9.3	10.37	9.71	9.61	9.64		
JT-3	13.42	6.92	7.49	7.79	8.03	8.12	7.47	7.72	7.31	7.12	-			7.94	7.82	7.6	8.07	7.57	7.78	7.88	8.61	8.5	8.47	6.93	7.61
JT-4	13.35	7.83	8.51	9.02	9.35	9.33	9.2	9.03	8.52	8.3	8.03	7.77		9.41	9.19	9.02	8.83	8.39	8.55			9.36	9.35	8.03	8.79
JT-6	12.75	7.45	9.6	8.7	9.04	9.01	8.9	8.69	8.27	8	7.76	7.45	7.34	9.03	8.85	8.61	8.58	8.01	8.19	8.78					
JT-7	13.47	7.22	8.01	8.37	8.67	8.66	8.49	8.34	7.97	7.68	7.48	7.26	7.2	8.58	8.52						9.19	9.07	9.08	7.55	8.29
JT-8	13.31	_		-		-	-			7.00	7.40					8.2	8.42	7.88	8.11	8.57	9	8.87	8.87	7.39	8.07
JT-9	13.22						_												8.18		8.79	8.67	8.63	7.46	7.85
IG-1	19.68	13.13	14.03	13.45	12.9	12.76	12 55	12.26	11.07	11.0	11.00	40.00		10						-	- "	-			6.17
IG-2	19.36	13.13					12.56	12.26	11.97	11.6	11.89	12.09	_	12.55	-	12.27	12.24	-			13.21	19.68	12.85	11.7	
IG-2			13.48	13.46	13.09	12.95	12.54	12.24	11.94	11.58	11.84	12.01	12.32		12.71	12.37	-	12.1	-	13.61	13.47	13.06	13.06	11.86	
	19.38	11.28		11.07	10.63	10.55	10.35	10.09	9.74	9.52	10.29	10.58	10.96	10.92	10.76		10.52	10.09	11.88	11.43	11.09	10.87	10.77	9.58	11.24
IG-4	19.19	11.03	11.45	11.03	10.62	10.56	10.39	10.07	9.73	9.54	10.29	10.56	10.89	10.93	10.83	10.33	-			11.39	11.13	10.89	-	9.6	_
BR-1	18.74	-	_		-			-	_	-							-			7.61	7.84	7.71	7.72	6.76	6.89
BR-2	19.4	-			-	-							-					_		7.82	8.01	7.82	7.91	7.23	
Shallow Wat	ter-Bearing Zo	one																	-	7.02	0.01	7.02	7.91	1.23	7.3
IW-2S	20.72	13.03	13.34	12.82	12.23	12.03	11.72	11.37	11.04	10.78	11.16	11.23	NM	11.95	11.95	11 50	11 55	44.0		40	40.4	10.11	10.01		
IW-3S	19.32	10.35	10.54	9.95	9.62	9.57	9.47	9.29	9.17	9.02	9.35	9.36				11.56	11.55	11.2	-	13	12.4	12.14	12.04	10.82	13.33
IW-4S	19.82	13.95	14.22	13.63	13.03	12.87	12.61	12.22	12.02				9.6	9.81	9.82	9.57	9.62	9.43		10.39	9.89	9.76	9.72	9.05	10.59
IW-5S	18.48	10.63	11.76	11.37	11.09	10.94				11.76	11.92	12.09	12.54	12.61	12.69	12.34	12.32	12.01	-	12.91	13.52	13	12.94	11.79	13.97
IW-6S							10.81	10.56	9.36	10.07	9.43	10.05	10.58	10.5	10.69	10.36	10.39	10.31		11.68	9.87	10.75	10.75	10.13	10.55
	19.08	9.18	9.53	9	9.12	8.91	8.9	8.28	8.18	8.2	8.35	8.47	8.77	8.93	9.06	8.68	8.78	8.48	8.83	9.29	9.27	9.02	9.11	8.09	9.25
IW-7S	19.36	11.38	11.68	11.23	10.72	10.65	10.44	10.17	9.86	9.65	10.57	10.87	11.33	11.21	11.13	10.61	10.86	10.4	11.88	12.86	11.81	11.26	11.1	9.92	11.48
MW-1S	22.8	16.69	17.12	16.65	16.07	16.02	15.84	15.61	15.37	15.17	15.5	15.7											_	-	-
MW-4	21.96	14.68	14.88	15.27	14.1	14.07	13.73	13.5	13.18	12.99	13.43	13.36				_									_
MW-11S	20.31	12.74	12.86	12.88	12.73	12.6	12.5	12.36	12.13	11.87	11.87	11.93		12.44	12.57	12.42	12.48	12.31			13.91				1
MW-15S	20.01	14.17	14.31	14.38	13.87	13.8	13.65	13.43	13.24	14.02	15.49	14.37		-	13.95	13.66	13.83	13.74					44.40	12.68	-
MW-18S	22.08	17.36	12.68	16.99	16.63	16.55	16.38	16.16	15.98	15.79	16.13	16.3		16.65	16.61		16.38		_	15.13	14.31		14.16	13.41	14.18
TT-1	21.54	15.53	15.85	15.82	15.12	15.1	14.81	14.57	14.42	14.35	14.52	14.66						16.1			16.99		16.75	15.93	17.67
TT-2	21.36	15.65	15.93	15.56	15.13	15.12	14.88	14.91	14.57	14.55	14.72							-		-					
TT-3	23.16	15.57	15.84	15.49	15.07	15.06	14.71	14.56	14.2	13.36		14.76	-			-	_		-						
TT-MW-7	22.88	17.37	17.64	17.05	16.61	16.57			15.46		14.33	14.41					-		-			-			-
Deep Water-F			17.04	17.00	10.01	10.57	10.15	13.85	15.46	16.45	15.88	16.06									- ,	-			-
IW-5D			0.0	0.00	0.00	0.04	0.70																		
	19.02	9.72	9.9	9.98	9.92	9.91	9.79	9.61	9.35	9.09	8.87	9.17	9.28	9.76	9.87	9.55	9.56	9.34		9.89	10.52		10.09	9.12	10.02
IW-8D	15.68	8.86	8.98	9.1	9.33	9.26	9.09	8.92	8.59	8.36	8.48	8.48	8.42	8.97	9.18	8.85	8.88	8.64	9.26	9.23	9.54	-	9.36	8.15	9.2
MW-1D	22.16	16.72	17.02	16.63	16.22	16.18	15.97		15.49	15.27	15.58	15.76				_		_	_			-			_
JT-5	12.32	8.87	7.72	9.42	9.73	10	9.81	9.46	9.17	9.1	9.02	8.99	8.84	9.74	9.53	9.37	9.38	-	9.34		9.65		9.62	8.97	9.28
	-																				0.00		3.02	0.57	3.20
Lake	12.16	-			-			-		-								_		8.88	9.2	9.22	9.21	7.65	8.46
1																				0.00	0.2	J. Z.Z.	3.21	7.00	0.40
Injection Poir	nts																								
IP-1	13.9	-										_		_	_				0 27		0.03	0.0	0.00		
IP-2	13.37	_			-	_			_			_		_	_				8.27	-	9.03	8.9	8.88	8	8.14
IP-3	13.62							100				_		_		-			8		8.72	8.55	8.55	7.36	7.73
IP-4	14.86				-		_		-			-						-	8.02	-	8.82	8.64	8.65	-	-
IP-5	12.81	_		-		_	-											-	8.13	-	8.75	8.56	8.56	7.24	7.89
IP-6							-		_		-				-	-			7.61	-	8.31	8.14	8.14	7.01	7.43
	13.26				-	-	-				_			_					8.12	-	8.84	8.56	8.57	7.45	7.91
IP-7	13	-		-	- ,		-	-								-	-		7.97	-	8.73	8.56	8.54	7.21	-
IP-8	13.02					-	-				-			_					7.8	_	8.6	8.42	8.43		7.57
IP-9	13.28	-	-					_	-		-								7.83		8.66	8.5	8.5	7.13	
IP-10	13.12						-		-		-						-	-	7.67						7.66
IP-11	12.96					-				_	_		_	_		_					8.31	8.09	8.09	6.84	7.05
IP-12	13.46					_					-				_	-			7.33		7.96	7.76	7.73	6.73	6.55
IP-13	13.3					-	_					_		-					8.14	-		8.69	8.67	7.3	7.97
IP-14	13.43			_	_	_	_			-		,		- "	-		, ,		7.97		8.64	8.45	8.45	7.13	7.67
IP-15	13.38	-		_		_		-	-		-								7.96	_	8.81	8.66	8.6	7.23	7.81
IP-16		_				-			_			-				_	-		7.92		8.7	8.59	8.57	7.4	7.77
	13.06	-										-							7.91	-	8.76	8.56	8.58	7.28	7.78
IP-17	13.1	-						-		-					-			-	7.9	_	8.65	8.98	8.6	7.34	7.8
																						_			
																									1

Summary of Volatile Organic Concentrations Detected in Groundwater

Monitoring Wells and Injection Points

1,2,4-TMB - I I I I I I I I I C 7 7 7 7 7 1 22222 2 0 $\supset\supset\supset\supset$ $\supset \supset \supset$ ココ つ つ 222 2222 $\supset \supset \supset$ na Chloromethane 1,1,2-TCA Benzene Toluene Ethylbenzene Xylenes Naphthalene 133 25.3 23 48,500 6,910 na 12,300 1 1 1 1 1 1 1 2 11111 $\supset \supset \supset \supset \supset$ - - - - -- - - - -2 D D 2 2 2 2 C 1 C 2 D - - - -- - - -2 D D - - - -- - - -0.5.0 1 1 C 22222 $\supset \supset \supset \supset \supset$ \supset 20 1 2 2 2 D D 2 D D 2 2 2 2 3.7 1 U 2222222 22222 22222 $\supset \supset \supset$ 1 0 0 22222 \supset 2 2 $\supset \supset \supset$ $\supset \supset \supset$ 1.3 1.2 1 U 2 D 1 22222 _ _ _ _ _ _ _ 1 U U $\supset \supset \supset$ 22 \supset 2 D 2 2 2 2 2 14 0 1 0 1 U 22222 36 27 1 89 3.8 1 4.7 1 1 1 2 2 2 2 1 2222 2 D D 1 0 0 2 D 22222 つ つ \supset $\supset \supset \supset$ >>>> 222 2 - - - 4 -1 1 1 D D D 10 25 10 11 \supset 22222 2222 2 2 D 3.1 1 U 1 C 1 U 1 U 1 0 0 1 32 1,2,3-TCB 6.6 1.0 U 5.5 1.0 U 3.1 2.4 1.0 U 0.1 0.1 0.0 0.1 21 1 U 110 1300 850 2500 92 111111-6.2 1.0 590 300 91 140 270 37 650 Concentration of Chlorinated Benzene Compounds in ug/L

CB m-DCB p-DCB o-DCB 1,2,4-TCB 1,2,3
030 na 4.86 4.200 1 1 1 0 0 0 111111-4.4 1.0 9.2 850 1200 9000 11000 4000 4000 2300 1100 1800 4700 1 6 1 5 0 1 7500 200 2600 250 62 64.4 550 190 88 13 65 9 2 7 7 D 0.5 U U L U L U L U L 1 U 7.2 10 1.4 2.6 1.0 U 24 1 U 31 670 59 580 550 550 230 310 54 210 120 36 36 100 80 75 7.4 6.1 J J J J J J J J J J 30 9.4 27.0 2.1 1.0 U p-DCB 4.86 1300 140 330 300 200 160 53 200 110 280 280 33 190 56 2.5 150 220 55 15 54 83 140 320 450 82 86 66 1 1 1 2 2 2 1 1 2 19 7.7 23.0 1.4 140 14 200 13 190 47 664871 4.6 170.0 120 32 6 27 41 160 400 350 160 74 82 0.50 U 6.00 U 6.00 U 6.00 U 7.00 U 7. 88 47 200 11 55 16 23 23 16 6.9 120 5 280 3.1 37 23 75 97 50 65 15 140 400 190 120 370 31 230 260 440 210 150 $\supset \supset \supset$ J U 1 U U) 1 1 0 $\supset \supset \supset \supset \supset$ 2222 1 C 1 1 1 U U U 450 400 ,500 1400 Concentration of Chlorinated Ethene Compounds in ug/l 1 U 1 U 2.2 _____ \supset $\supset \supset \supset \supset \supset$ $\supset \supset \supset$ \supset 22 2 400 420 900 620 0.2 U 1 U 5 U 5 U 5 U 5 U 5 U 15 1 U 9.3 1.5 5 U 7 1 U 2.9 11 5 U 1.2 4.7 1.1 cis-DCE 1300 1000 2200 3.4 999 43 25 22 22 170 120 14 190 21 96 20 62 62 29 0.2 U 1 U 5 U 5 U 5 U 5 U 5 U trans-DCE 32,800 2 D D 1 _____ 2 D $\supset \supset \supset \supset$ 2222 2 D 2 D 2 D D 2 2 2 2 $\supset \supset \supset$ $\supset \supset \supset$ ______ 2 2 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 1 1 0 0 2 D 1 0 222 2222 $\supset \supset \supset$ 1,1-DCE 1.93 ------Vinyl Chloride 5 U 1 U 16 2.4 59 130 0.2 U 5 U 0.2 U 0.2 U 0.2 U 5.5 5 U 1 U 6.7 0.2 U 0.2 U 41 410 81 74 52 59 370 32 500 23 340 300 140 68 160 55 4/15/2002 6/4/2002 3/13/2003 12/11/1997 4/8/1998 1/20/2000 4/7/2000 7/7/2000 10/11/2000 2/25/2003 5/1/2003 Date Level (1) 2/20/2001 4/10/2001 7/10/2001 10/22/2001 12/17/2001 6/3/2002 2/20/2001 4/10/2001 7/10/2001 10/22/2001 12/17/2001 6/3/2002 2/20/2001 4/10/2001 7/10/2001 10/22/2001 6/3/2002 10/22/2001 6/3/2002 3/13/2003 4/15/2002 1/30/2002 6/3/2002 1/30/2002 6/3/2002 1/30/2002 6/3/2002 10/22/2001 12/17/2001 6/3/2002 10/22/2001 12/17/2001 6/3/2002 3/13/2003 10/22/2001 12/17/2001 6/3/2002 Cleanup Depth in Feet 19 to 22 19 to 22 6 to 11 14 to 17 14 to 17 14 to 17 1.5 to 14. 14 14 14 to 17 14 to 17 14 to 17 1.5 to 7 11.5 to 1.5 to HC-MW-3 Location BR-1 BR-2 IP-10 IP-11 IP-1 IP-5 IP-2 IP-3 9-d1 1P-8 1P-7

JT-7	JT-6	JT-5 ³	JT-3	IP-17	IP-16	IP-14	IP-13	IP-12	Location
14 to 19	14 to 19	26 to 29	11.5 to 16.5	14 to 17	14 to 17	14 to 17	to	11.5 to 14.	Depth in Feet Clea
3/22/1999 7/30/1999 10/15/1999 10/18/1999 10/18/1999 1/21/2000 4/7/2000	3/22/1999 6/17/1999 7/30/1999 10/15/1999 10/18/1999 11/21/2000 4/7/2000 7/7/2000 11/16/2001 4/10/2001 1/16/2001 1/17/2002 6/17/2003 5/17/2003	3/22/1999 7/30/1999 4/10/2001	3/15/1996 3/22/1999 7/30/1999 10/15/1999 1/20/2000 4/7/2000 1/7/2000 10/11/2000 1/16/2001 4/10/2001 7/10/2001 7/10/2001 10/22/2001 10/22/2001 10/22/2001 12/17/2001 4/15/2002 6/4/2002 5/1/2003	6/3/2002	6/3/2002	6/3/2002	_	6/3/2002	Date
64 51 7 10 69 48	390 430 430 400 24 41 150 230 52 78 94 77 20 5 U 8.6 9.4 9.4 9.4 5 U 0.2 U 0.2 U	5 U	12 88 6.4 5 U 5 U 5 U 0.2 U 0.2 U	0.2 U	0.2 U	0.2 U	650 380	32	Concer Vinyl Chloride 2.92
5 5 5 5 C C C C C	1 1 1 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	5 U	5 5 C C C C C C C C C C C C C C C C C C	10		1 0		1 U	Concentration of Cloride 1,1-DCE
5 5 C C C C	9.5 11 12 6.4 10 55 55 55 55 71 71 71 71 71 71 71 71 71 71 71 71 71	5 U	1.7 5 5 C C C C C C C C C C C C C C C C C	1 0		1 0	1 U	1 U	trans-DCE 32,800
7.2 5 U 3 2.1 6.5 5 U	140 160 160 58 61 49 84 120 65 31 54 225 18 5 U 5 U 5 U 1 U	5 U 1 U	10 C C C C C C C C C C C C C C C C C C C	1 U	10	13	240 120	51	cis-DCE
	1.5 1.4 1.5 1.5 1.6 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7	100	1.5 1.0 1.0 1.0 1.0 1.0 1.0	1 U		1 0	1 U	1 U	Chlorinated Ethene Compounds in ug/L trans-DCE cis-DCE TCE 32,800 na 55.6
	1.3 1.2 1.0 1.0 3.1 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1	5.3 1 U 1 U	10 10 10 10 10 10	1 U		1 0	1 U	1 U	PCE 4.15
160 240 140 140	300 5 U 410 840 610 300 550 1100 660 480 500 550 930 1000 720 650 740	5 U	140 74 130 100 56 45 84 85 88 100 88 86 43	38.0	32.0	5.9	1 U 170	250.0	Conce CB 5,030
190 140 110 97 150 120	570 580 400 240 250 250 270 270 230 230 230 220 310 130 28 28 28 28 28	111	5 U 77 25 15 34 25 12 1 U 24 6.9 1 U 21 1 U 2.1 1 U 2.1	68	14	90	1 ∪ 8.6	12.0	Concentration of Chlorinated Benzene B m-DCB p-DCB o-DCB Ona 4.86 4.200
180 140 93 88 150 110	360 300 270 120 130 180 170 190 250 190 260 220 140 20 32 40 68	111	5 U 44 19 8.7 25 16 10 1 U 1 U 1 U 3.1 1 U 2.7	26	87	100	1 U	24.0	Chlorinated p-DCB 4 86
16 16 6.8 3.3 9.1	47 31 24 19 9.2 13 17 18 10 10 10 20 10 10 2.5 1 U	111	10 3.2 1.4 2.8 2.8 2.8 1 U 1 U 1 U 1 U 1 U 1 U	10	120	25	1 1	3.0	Benzene Cc o-DCB 4 200
11111	1.1.4.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1	1	111111111111	45	4600	2300	1800 23	4.9	Compounds in ug/L 1,2,4-TCB 1,2,3-TCB
11111	1.0 U	1 1	1111111111111	1 U	450	32	37 1 U	1.0 U	-
5 5 5 5 5 5 C C C C C C	1 1 1 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	5 U	1 1 5 1 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5		10		5 1 U	1 U	Chloromethane
11111	11111111111111111111111111111111111111	100			1 -	1 0	1 U	1 U	oncentratio 1,1,2-TCA
2.6 3.4 2.7 2.1 2 1 U	8.8 16 20 20 21 37 29 18 29 26 27 28 29 28 29 29 29 29 29 29 29 29 29 29 29 29 29	111		10	4.5		1 U 3.8	4.7	Concentration of Other D 1,1,2-TCA Benzene
1.6 1.0 1.0	1.2 1.4 1.1 1.7 2.8 2.8 4.0 1.0 2.4 1.0 2.4 2.9 2.9 1.0 2.1 1.7 1.0 1.7 1.0 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7	1.8 1 U			1 -		10	1 U	Toluene to
1.3		100			1 -	1 0	10	1 U	latile Organic Ethylbenzene
2.7 1.4 1 U .1 U 1.9 1 U	2.5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1100		10	1 -		1 0	1 U	ound
	S 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 0			1 -		10	1 U	ls in ug/L Naphthalene
11111	1.7 C	111	11111111111111111111111111111111111111				110	1 U	_

	Depth in		Conce	ntration of C	Chlorinated Et	hene Compo	ounds in ug	'L	Conce	entration of 0	Chlorinated	Benzene Co	ompounds in	n ug/L	C	oncentratio	n of Other	Detected Vo	olatile Organic	Compour	ds in ua/l	
Location	Feet	Date	Vinyl Chloride	1,1-DCE	trans-DCE	cis-DCE	TCE	PCE	CB	m-DCB	p-DCB	o-DCB	1,2,4-TCB			1,1,2-TCA	Benzene		_	Xylenes	Naphthalene	1,2,4-TMB
	Clear	up Level (1)	2.92	1.93	32,800	na	55.6	4.15	5,030	na	4.86	4.200	227	na	133	25.3	23	48.500	6.910	na	12,300	na
		7/7/2000	14	10 U	10 U	6.7	2 U	2 U	200	140	200	10			5 U	2 U	4.6	2 U	2 U	2 U	12,300	IIa
		10/11/2000	31	5 U	5 U	5 U	1 U	1 U	190	90	110	5.3			5 U	1 U	2.4	1 U	1 U	1 U		
		1/16/2001	5 U	5 U	5 U	5 U	1 U	1 U	26	20	22	1 U			5 U	1 U	1 U	1 U	1 U	1 U		
		4/10/2001	50	1 U	1 U	2.3	1 U	1 U	180	77	82	4.1	1 U	1 U	1 U	1 U	1 /	1 1	1 U	1 U	1 U	4.11
		7/10/2001	45	5 U	5 U	16	1 U	9.6	240	98	130	7.8			5 U	1 U	1 U	1 U	1 U			1 U
		10/22/2001	32	5 U	5 U	5 U	1 U	1 U	150	42	74	5.0			5 U	1 U	1 U	1 1	1 U	1 U		
		12/17/2001	30	1 U	1 U	1 U	1 U	1 U	170	86	91	4.7	2.8	1 U	15	1 U	2	1 0	1 U	1 U 1 U	4.11	4.11
		4/15/2002	90	5 U	5 U	5 U	1 U	1 U	140	140	170	5.6			5 U	1 U	1 U	1.4	1.3	1 0	1 U 1 U	1 U
		6/4/2002	37	1 U	1 U	1 U	1 U	1 U	150	73	82	3.7	85.0	17	1 U	1 U	1 U	1.4 1 U	1.3 1 U	1 U	1 U	1 U
		10/1/2002	29	1 U	1 U	1 U	1 U	1 U	200	57	71	6.5			5 U	1 U	1.8	3.2	1.7	6.3		1 U
		5/1/2003	25	1 U	1 U	1 U	1 U	1 U	113	33	40	1.0 U	1.0 U	1 U	1 U	1 U	1.0	1 U	1.7 1 U	1 U	 1 U	1 U
															10	1 0	1 0	10	1 0	1 0	1 0	10
JT-8	14 to 17	1/11/2001	86	5 U	5 U	19	1 U	1 U	630	260	160	21			5 U	1 U	4.4	2	1 U	2.7		
		2/20/2001	5 U	5 U	5 U	5 U	1 U	1 U	530	210	200	1 U			5 U	1 U	1 U	1 U	1 U	1 U		
		4/10/2001	20	5.8	1 U	1 U	1 U	1 U	150	660	670	18	250	26	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
		7/10/2001	42	1 U	1 U	8.7	1 U	1 U	370	210	210	67	1300	87	1 U	1 U	3.4	1 U	1 U	1 U	1 U	1 U
		10/22/2001	0.2 U	1 U	1 U	1 U	1 U	1 U	46	82	150	120	1300	180	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
		12/17/2001	0.2 U	1 U	1 U	1 U	1 U	1 U	53	110	340	290	4500	470	1 U	1 U	1 U	1 U	1 U	1 U	- 1 U	1 U
		6/4/2002	11	1 U	1 U	1 U	1 U	1 U	260	79	240	220	3900	420	1 U	1 U	1 U	1 U	1 U	1 U	8.9	1 U
		3/13/2003	0.2 U	1 U	1 U	1 U	1 U	2.1	220	82	450	560	9100	650	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
JT-9	12.5 to 17.	3/13/2003	7.4	1 U	1 U	1 U	1 U	1 U	1.0 U	1.0 U	1 U	1.0 U	1 U	1 U	1 U	1.11	44	4.11	4.11	4.11	4.11	4.11
										1.0 0	10	1.0 0	1 0	. 10	1 0	1 U	44	1 U	1 U	1 U	1 U	1 U
JT-11	16 to 19	6/5/2003	38	1 U	1 U	57	1 U	1 U	360.0	90.0	50	4.8	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U

Notes:

- (1) Cleanup level based on Cleanup Action Plan (Hart Crowser, 1999) or, if not included, on MTCA Method B Surface Water Cleanup levels
- J Estimated value
- U Not detected at indicated detection limit
- -- Not analyzed
- CB Chlorobenzene
- m-DCB m-Dichlorobenzene
- p-DCB p-Dichlorobenzene o-DCB o-Dichlorobenzene
- 1,2,3-TCB 1,2,3-Trichlorobenzene
- 1,2,4-TCB 1,2,4-Trichlorobenzene
- 1,2,4-TMB 1,2,4-Trimethylbenzene

PCB Concentrations in Groundwater

Sample Location	Sampling Date	Total Suspended Solids in mg/L	PCB Concentration in ug/L (Aroclor 1260)
JT-3			
010	4/10/2001		0.4 U
	12/17/2001		0.4 U
	6/4/2002	7.4	1.5
	10/1/2002	1 U	0.033 U
JT-6			0.000 0
	4/10/2001		0.4 U
	12/17/2001	1.4	0.017 U
	6/4/2002	23	0.2
	10/1/2002	3.1	0.056
	6/12/2003	25	0.089

)	Calliple Deput		ווכפוווומווטוו טו	Concentration of Childrinated Allphatic Compounds in ugh	וומנוכ בטוווסטנו	וחא ווו מארר			COLICELLIA	Concentration of Chionnated Benzenes in ug/	aled perizenes	s in ug/L			Concentrat	ion of Other D	etected VOCs	in ug/L	
Location	Date	in Feet	Vinyl Chloride	1,1-DCE	trans-DCE	cis-DCE	TCE	PCE	СВ	m-DCB	p-DCB	o-DCB	1,2,4-TCB	1,2,3-TCB	Chloroform	Benzene	enzene Toluene Xylenes Naphthalene 1,2,4-TMB	Xylenes N	aphthalene 1	1.2.4-TMB
			270		1	}				*										
10-24	10/24/2000	14 10 17	0/7	000	50 0	80	84	140	240	700	1,200	670	1	1	10 U	10 U	10 U	10 U	1	1
HC-25	10/24/2000	14 to 17	200	25 U	25 U	51	25 U	25 U	360	150	230	680	ı	ı	л i	л (л (л (1	1
HC-26	10/24/2000	14 to 17	150	5 U	4.2 J	18	1 _	1 _	45	46	46	120	1	ı	1 0	1 0	1 0	<u>.</u> (
HC-27	10/24/2000	14 to 17	240	5 U	5 0	110	1	1 _	14	5.2	12	1 :	1	1	л w -			<u>.</u>	1	
HC-28	10/24/2000	14 to 17	620 J	5 _	33	330 J	1 _	1 _	34	67	ى د	1 .						<u>.</u> -		1
HC-29	10/24/2000	14 to 17	164	5 _	6.7	190	1	1	160	140	140	1 (١	١
HC-30	10/24/2000	14 to 17	300	50 U	50 U	110	10 U	10 U	50 U	330	330	8 :	ı	1	5 -	<u>1</u>	<u></u>	<u>-</u>	1	,
HC-31	10/24/2000	14 to 17	194	50 U	50 U	120	37	34	50 U	150	220	300	1	!	50 U	10 1	10 11	10 11	1	,
HC-32	10/24/2000	14 to 17	500	50 U	50 U	50 U	76	41	110	140	190	1200	ı	1	50 U	10 U	10 U	10 U	I	ı
SP-15S	5/22/2001	14 to 17	1 U	<u></u>	1	1		<u>.</u>	22	л	7.1		_		_	_				
20150	5/00/0001	31 to 34				- (_ (- 0		. (-	-	-	-	_	9.3	-
00.700		1707					-	-	-	-	_	_	1	1 0	1		1	1	1	1
07-1/U	5/27/2007	14 to 1/	1 0	1 0	1 0	1		1 0	1 0	1 U	1 0	1 _	1	1 _	1 _	1 _	1 _	1 U	1 U	1 U
SP-30	1/15/2002	20 to 22	59	1 U	, 1 C	95	1	1 _	1 _	1	1 U	1		1	1	1	<u>.</u>			<u></u>
SP-31	1/15/2002	20 to 22	8.8	1 _	1			1	1 _		1 .	1 .	<u> </u>	1 0	1 0	۸ - ۸				
SP-32	1/15/2002	20 to 22	31	2.3	4.9	1,700	5,400	30,000	1 _	1 _		1 U	1 0	1 .	1 .	100	27	ω Σ -		<u>.</u> - 0
SP-32(B)	1/30/2002	20 to 23	47	1 _	3.6	1,900	1,100	3,200	1 _	1	1 _	1	1 -	1 .		53	1 !	4 9	_ (<u>.</u>
SP-33	1/30/2002	18 to 21	4.7	· 1 C	1		1 _	1	1 _	1 0	1	1		1 .	1 -	170	40	13		7
SP-34	1/30/2002	17 to 20	68	1 U	1 0	9.5	1	1	1 _	1	1	1 0	1 .	1 .	1 .	1 3	1	1		- -
SP-35	1/30/2002	18 to 21	150	.1 _		510	27	65	1 _	1 _	1	1 0	1	1 .	1.	45	л Л -	37-0	= c	

J Estimated value
U Not detected at indicated detection limit
- Not analyzed
CB Chlorobenzene
m-DCB m-Dichlorobenzene
p-DCB p-Dichlorobenzene
o-DCB o-Dichlorobenzene
1,2,3-TCB 1,2,3-Trichlorobenzene
1,2,4-TMB 1,2,4-Trimethylbenzene

Notes:

Summary of Chemical Concentrations Detected in Soil

			PCB Concentration		2 20											T								
Location	Date	Sample Depth in Feet	in mg/kg Aroclor 1260	Vinyl Chloride	oncentration of 1,1-DCE	Chlorinated Aliph trans-DCE	natic Compoun cis-DCE	ds in ug/kg TCE	PCE	СВ	Concent 1,3-DCB	ration of Chlor 1,4-DCB	rinated Benzen 1,2-DCB	es in ug/kg 1,2,4-TCB	1,2,3-TCB	Chlomform	Deserve			Detected VOC				
0-4-6 200	10 - Di-hih						0.0 0 0 0		. 02		1,0-000	1,4-000	1,2-000	1,2,4-100	1,2,3-100	Chloroform	Benzene	Toluene	Xylenes	1,2,4-TMB	1,3,5-TMBn	n-Butylbenzen	НСВ	Naphthalene
HC-31	10/24/2000	nzene Assessme 11 to 14	ent _	50 U	50 U	50.11	50.11	50.11	50.11	500	040													
HC-31	10/24/2000	14 to 17	_	50 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U	580 250 U	210 230	380 320	4,000	_		50 U	50 U	50 U	50 U	-		-	-	
										255 5	200	020	450			30 0	50 U	50 U	50 U	- '	-		-	-
February 200 IP-1	01 Injection Po 2/20/2001		260 TIC	50.11	50.11	50.11	· ·																	
IP-2	4/11/2001	Drill Cuttings Drill Cuttings	360 TIC 110	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	500 U 260	660 920	2,700 2,900	3,200 4,700	230 TIC		50 U	50 U	560	50 U	-	-	-		-
IP-3	4/11/2001	Drill Cuttings	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	120	170	330	50 U	560,000 2,800	13,000 450	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U	50 U	50 U	50 U	50 U
JT-8	2/20/2001	Drill Cuttings	-	50 U	50 U	50 U	50 U	50 U	50 U	250 U	50 U	370	50 U	_	-	50 U	50 U	180	50 U	50 U	50 U	50 U	50 U	50 U
JT-8	4/11/2001	Drill Cuttings	2.5	-	_			-	-	-	-		-		-	-			-	-	-		-	-
,	CB/TCB Assess	ment																						
SP-1 SP-2	5/23/2001 5/22/2001	12 to 16	2.7	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-2	5/22/2001	12 to 16 16 to 20	550 0.31	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	840	620	50 U	11,000	790	50 U	50 U	50 U						
SP-3	5/22/2001	12 to 16	14	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U	50 U	520 5,800	50 U 450	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-4	5/23/2001	8 to 12	530	50 U	50 U	50 U	50 U	50 U	50 U	790	250	550	50 U	28,000	2,000	50 U	50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U
SP-4 SP-5	5/23/2001	12 to 16	3.4	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	840	210	50 U	50 U	50 U						
SP-5 SP-5	5/22/2001 5/22/2001	0 to 4 4 to 8	18 3.6	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U 50 U	570 5,800	50 U 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-5	5/22/2001	16 to 20	0.43	50 U	50 U	50 U	50 U	50 U	50 U	5,800 50 U	50 U	210 50 U	50 U 50 U	50 U 900	50 U	50 U 50 U	50 U	50 U 50 U	50 U	220	100	50 U	50 U	210
SP-6	5/23/2001	0 to 4	0.35	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U
SP-6 SP-6	5/23/2001	8 to 12	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	170	50 U	150	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-6	5/23/2001 5/23/2001	12 to 16 16 to 20	25 1.2	50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U 50 U	930	860	180	45,000	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-7	5/22/2001	12 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U	50 U	680 410	560 50 U	50 U 50 U	2,700 1,600	2,500 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-8	5/22/2001	4 to 8	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	310	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U
SP-8	5/22/2001	12 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-9 SP-10	5/22/2001 5/22/2001	12 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	140	450	150	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	140
SP-10	5/21/2001	16 to 20 12 to 16	0.2 U 0.2 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U 50 U	50 U	50 U 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-12	5/22/2001	4 to 8	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U
SP-12	5/22/2001	16 to 20	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	240	50 U	180	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U
SP-13 SP-14	5/21/2001 5/21/2001	12 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-14	5/21/2001	4 to 8 16 to 20	0.2 U 0.2 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-15	5/21/2001	16 to 20	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U
SP-15	5/21/2001	24 to 28	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U	50 U 50 U
SP-16	5/21/2001	0 to 4	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-16 SP-17	5/21/2001 5/21/2001	16 to 20 0 to 4	0.2 U 0.2 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-17	5/21/2001	16 to 20	0.2 U	50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-17	5/21/2001	20 to 24	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U
SP-18	5/21/2001	0 to 4	0.22	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	260	50 U	50 U	50 U	50 U	360	50 U	250	440	820
SP-18 SP-18	5/21/2001 5/21/2001	4 to 8 16 to 20	0.2 U 0.2 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-19	5/23/2001	8 to 12	820	50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U 15,000	50 U 320	50 U 1,400	50 U	50 U 900	50 U	50 U	50 U 450	50 U	50 U	50 U				
SP-19	5/23/2001	16 to 20	0.5	50 U	50 U	50 U	50 U	50 U	50 U	710	50 U	50 U	50 U	190	50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U 50 U	50 U	50 U 50 U
SP-20	6/6/2001	16 to 20	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-20 SP-21	6/6/2001 6/6/2001	20 to 24 8 to 12	0.2 U 0.12 J	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	130
SP-21	6/6/2001	12 to 16	0.12 J	50 U	50 U	50 U 50 U	1,400 50 U	50 U 50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-22	6/6/2001	8 to 12	0.16 J	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U
SP-22	6/6/2001	16 to 20	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-23 SP-24	6/6/2001 6/6/2001	12 to 16	0.2 U 17	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-24	6/6/2001	4 to 8 12 to 16	0.2 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U	280 50 U	50 U 50 U	170 50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-25	6/6/2001	0 to 4	9.5	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U 50 U	50 U	50 U 50 U	50 U	50 U	50 U 1,000
SP-25	6/6/2001	12 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-26 SP-26	6/6/2001 6/6/2001	4 to 8 12 to 16	0.2 U	50 U 50 U	50 U 50 U	50 U	50 U	50 U	50 U	4,400	50 U	280	50 U	50 U	1,800	50 U	50 U	170						
SP-27	6/6/2001	12 to 16	0.2 U 0.2 U	50 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U	340 50 U	620 380	530 280	50 U 50 U	26,000 3,200	280	50 U	50 U	50 U						
SP-28	6/6/2001	12 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	160	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U 50 U	50 U	50 U 50 U	50 U 50 U	50 U 50 U	50 U
SP-29	6/6/2001	0 to 4	0.6	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	210	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U 50 U
SP-29	6/6/2001	12 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	490	250	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
	Injection Point	Installation																						
IP-4 S1	8/22/2001	2.5 to 4	4.7	-	-	-	-	-	-	-	_	"			-	-			-	_			_	-
IP-4 S2 IP-5 S1	8/22/2001 8/22/2001	10 to 11.5	96	-	-	-	-		-	-	-	-	-		-	-		-	-	-	-		-	
IP-6 S1	8/22/2001	10 to 11.5 10 to 11.5	0.97 280	_	_		-		-	_	-	-		-	-	-	-	-	-					-
IP-7 S1	8/23/2001	2.5 to 4	0.2 U	_	-	_	_	_	_		-	-	-	-	-	_		_	-	-	_		-	
									1		_			_				_						

			PCB Concentration	T						Γ														
		Sample Depth	in mg/kg	Conc	centration of Ch	lorinated Alin	hatic Compour	de in ua/ka			0		- 4- 4- 5											
Location	Date	in Feet	Aroclor 1260	Vinyl Chloride		trans-DCE	cis-DCE	TCE	PCE	СВ	1,3-DCB	tration of Chlor 1.4-DCB		0 0	400 700	011	_			Detected VOC	5 5			
IP-7 S2	8/23/2001	10 to 11.5	0.41	- Villy Official	1,1-002	tialis-DCL		TOE	-	СВ	1,3-006	1,4-DCB	1,2-DCB	1,2,4-TCB	1,2,3-TCB	Chloroform	Benzene	Toluene	Xylenes	1,2,4-TMB	1,3,5-TMBn-E	Butylbenzen	HCB	Naphthalene
IP-8 S1	8/22/2001	15 to 16.5	32		-		_	-	_		_		_	-	_	_				-				-
IP-9 S1	8/21/2001	15 to 16.5	400	_	_			_	_		_			-		_	_		-					
IP-10 S1		15 to 16.5	0.2 U	_				_			_	_		-	-	-	-	-					-	
IP-11 S1		14.5 to 16	4.6	_			_	_	_	_	_	_			-	_	-			-			-	
IP-12 S1		10 to 11.5	0.19 J					-			_	_			_	-	_		_	-				
IP-13 S1	8/23/2001	12.5 to 14	0.28	_								_	_	_	_	_	-			-	-		-	-
												-	-	_	-	_		-		-				-
January 200	02 Railroad Track	k Investigation																						
SP-32	1/15/2002	16 to 20		50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	60 11	50 U
SP-35	1/30/2002	16 to 20		50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	20 U	50 U	50 U	330	50 U	50 U	50 U	50 U
SP-35	1/30/2002	20 to 23	-	50 U	50 U	50 U	50 U	50 U	6.7 J	50 U	50 U	50 U	50 U	50 U	50 U	50 U	20 U	50 U	50 U	160	50 U	50 U	50 U	50 U
				(*)								00 0	50 0	00 0	30 0	30 0	20 0	30 0	30 0	100	30 0	50 0	50 0	50 0
January 200	02 Performance I	Monitoring														*								
IP-1(B)	1/15/2002	8 to 12	0.2	50 U	50 U	50 U	50 U	50 U	50 U	950	280	790	100	420	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
IP-1(B)	1/15/2002	12 to 16	0.2	50 U	50 U	50 U	50 U	50 U	50 U	50	200	170	50 U	200	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
IP-6(B)	1/15/2002	8 to 12	6	50 U	50 U	50 U	50 U	50 U	50 U	3,400	650	1,300	120	1,200	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-2(B)	1/15/2002	12 to 16	410	50 U	50 U	50 U	50 U	350	1,400	50 U	50 U	50 U	50 U	200	300	50 U	20 U	50 U	50 U	50 U	50 U	50 U	500	350
SP-4(B)	1/15/2002	8 to 12	210	50 U	50 U	50 U	50 U	50 U	330	2,000	2,600	11,000	1,500	270,000	12,000	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-6(B)	1/15/2002	12 to 16	800	50 U	50 U	50 U	50 U	50 U	6.7 J	210	1,900	2,000	500	130,000	5,900	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-19(B)		12 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	6.7 J	50 U	120	140	50 U	7,800	690	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-26(B)		12 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	6.7 J	220	350	290	50 U	2,100	140	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-36	1/29/2002	12 to 16	210	50 U	50 U	50 U	50 U	50 U	6.7 J	150	1,500	1,200	280	240,000	4,500	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	110
SP-37	1/29/2002	13.5 to 15.5	0.2 U	50 U	50 U	50 U	50 U	50 U	6.7 J	50 U	1,100	1,000	140	8,200	250	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	68
SP-38	1/29/2002	13 to 16	880	50 U	50 U	50 U	50 U	50 U	6.7 J	420	13,000	11,000	3,200	310,000	2,400	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-39	1/29/2002	10 to 13	0.2 U	50 U	50 U	50 U	50 U	50 U	6.7 J	88	470	410	130	1,900	2,400	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-39	1/29/2002	13 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	6.7 J	50 U	300	260	50 U	3,000	190	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-40	1/29/2002	10 to 13	0.2	50 U	50 U	50 U	50 U	50 U	6.7 J	170	130	180	50 U	710	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-40	1/29/2002	13 to 16	0.2 U	50 U	50 U	50 U	50 U	50 U	6.7 J	50 U	160	120	50 U	440	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
		2.							1									,			00 0	00 0	00 0	00 0
	Railroad Monitor	1	ation						1															
BR-1	4/11/2002	21.5 to 23	, p	50 U	50 U	50 U	380	20 U	330	50 U	50 U	50 U	50 U	50 U	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
BR-2	4/11/2002	22 to 23.5		50 U	50 U	50 U	470	620	960	50 U	50 U	50 U	50 U	50 U	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
4 2000 0																								
SP-41			est previous sample		50 11	==																		
SP-41 SP-42	6/5/2002	12 to 16	290	50 U	50 U	50 U	50 U	20 U	20 U	6,600	5,600	15,000	1,100	84,000	7,200	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	200
1	6/5/2002	8 to 12	690	50 U	50 U	50 U	1,500	130	20 U	5,000	5,600	14,000	820	14,000	7,800	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	710
SP-42 SP-43	6/5/2002	12 to 16	2.4	50 U	50 U	50 U	50 U	20 U	20 U	610	970	2,500	130	6,300	180	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	180
SP-43 SP-43	6/5/2002	8 to 12	42	50 U	50 U	50 U	50 U	20 U	20 U	22,000	4,200	4,800	640	27,000	1,000	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-43 SP-44	6/5/2002	12 to 16	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	390	700	850	180	6,600	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-44	6/5/2002 6/5/2002	8 to 12	200	50 U	50 U	50 U	50 U	20 U	20 U	880	2,100	7,800	2,100	180,000	26,000	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	690
SP-45	6/5/2002	12 to 16	290	50 U	50 U	50 U	50 U	20 U	20 U	190	1,500	1,000	430	98,000	9,000	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-45 SP-45	6/5/2002	4 to 8	0.33	50 U	50 U	50 U	50 U	20 U	20 U	760	290	340	100	3,500	370	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-45	6/5/2002	8 to 12	0.2 U	50 U	50 U	50 U	400	20 U	20 U	110	50 U	210	50 U	1,600	220	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-46	6/5/2002	12 to 16	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	50 U	940	550	88	3,200	290	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-47	6/5/2002	12 to 16	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	50 U	1,600	1,200	190	4,600	190	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-47	6/5/2002	8 to 12 12 to 16	0.2 U	830	50 U	50 U	4,300	20 U	20 U	50 U	150	200	290	14,000	2,200	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-48	6/5/2002		250	50 U	50 U	50 U	50 U	20 U	20 U	50 U	1,500	2,000	1,300	360,000	18,000	50 U	20 U	50 U	50 U	50 U	50 U	50 Ú	50 U	50 U
SP-48	6/5/2002	8 to 12 12 to 16	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	50 U	1,400	2,000	1,000	170,000	4,000	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
SP-49	6/5/2002	12 to 16	70	50 U	50 U	50 U	50 U	20 U	20 U	50 U	1,200	1,400	790	33,000	3,000	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
01-43	0/3/2002	12 10 10	0.2 U	50 U	50 U	50 U	50 U	20 U	20 U	320	250	300	50 U	2,500	400	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
June 2003 In	stallation of Wel	II JT-11																						
JT-11	6/3/2003	13 to 19		50 U	50 U	50 U	50 U	20 U	20 U	50 U	400	100	50.11	50	50.11	50.11	00.11	50.11						
		.0 10 10		50 0	50 0	30 0	30 0	20 0	20 0	50 U	400	190	50 U	50 U	50 U	50 U	20 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
																								4, 4

J Estimated value
U Not detected at indicated detection limit
- Not analyzed
CB Chlorobenzene
m-DCB m-Dichlorobenzene
p-DCB p-Dichlorobenzene
o-DCB o-Dichlorobenzene
1,2,3-TCB 1,2,3-Trichlorobenzene
1,2,4-TCB 1,2,4-Trichlorobenzene
1,2,4-TCB 1,2,4-Trimethylbenzene
HCB Hexachlorobutadiene
TIC Quantified by TIC Scan

Calculation of the GAC content for a 2-foot thick sorptive wall to achieve a 30-year operating life is shown in Table 5. The design GAC content uses the minimum estimated carbon usage rate, which is based on breakthrough of 1,4-dichlorobenzene above the cleanup level.

An underlying assumption of using the bench-scale carbon usage rate to design a full-scale system is that the water-carbon system is close to equilibrium. Because the residence time of Column B is approximately 2 hours, whereas residence times for conventional full-scale GAC treatment applications are typically less than one hour, this assumption is likely valid. In a full-scale wall, the carbon usage rate may be slightly less due to longer residence time (site groundwater in a 2-foot thick reactive wall would have a residence time of approximately 5 days), resulting in a longer-than-predicted wall life.

The treatability study was conducted using water from the source area to represent worst-case groundwater conditions. If the wall were installed directly downgradient of the source area and entering concentrations were similar to those used in this test, a 2-foot-thick wall constructed of 100 percent GAC could meet cleanup levels and performance standards potentially as long as 99 and 113 years, respectively. To meet cleanup levels and performance standards for the target operating life of 30 years, the wall should be constructed of at least 30 percent GAC by volume.

Significant attenuation of chlorinated benzenes occurs downgradient of the source area. Total chlorinated benzene concentrations at well JT-11, located 40 feet downgradient of the source area, are approximately one-sixth those detected in the source area. Therefore, a wall constructed near JT-11 would likely last significantly longer before carbon capacity was reached and breakthrough observed.

One set of samples collected from Column B at the end of the bench test was also analyzed for PCBs to confirm the design assumption that the wall would also remove PCBs, and that breakthrough of PCBs would not be a performance limitation. In these samples a PCB concentration of 0.4 ug/L was detected at the midpoint of the column and at the column inlet at a concentration of 460 ug/L. The detected inlet concentration is more than 10 times the solubility of the detected PCB mixture (Aroclor 1260). It is possible that due to the strongly sorbing nature of PCBs the inlet concentrations were biased high by suspended solids. Although PCBs were detected at the column midpoint, the detected concentration was more than 1,000 times less than entering the column. Therefore, it is likely that PCBs will not be a limiting constituent for wall life.

At the end of the bench test, chloride concentrations entering and exiting Column B were 24 and 23 mg/L, respectively, indicating that the decrease in chlorinated benzene concentrations across the column was likely due to sorption onto GAC rather than reaction with zero-valent iron (which would create chloride from dechlorinating the chlorinated benzenes). This is consistent with previous laboratory studies that have found that the reaction time of iron with chlorinated benzenes is too slow to be a significant contributor to removal.

Calculation of Vinyl Chloride Degradation Rate

Although the column study was not designed to accurately estimate the degradation rate of vinyl chloride by zero-valent iron, the data were used to provide a rough estimation of the degradation rate, and that estimate was compared to the rate predicted by studies done for the adjacent Market Street site. A first-order degradation reaction was assumed based on previous studies. The inlet and outlet concentrations of vinyl chloride for Column B during the May 27, 2003, sampling event (as a conservative test) were 22 ug/L and 1.9 ug/L, respectively. With a column residence time of 5 hours and an iron composition of 40 percent, this results in a calculated "laboratory" half-life of 0.6 hour. This is less than the 1.4-hour "laboratory" half-life calculated during the Market Street property bench-scale test. ("Laboratory" half-lives are generally increased by a factor of two to account for slower reaction kinetics at groundwater temperatures). Although the uncertainty in this study's estimate is too great for the difference to be significant, it is possible that the higher removal rate in this study is due to partial adsorption of vinyl chloride onto the GAC. The results suggest that it would be appropriate to use the Market Street property half-life to design the iron component of the wall.

Although vinyl chloride was removed throughout the first month of the bench test, reduced removal of vinyl chloride was noted in samples collected near the end of the bench test. The reason for the decreased performance is unknown; inspection of the columns did not indicate fouling or observable consumption of iron. The decreased performance could be the result of experimental error (vinyl chloride concentrations at all columns were generally low and fluctuated more than other constituents, likely due to its volatility), but they could also indicate the potential for the iron in the wall to need maintenance (via mixing, ultrasound cleaning, or other technology) after 20 to 30 years of operation.

Identification of Potential Maintenance Issues

At the end of the study, the columns were opened up and inspected for signs of precipitation and biofilm growth. Iron scale and orange biofilm was noted in the tubing leading to and between the columns, and a small amount of orange fouling was noted within approximately 2 cm of the entrance of Column B. No visible fouling was observed in the rest of the columns. The Column B mixture of iron, sand, and carbon was slightly cemented together; the mixture broke apart under pressure but was not loose like the Column A mixture of carbon and sand. Pressure drop across the columns during the study increased about 15 percent, but based on inspection of the columns and the tubing, more fouling was observed in the small diameter tubing than in the columns themselves. Flow through Column A halted halfway through the test; however, this was likely due to plugging of the inlet line. Inspection of Column A indicated that the plugging occurred from iron and bacteria buildup in the small-diameter tubing leading to the column and not in the column itself.

Dissolved oxygen concentrations higher than typically measured in site groundwater were measured at the column inlet at the beginning of the study. It is likely that oxygen entered the test water (e.g., via diffusion through the small-diameter polyethylene tubing) and caused mineral precipitation and biofilm formation in the tubing, leading to the

Total Organic Carbon Concentrations in Soil

Sample Location	Sample Depth in Feet	Sampling Date	Total Organic Carbon in Percent
IP-4 S1	2.5 to 4	8/22/2001	1.3
IP-4 S2	10 to 11.5	8/22/2001	2.9
IP-6 S1	10 to 11.5	8/22/2001	3.5
IP-9 S1	15 to 16.5	8/21/2001	0.13
IP-12 S1	10 to 11.5	8/22/2001	1.3
JT-9 S2	8 to 9.5	3/5/2002	5.1
JT-9 S3 Comp	15.5 to 18	3/5/2002	0.17

Air Data - Sewer Manhole

Sample Name	MH-1	MH-2	MH-3
Manhole Location Relative to Site Sewer Connection	80 Feet	200 5	380 Feet
Sample Date	Downstream 6/5/2002	260 Feet Upstream 6/5/2002	Upstream 6/5/2002
Analyte	0/3/2002	0/3/2002	0/3/2002
Dichlorodifluoromethane	0.5 U	0.5 U	0.5 U
Chloromethane	0.5 U	0.5 U	0.5 U
Vinyl Chloride	0.5 U	0.5 U	0.5 U
Bromomethane	0.5 U	0.5 U	0.5 U
Chloroethane	0.5 U	0.5 U	0.5 U
Trichlorofluoromethane	0.5 U	0.5 U	0.5 U
1,1-Dichloroethene	0.5 U	0.5 U	0.5 U
Methylene Chloride	0.5 U	0.5 U	0.5 U
trans-1,2-Dichloroethene	0.5 U	0.5 U	0.5 U
1,1-Dichloroethane	0.5 U	0.5 U	0.5 U
cis-1,2-Dichloroethene	. 0.5 U	0.5 U	0.5 U
2,2-Dichloropropane	0.5 U	0.5 U	0.5 U
Chloroform	0.5 U	0.5 U	0.5 U
Bromochloromethane	0.5 U	0.5 U	0.5 U
1,1,1-Trichloroethane	0.5 ∪	0.5 U	0.5 U
1,2-Dichloroethane	0.5 U	0.5 U	0.5 U
1,1-Dichloropropene	0.5 U	0.5 U	0.5 U
Carbon Tetrachloride	0.5 U	0.5 U	0.5 U
Benzene	0.5 U	0.5 U	0.5 U
Trichloroethene 1,2-Dichloropropane	0.5 U	0.5 U	0.5 U
	0.5 U	0.5 U	0.5 U
Dibromomethane Bromodichloromethane	0.5 U	0.5 U	0.5 U
	0.5 U 0.5 U	0.5 U	0.5 U
cis-1,3-Dichloropropene	0.5 U	0.5 U	0.5 U
Toluene trans-1,3-Dichloropropene	0.5 U	0.5 U 0.5 U	0.5 U 0.5 U
1,1,2-Trichloroethane	0.5 U	0.5 U	0.5 U
1,3-Dichloropropane	0.5 U	0.5 U	0.5 U
Dibromochloromethane	0.5 U	0.5 U	0.5 U
Tetrachloroethene	0.5 U	0.5 U	0.5 U
1,2-Dibromoethane (EDB)	0.5 U	0.5 U	0.5 U
Chlorobenzene	0.5 U	0.5 U	0.5 U
1,1,1,2-Tetrachloroethane	0.5 U	0.5 U	0.5 U
Ethylbenzene	0.5 U	0.5 U	0.5 U
Xylenes	0.5 U	0.5 U	0.5 U
Styrene	0.5 U	0.5 U	0.5 U
Bromoform	0.5 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	0.5 U	0.5 U	0.5 U
Isopropylbenzene	0.5 U	0.5 U	0.5 U
1,2,3-Trichloropropane	0.5 U	0.5 U	0.5 U
Bromobenzene	0.5 U	0.5 U	0.5 U
n-Propylbenzene	0.5 U	0.5 U	0.5 U
2-Chlorotoluene	0.5 U	0.5 U	0.5 U
4-Chlorotoluene	0.5 U	0.5 U	0.5 U
1,3,5-Trimethylbenzene	0.5 U	0.5 U	0.5 U
tert-Butylbenzene	0.5 U	0.5 U	0.5 U
1,2,4-Trimethylbenzene	0.5 U	0.5 U	0.5 U
sec-Butylbenzene	0.5 U	0.5 U	0.5 U
1,3-Dichlorobenzene	0.5 U	0.5 U	0.5 U
1,4-Dichlorobenzene	0.5 U	0.5 U	0.5 U
Isopropyltoluene	0.5 U	0.5 U	0.5 U
1,2-Dichlorobenzene	0.5 U	0.5 U	0.5 U
n-Butylbenzene	0.5 U	0.5 U	0.5 U
1,2-Dibromo-3-Chloropropane	0.5 U	0.5 U	0.5 U
1,2,4-Trichlorobenzene	0.5 U	0.5 U	0.5 U
Naphthalene Hexachloro-1,3-butadiene		0.5 U	0.5 U
1,2,3-Trichlorobenzene	0.5 U 0.5 U	0.5 U 0.5 U	0.5 U 0.5 U
1,2,0-111011010001120110	U.5 U	0.5 0	0.5 0

APPENDIX B

Fate and Transport Study/Remedial Action Objectives Evaluation

(to be included in Final Report)

APPENDIX B

Fate and Transport Study/Remedial Action Objectives Evaluation

(to be included in Final Report)

APPENDIX C

Coupled *In Situ* Reactors Using Fe^o and Activated Carbon for the Remediation of Complex Contaminant Mixtures in Groundwater

(Koeber, Schaefer, Ebert & Dahmke 2000)

APPENDIX C

Coupled *In Situ* Reactors Using Fe⁰ and Activated Carbon for the Remediation of Complex Contaminant Mixtures in Groundwater

(Koeber, Schaefer, Ebert & Dahmke 2000)

Coupled in-situ reactors using Fe⁰ and activated carbon for the remediation of complex contaminant mixtures in groundwater

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Abstract The use of a combination of Fe⁰ and granular activated carbon as fillings for reactive permeable barriers was investigated for the remediation of complex contaminant mixtures. Column tests carried out with the same concentration of the two model contaminants trichloroethene (TCE) and monochlorbenzene (MCB) showed an increased durability of the activated carbon by a factor of 4 in combination with Fe⁰ and no substantial limitations in the use of activated carbon by Fe⁰. Keeping the two materials separate yielded better results than mixing them presumable due to precipitatate build-up in the activated carbon in the mixed system.

Key words Fe⁰, activated carbon, permeable reactive barriers, mixed contamination, sequential treatment, reductive dechlorination, sorption

INTRODUCTION

The use of permeable reactive barriers (PRBs) has been shown suitable for the treatment of polluted groundwater (O'Hannesin & Gillham, 1998, Vogan et al., 1999, Warner et al., 1998, Ebert et al., 1999). Zerovalent iron (Fe⁰) is the most popular filling material and can be used for the treatment of aliphatic halocarbons and several inorganic contaminants (Dahmke, 1997, Gavaskar et al., 1997, O'Hannesin & Gillham, 1998, Puls et al., 1999). Granular activated carbon (GAC) (O'Brien & Keyes, 1997, Niederbacher & Gregori, 1999, Schad et al., 2000) and oxidant/reductant releasing compounds (e. g. ORC[®], HRC[®]) (Koenigsberg & Norris, 1999) have also been used in PRBs and enable remediation of contaminants which are nondegradable by Fe⁰ such as PAH, BTEX and chloroaromatics. Thus a broad spectrum of contaminants can be treated with PRBs choosing the appropriate material but all these reactor fillings are limited by the fact that they suit only certain groups of contaminants. Frequently however, groundwater is contaminated by a complex mixture of substances showing different physical, chemical and thermodynamic properties and one single reactive material would not yield the desired remediation.

This study investigates whether the theoretically promising combination of Fe⁰ and GAC in PRBs could extend the life-time of GAC under in situ conditions to efficiently cleanup heterogeneously contaminated groundwater. In particular the question of whether iron corrosion and associated mineral precipitation can negatively affect GAC sorption capacity will be examined.

METHODS

Column experiments (Ø: 10 cm, L: 100 cm) were performed for the simulation of three

different PRB systems. Two of the systems were represented by single columns, one filled with GAC (TL 830, Chemviron Carbon) and the other containing a mixture of Fe⁰ (Graugussgranulat FG 1000/3000/1X, G. Maier) and GAC. The third system consisted of a sequential combination of a Fe⁰ column followed by a GAC column. The water used contained 17-20 mg/l each of MCB and TCE and was pumped through the column systems to obtain a velocity between 0.5 and 0.7 m/d. The GAC was diluted to enable the quantitization of sorption front migration under the selected conditions in an appropriate period. The GAC was diluted in a ratio of 1:90 (vol%) for the mixture with Fe⁰ and 1:50 with quartz sand for the 'pure' GAC columns.

All samples were analysed for MCB, TCE, DCE isomers, VC, Fe, Cl and pH by analytical standard methods.

RESULTS AND DISCUSSION

As expected, TCE was markedly less retarded than MCB in the pure GAC system documented from the enlarging separation of the sorption fronts with time (fig. 1). When the slower moving MCB sorption front reaches TCE saturated GAC areas, new equilibrium sorption conditions are established at the GAC surfaces and TCE is partially removed by MCB due to competitive exchange processes (fig. 1).

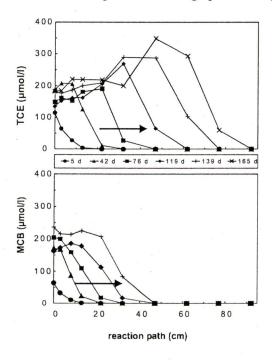


Fig. 1 Breakthrough of TCE and MCB in the pure GAC system.

The intersection of the concentration curves with a chosen reference concentration (50 μ mol/I) was taken to represent the migration of the sorption fronts and the respective velocities were calculated. These velocities can be converted to the sorbed equilibrium concentration (C_s) (fig. 2). $C_{s, MCB}$ accounts for 1.6 mmol/g in the pure GAC system and MCB sorbs uniformly. In contrast, the sorption of TCE can be divided into two phases due to competition reactions. Initially (up to 21 mmol TCE input) TCE sorption resulted in a $C_{s,TCE}$ of 1.0 mmol/g but subsequently the sorption front migration

was accelerated by TCE desorption due to sorption of MCB which results in a larger amount of saturated GAC per mmol TCE input and a $C_{s,TCE}$ of 0.7 mmol/g.

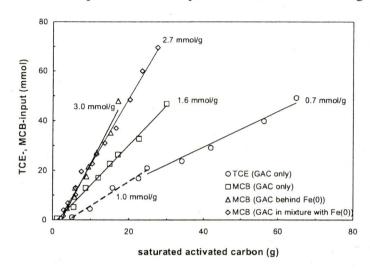


Fig. 2 Sorbed equilibrium concentrations.

TCE was completely degraded in the Fe⁰ column of the sequential system and an approximately constant half-life period of 2.5 h was achieved throughout. Intermediates of the reductive dehalogenation were mainly 1,2-DCE(cis) and minor amounts of 1,1-DCE and 1,2-DCE(trans). Initially, 1,2-DCE(cis) was not completely degraded by Fe⁰, reached the subsequent GAC column with a maximum concentration of 7 µmol/l and was fixed in the first centimeters of the column length. Since the release of DCE was restricted to the initial phase and because of the low concentrations, DCE basically did not compete with the parent contaminants for the sorption capacity. MCB was initially sorbed in the Fe⁰ column until breakthrough after 20 exchanged pore volumes and subsequently it was continously removed by GAC resulting in 3.0 mmol/g for C_{S,MCB}.

Using the average input concentration in our column experiments ($C_{w,MCB}$: 156 µmol/l) and Freundlich isotherms for the single solutes from Tiehm *et al.*(2000), $C_{s,MCB}$ yields 2.53 mmol/g. Since this value differs only slightly from the $C_{s,MCB}$ of the sequential system, the Fe⁰ in the preceding column cannot have a significantly negative influence on GAC sorption capacity. Possibly the long experimental period and slow pore diffusion in the micro pore area is responsible for the higher value from our experiments. Calculating $C_{s,TCE}$ from the isotherm yields 2.14 mmol/g indicating that competition with MCB reduces $C_{s,TCE}$ by a factor of three.

As in the already described systems, continuous breakthrough of the MCB sorption front could be observed in the mixed system resulting in 2.7 mmol/g for $C_{s,MCB}$ (fig. 2). Initially, TCE removal was markedly faster in the mixed than in the sequential system and already after 30 cm (residence time: 15 h) TCE was undetectable. In this phase chloride accounted for just 30% of the concentration that would have been expected for total dechlorination of TCE. This indicates that sorption of TCE was an important process auxillary to reductive degradation and that sorption predominated. Contrary to the pure GAC system, the migration velocity for the TCE and the MCB front was equal since TCE desorbed by MCB could be degraded directly by Fe⁰. After 80 days the chloride balance accounted for approximately 100% and the TCE front migration ceased. Subsequently, TCE was completely degraded by 70 cm with a half-life of 2.1 h showing just a slight improvement over the sequential system (80 cm, 2.5 h).

Comparison of the GAC C_s s of the combined PRB systems (fig. 2) shows that $C_{s,MCB}$ is 94% to 69% higher in the combined Fe⁰-GAC-systems than in the pure GAC system because all of the sorptive surface area is at the disposal of MCB due to TCE degradation by Fe⁰. The GACs lifetime is extended under the selected conditions (concentrations, velocity) by a factor of four since the durability of the pure GAC system is restricted by breakthrough of TCE.

The reasons for the lower $C_{s,MCB}$ of the mixed system compared to the sequential system have not yet been finally understood. However, the formation of iron precipitates on GAC surfaces are assumed to be responsible since precipitation occurs along the whole Fe^0 reaction path and thus the GAC of the mixed system can be permanently affected. The dissolved iron entering the activated carbon column from the preceding Fe^0 column, in contrast, is removed only initially (max. 30 days), probably due to oxygen released from the GAC.

CONCLUSIONS

The study showed the basic suitability and effectiveness of the combination of Fe⁰ and GAC in PRBs for the remediation of complex contaminant mixtures in groundwater containing substances reducible with Fe⁰ and constituents adsorbable to GAC. Best results were obtained when Fe⁰ and GAC were in sequence because a potential decrease in GAC sorption capacity can be minimized or prevented with the spatial separation of the reduction zone and the sorption zone. For higher mineralized groundwaters with a greater potential for precipitation, efficient decontamination of organic compounds is also possible since the formation of precipitates is restricted to the first centimeters of inflow in Fe⁰ (O'Hannesin & Gillham, 1998, Puls *et al.*, 2000) thus preventing precipitation on GAC surfaces. Further, the separation of the two materials simplifies the exchange of one of them in case of exhaustion of the sorption capacity or decreasing Fe⁰ reactivity.

The profitability of a combined PRB in comparison to a pure sorption barrier increases with increasing hydrophobicity of the non-iron-degradable substances. The same is true if TCE is replaced by weakly sorbing, iron-degradable contaminants like DCE or vinyl chloride. For these lower chlorinated ethenes it should be taken into account that there are references reporting dechlorination rates increasing (Johnson *et al.*, 1996) or decreasing (Arnold & Roberts, 2000) with increasing chlorination level and thus specific preliminary investigations have to be performed for a practical implementation of a combined Fe⁰-GAC PRB.

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APPENDIX D

Draft Treatability Study Report

APPENDIX D

Draft Treatability Study Report

DRAFT TREATABILITY STUDY REPORT Jacobson Terminals Sorptive/Reactive Wall

Prepared for: A&B Jacobson LLC

Project No. 020030 • August 27, 2003 Draft

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Prepared for: A&B Jacobson LLC

Project No. 020030 • August 27, 2003 Draft

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Appendix A Sorptive/Reactive Wall Bench Test Design Memo

dated April 4, 2003

Appendix B Laboratory Certificates of Analysis

Executive Summary

Aspect Consulting and Hart Crowser conducted a bench-scale treatability study of a combined sorptive and reactive wall to treat chlorinated hydrocarbons dissolved in groundwater at the Jacobson Terminals site in Seattle, Washington. The study was conducted between July 8 and August 5, 2003. The treatability study was designed to evaluate the feasibility of implementing the sorptive/reactive wall and to determine key design parameters. The bench test objectives and design were described in a Hart Crowser memo, dated April 4, 2003, which is provided in Appendix A.

The treatability study consisted of pumping site groundwater through columns containing sorptive or reactive media. The media used were granular iron, to remove vinyl chloride; granular activated carbon (GAC), to remove 1,2,4-trichlorobenzene and 1,4-dichlorobenzene; and sand, as an inert filler material. The results can be summarized as follows:

- Biofouling of the media was not observed.
- Reductions in vinyl chloride concentrations across the column containing iron indicate that using the 2.8 hour half-life determined for vinyl chloride in the Market Street property treatability study is appropriate.
- The carbon usage rate estimated from the column test indicates that for a target wall life of 30 years, a 2-foot-thick wall placed directly downgradient of the source area should contain a minimum of 30 percent GAC by volume.
- No significant differences were observed between treating site groundwater by GAC and iron in sequence versus a mixture of GAC and iron.
- Decreases in iron performance, possibly due to mineral precipitation, could require maintenance of iron after 20 to 30 years of groundwater treatment.

The results of the treatability study indicate that site groundwater can be treated effectively by a sorptive/reactive wall containing a mixture of iron and GAC.

Objectives

The general objectives of the study were as follows:

- Determine the necessary composition and thickness of the proposed sorptive/reactive wall to achieve a minimum wall life of 30 years;
- Evaluate the potential for long-term maintenance issues for the proposed wall;
- Evaluate the compatibility of iron-carbon mixtures as wall materials; and
- Evaluate the appropriateness of using data from the Environmental Technologies bench-scale treatability study (performed for the Market Street Property iron wall in September 1999) to design the iron filings component of the proposed wall.

The specific data requirements for the bench-scale treatability study to achieve the above objectives were as follows:

- Determine the carbon usage rate for treating site groundwater with and without granular iron present;
- Estimate the degradation rate of vinyl chloride by granular iron;
- Measure changes in pressure drop across the columns during the bench study, as an indicator of media fouling; and
- Visually inspect media at the conclusion of the study for evidence of fouling.

Methods

Materials and Operation

Materials used in the study were as follows:

- Granular iron.
- Granular Activated Carbon (GAC) provided by Terra Hydr of Portland, Oregon, for Columns A and B, and provided by Clean Environmental Concepts of Kelso, Washington, for Column D.
- Sand was 10/20 Silica Sand.
- Columns were constructed of 4-inch (Columns A, B, and C) or 2-inch (Column D) Schedule 40 PVC pipe and were plumbed with ¼-inch O.D. polyethylene tubing and quick connect fittings. A pressure gauge was installed at the inlet of Columns A and B to measure potential clogging of the media.

Water was provided by pumping site groundwater approximately once a week with a Whale electric submersible pump from monitoring wells JT-8 and IP-10 to a

polyethylene-lined 55-gallon reservoir drum. The drum was covered with a collapsible polyethylene liner and drum lid to minimize volatilization. A Masterflex peristaltic pump transferred water from the reservoir drum to each column at a rate of 8 mL/min per column (continuous operation).

Four independent columns (A, B, C, and D) were mounted vertically in a weather-protected enclosure, with flow from the bottom to the top. Columns A and B consisted of two PVC pipe segments connected in series, whereas Columns C and D consisted of single pipe segments. Each pipe segment contained approximately one foot of granular media. A column schematic is provided on Figure 1. Flow through columns A, B, and C began on May 8, 2003. Column D was started on July 8, 2003. Due to a power outage, the columns did not run between July 16 and July 21, 2003.

Column A was filled with a mixture of GAC (5 percent by volume) and sand.

Column B was filled with a mixure of GAC (5 percent by volume), iron (40 percent by volume), and sand.

Column C was a control column containing only sand and was operated for five days to evaluate the potential for contaminant losses (e.g., sorption to column and tubing materials or biodegradation) in the columns other than through the reactive/sorptive media. No significant losses were detected, and this column was removed from service for the duration of the study.

Column D was also filled with a mixture of GAC (10 percent by volume) and sand, and was added to replace Column A when Column A experienced operating difficulties (see Results Section).

Sampling and Analysis

Water samples were collected periodically from column inlets and either the midpoint or the outlet. Samples were collected in 40-ml glass vials and shipped to the Environmental Services Network, NW, laboratory in Bellevue, Washington, for analysis for volatile organic compounds by EPA Method 8260B. Selected water samples were also analyzed in the field for temperature, pH, conductivity, and dissolved oxygen.

At the conclusion of the study, water samples from the inlet and midpoint of Column B were collected in two 1-L amber glass bottles and one 250-ml polyethylene bottle and sent to the Analytical Resources, Inc. Laboratory in Tukwila, Washington, for analysis for PCBs by EPA Method 8082 and for chloride by EPA Method 325.2. Laboratory certificates of analysis are provided in Appendix B.

Results

Chemical concentrations entering and exiting each column are provided in Table 1 for Column A, Table 2 for Column B, and Table 3 for Columns C and D.

Column A experienced early breakthrough, and to test if preferential pathways had developed through the first 1-foot column segment, flow through the segments was

reversed. Breakthough continued and, shortly thereafter, flow through this column halted (discussed further in Identification of Potential Performance and Maintenance Issues). Column B operated without incident throughout the study and showed gradual breakthrough after several weeks of operation. To determine if Column A's behavior was anomalous, a second GAC/sand column (Column D) was constructed and started on July 8, 2003. This column was constructed of 2-inch diameter PVC but fed with the same flowrate to reduce the time needed to simulate 30-years of wall operation. Breakthrough in Column D was similar to that observed in Column B, indicating that Column A results may be anomalous. Therefore, only results from Columns B and D were used to develop carbon usage rates for design of the full-scale wall.

Calculation of Carbon Usage Rate

The calculation of carbon usage rate for the above system is described below. This estimate is conservative because the test was run at ambient temperature (16 to 22 degrees Celsius), which is warmer than site groundwater (typically 11 to 14 degrees Celsius). Adsorption to carbon is generally stronger at lower temperatures; therefore, the actual carbon usage rate for the in-ground wall would be slightly lower.

"Breakthrough" is defined in this study as the point at which constituent concentrations in the column effluent exceed the applicable screening levels. There are two potentially applicable screening levels for each constituent: 1)the surface water cleanup level, based on applicable state and federal regulations; and 2)the wall performance standard, which takes into account chemical transformation and attenuation mechanisms (e.g., sorption, dispersion, biodegradation) between the proposed wall and the conditional point of compliance. This treatability test was designed to evaluate treatment of two chemicals of concern – 1,2,4-trichlorobenzene and 1,4-dichlorobenzene. The applicable screening levels are:

- 1,4-Dichlorobenzene. 4.86 ug/L Cleanup Level; 17 ug/L Wall Performance Standard.
- 1,2,4-Trichlorobenzene. 227 ug/L Cleanup Level; 95 ug/L Wall Performance Standard.

The performance standard for 1,2,4-trichlorobenzene is less than the cleanup level because 1,2,4-trichlorobenzene has the potential to form 1,4-dichlorobenzene when biodegraded under anaerobic site conditions.

Breakthrough curves for 1,2,4-trichlorobenzene and 1,4-dichlorobenzene are shown on Figures 2 and 3, respectively. The columns exhibited slow breakthrough of both constituents, which is typical for carbon treatment of mixtures containing chemicals of varying adsorptive coefficients. The carbon usage rate for each constituent was calculated based on the volume of GAC present and the volume of water treated at breakthrough. The calculation of volume of GAC used per volume water treated is demonstrated in Table 4 for Columns B and D. Calculating the volume of water treated per volume of GAC allows plotting of Column B and D results on the same graph (Figures 2 and 3). From these graphs, the carbon usage rate (the inverse of the volume of water treated) is obtained as the point at which breakthrough occurs, shown in Table 5.

plugging of Column A. Later in the study, dissolved oxygen concentrations at the inlet of Column B decreased significantly, likely due to the buildup of a biofilm/scale layer on the inside of the tubing that would consume any oxygen diffusing in. An *in situ* wall is unlikely to encounter the conditions leading to plugging because the groundwater conditions are reducing across the site, with very little dissolved oxygen.

Across Column B (containing 40 percent iron), water pH increased from an average of 7.2 to 8.6 and specific conductivity decreased from an average of 540 to 380. This is consistent with the behavior of the Market Street iron wall, in which the iron elevates the pH and causes dissolved minerals to precipitate out of the water, leading to decreased conductivity. Alkalinity in site groundwater is typically around 500 mg CaCO3 per liter, less than the upgradient Market Street property, so mineral precipitation would not be expected to significantly reduce wall effectiveness or hydraulic conductivity in the operating life of the wall based on the Market Street property bench study. However, in this study the amount of pH elevation and conductivity depression across Column B decreased during the last two months of the study, consistent with the decreased removal of vinyl chloride in this period.

The decreased iron performance observed at the end of the study combined with the observation that the Column B media mixture became partially cemented could indicate that mineral precipitation on the iron was affecting treatment of vinyl chloride. Based on the volume of water treated at the point reduced performance was noted, the wall could operate for 20 to 30 years before potentially needing iron maintenance.

Note that because this bench-scale test used accelerated groundwater flow rates to simulate long-term greater than 30 years of wall operation in 3 months, the results do not take into account kinetic considerations for reductions in performance; i.e., if the rate of mineral precipitation is slow such that a longer residence time would result in more precipitation, iron maintenance could be required sooner. Likewise, the calculated carbon usage rate assumes that the usage rate is limited by the mass of organics adsorbed by the carbon, and not the rate of adsorption (previously discussed) or the rate of fouling of the carbon. Kinetic considerations such as these can only be fully analyzed under long-term treatment tests.

Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of A&B Jacobson for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

Table 1 - Chemical Results - Column A

						Column A					
				981	5% GAC, 95%	Sand - Start	ed 5/8/2003				
		Inlet (Midpoin	t (A-2)			Outlet (A-3)	
Sample Date	5/13/2003	5/20/2003	5/27/2003	6/10/2003	5/13/2003	5/20/2003	5/27/2003	6/10/2003	5/13/2003	5/20/2003	6/10/2003
Test Day Number	5	12	19	33	5	12	19	33	5	12	33
Constituent											
Chemicals of Concern (Concentrations	in ug/L)										
Vinyl Chloride	nd	25	23	nd	3	nd	3.4	nd			
1,4-Dichlorobenzene	220	160	190	170	9.7	75	67	68			
1,2,4-Trichlorobenzene	780	1,900	2,500	1,700	74	150	870	380			
PCBs (Aroclor 1260)											
 Other Detected Chemicals (Concentrati	ons in ug/L)										
cis-1,2-Dichloroethene	nd	nd	3.6	nd	nd	nd	nd	nd			
Benzene	nd	nd	3.6	nd	nd	nd	1.3	nd			
Toluene	nd	nd	nd	nd	nd	nd	nd	nd			
Chlorobenzene	180	78	170	120	9.4	78	66	nd			
1,3-Dichlorobenzene	54	80	69	54	2.8	25	21	19			
1,2-Dichlorobenzene	270	150	200	230	12	76	75	82			
Naphthalene	3.7	nd	nd	nd	nd	nd	nd	nd			
Hexachlorobutadiene	3.5	nd	nd	nd	nd	nd	nd	nd			
1,2,3-Trichlorobenzene	540	160	97	130	4.7	57	31	32			
Inorganic Parameters								-			
Temperature in Degrees Celsius	15.5	14.8				16.9			20.7	14.8	15.8
рН	7.5	6.8				7.2			7.4	7.3	7.1
Conductivity in uS	610	660				310			450	660	300
Dissolved Oxygen in mg/L	4.5	2.3				0.3			4.7	1.6	0.3
Chloride in mg/L											

Note: Order of First and Second Column Segment was switched on June 3, 2003. Sample collected on 6/10/2003 was from new Midpoint, which was originally the Outlet

⁻⁻ Not Analyzed

nd Not Detected

Table 2 - Chemical Results - Column B

To the state of th																	
									Column B							18	
				(D. 1)			5%	GAC, 40% Iro		- Started 5/8/2	2003						
Sample Date	Inlet (B-1)							nt (B-2)					Outlet (B-3)				
	5/13/2003	5/20/2003	5/27/2003	6/10/2003	7/14/2003	8/7/2003	5/13/2003	5/20/2003	5/27/2003	6/10/2003	7/14/2003	8/7/2003	5/13/2003	5/27/2003	6/10/2003	7/14/2003	8/7/20
Test Day Number Constituent	5	12	19	33	67	91	5	12	19	33	67	91	5	19	33	67	91
Sonstituent																	
I Chemicals of Concern (Concentration	ns in ua/L)																
Vinyl Chloride	19	24	22	9	11	14	nd	nd	1.9	nd	10	18					10.72
1,4-Dichlorobenzene	170	170	190	190	190	290	nd	nd	1.5	5.4	23	210					4.6
1,2,4-Trichlorobenzene	2.000	2.000	1,200	2.600	2,900	5.400	nd	nd	13	63	180	110					nd
PCBs (Aroclor 1260)		-,				460					160	0.4	-				4.5
,						400						0.4					
Other Detected Chemicals (Concenti	rations in ug/l	_)					1										
cis-1,2-Dichloroethene	nd	nd	3.8	nd	nd	5.1	nd	nd	nd	nd	nd	2.6					nd
Chloroform	nd	nd	nd	nd	nd	1.1	nd	nd	nd	nd	nd	nd			-		nd
Benzene	2.7	nd	3.3	nd	3.7	3.2	nd	nd	nd	nd	nd	1.3					nd
Toluene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd					nd nd
Chlorobenzene	120	200	170	120	120	140	nd	nd	1.8	7.4	14	31					nd
1,3-Dichlorobenzene	51	79	68	54	71	96	nd	nd	nd	1.7	6.3	34					nd
1,2-Dichlorobenzene	180	170	200	230	210	370	nd	nd	2.4	8.4	19	43			-		nd
Naphthalene-	nd	nd	nd	nd	nd	2.3	nd	nd	nd	nd	nd	nd					nd
1,2,3-Trichlorobenzene	76	180	16	310	390	730	nd	nd	nd	8.5	26	43	-				1.1
norganic Parameters																	
Temperature in Degrees Celsius	16.1	14.8		16.9	19.3	20.8			,				20	440	40.0		
pH	7.5	6.8		7.2	7.4	7.1							9.4	14.8	16.9	19	21.8
Conductivity in uS	510	640		310	520	700							300	8.9 340	8 290	8.4	8.3
Dissolved Oxygen in mg/L	4.5	1.6		0.3	0.3	0.3					-	-	1.2			490	490
Chloride in mg/L					0.5	24						23		1.6	0.1	0.2	0.2
						~ -		-				23					

⁻⁻ Not Analyzed

nd Not Detected

Table 3 - Chemical Results - Columns C and D

	Colu	mn C		Colu	mn D	
	100% Sand - S	tarted 5/8/2003	10% GA	C, 90% Sar	nd - Started	7/8/2003
	Inlet (C-1)	Outlet (C-2)	Inlet	(D-1)	Outlet	(D-2)
Sample Date	5/13/2003	5/13/2003	7/14/2003	8/7/2003	7/14/2003	8/7/2003
Test Day Number	5	5	6	30	6	30
Constituent	*					
Chemicals of Concern (Concentrations	s in ug/L)					
Vinyl Chloride	20	16	10	15	4.8	8.1
1,4-Dichlorobenzene	210	180	230	290	nd	45
1,2,4-Trichlorobenzene	1,600	2,300	4,500	5,200	5.6	830
PCBs (Aroclor 1260)	2	¥				
Other Detected Chemicals (Concentra	itions in ug/L)					
cis-1,2-Dichloroethene	2.1	3.3	nd	4.6	nd	2.2
Benzene	2.8	3	nd	3.2	nd	1.6
Toluene	nd	nd	nd	nd	nd	nd
Chlorobenzene	160	160	140	150	nd	33
1,3-Dichlorobenzene	50	44	82	88	nd	16
1,2-Dichlorobenzene	250	210	230	360	nd	88
Naphthalene	1.9	4.3	1.5	1.9	nd	nd
1,2,3-Trichlorobenzene	300	200	560	770	1.3	110
Inorganic Parameters		,				
Temperature in Degrees Celsius	16	18.2	19.3	20.8	18.8	19.1
pH	7.5	7.5	7.5	7.1	7.4	7.2
Conductivity in uS	470	420	530	710	550	700
Dissolved Oxygen in mg/L	6.8	6	0.3	0.3	1.4	1.2
Chloride in mg/L						

⁻⁻ Not Analyzed

nd Not Detected

Table 4 - Calculation of Volume of Water Treated

	Unit	Column B	Column D
Duration of Test	Days	87	26
Column Flowrate	Cubic Feet per Day	0.41	0.41
Column Area	Square Feet	0.087	0.022
Column Length 1	Feet	1	1
Porosity		0.4	0.4
Residence Time	Hours	2.0	0.5
GAC Content	Percent by Volume	5	10
Volume of GAC	Cubic Feet	0.0044	0.0022
Volume of Water Treated	Cubic Feet	35.7	10.7
Volume of Water Treated	Cubic Feet per Cubic Foot GAC	8200	4845

Notes:

¹ Total column length was 2 feet, but samples were collected at the 1-foot interval

Table 5 - Calculation of Design GAC Composition for a 2-Foot Thick Wall

	Unit	1,2,4-Trich	lorobenzene	1,4-Dichlorobenzene		
	1	Cleanup Level	Wall Performance	Cleanup Level	Wall Performance	
Constituent Standard	ug per Liter	227	95	4.86	19	
Volume Water Treated	Cubic Feet per Cubic Foot GAC	3700	3300	2900	3900	
Carbon Usage Rate	Cubic Foot GAC per Cubic Foot Treated Water	0.00027	0.00030	0.00034	0.00026	
Site Groundwater Velocity	Feet per Day	0.4	0.4	0.4	0.4	
Porosity		0.4	0.4	0.4	0.4	
Site Groundwater Flowrate	Cubic Feet per Square Foot per Day	0.16	0.16	0.16	0.16	
Wall Width	Feet	2	2	2	2	
Maximum GAC Composition	Percent	100	100	100	100	
Volume of GAC in Wall	Cubic Feet per Square Foot	2	2	2	2	
Time to Breakthrough		127	113	99	134	
	6					
Target Lifetime	Years	30	30	30	30	
Design GAC Composition	Percent	24	27	30	22	

ASPECICONSULTING IN-DEPTH PERSPECTIVE		*	Date
811 First Avenue, Suite 480 Seattle, WA 98104 (206) 328-7443 Telephone (206) 838-5853 Fax	Project		Project No
179 Madrone Lane North Bainbridge Island, WA 98110 (206) 780-9370 Telephone (206) 780-9438 Fax	Subject Reviewed by		Page of
Figure 1. Col	umn Scher	matic	
(A3): X	(83) 7		Key Sample Port Location and
5% GAC 95% Sand	5% GAC 40% Iron 55% Sarel		Name Pressure Gayye Location
	33)		
56 GAC 95% Sand	5% GAC 40% Iron \$5% Sard	100% Sand	10% GAC 909%
			Sárd
[P] X-QI)	(B1)		
Reservoir		>	
Column A	Zolumn B C	olumn C	Column D

Figure 2 - Trichlorobenzene Breakthrough Curve

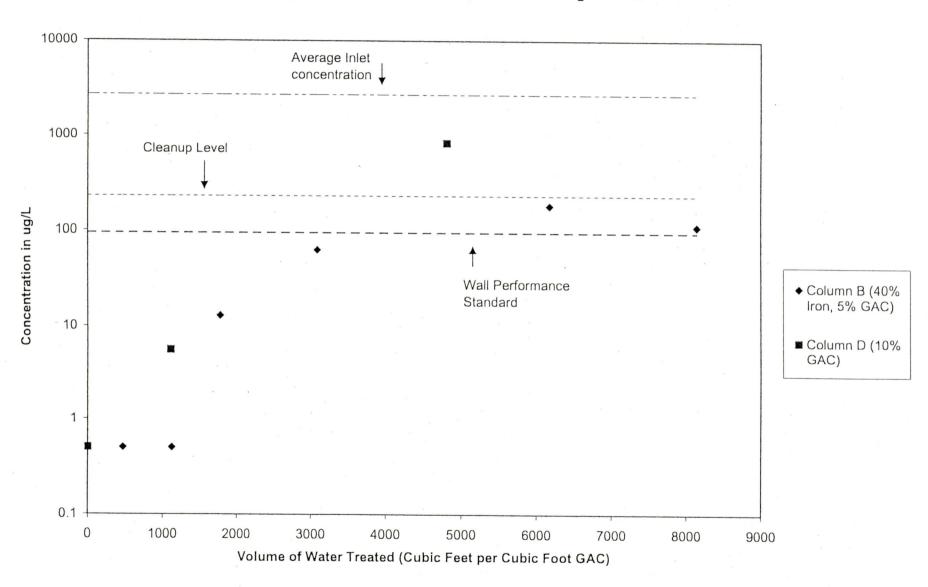
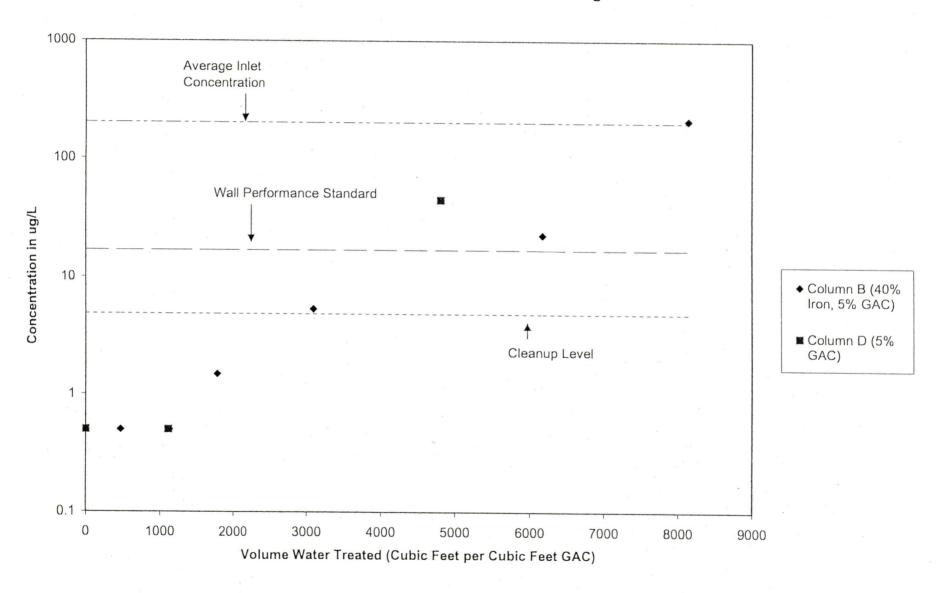


Figure 3 - 1,4-Dichlorobenzene Breakthrough Curve



APPENDIX A

Sorptive/Reactive Wall Bench Test Design Memo dated April 4, 2003

MEMORANDUM

DATE: April 4, 2003

TO: Barry Kellems, Hart Crowser

FROM: Jeremy Porter, Hart Crowser

RE: Sorptive/Reactive Wall Bench Test Design

Jacobson Terminals

4063-15

This memorandum presents the design of a bench-scale test of an in-situ reactive/sorptive wall that uses zero-valent iron to destroy vinyl chloride and liquid-phase granular activated carbon (GAC) to absorb chlorinated benzenes. Details of the proposed bench test are presented below.

CONCEPTUAL DESIGN

The sorptive/reactive wall would be installed as follows:

- A 2-foot diameter auger would excavate a cylinder of soil to a depth of approximately 16 to 18 feet, depending on the depth of the clay layer. The auger would penetrate no more than 6 inches into the clay layer because of the layer's variable thickness. The boring will be cased.
- Excavated soil would be stockpiled pending characterization and disposal. Free water in the cased boring would be pumped out into a Baker Tank, pending characterization and disposal.
- The boring would be backfilled to an elevation approximately 1 foot above the seasonally highest water table with a mixture of GAC, iron filings, and sand. Mixture composition to be determined based on bench test; an initial estimate is 10 percent GAC, 40 percent iron, and 50 percent sand by volume.
- Structural fill would be placed above the water table and the asphalt pavement replaced.

Two rows of 2-foot diameter cylinders would be installed on offset centers, so that the minimum wall thickness would be 2 feet.

DESIGN PARAMETERS

To adequately design a sorptive/reactive wall, the following parameters are necessary:

- Groundwater flowrate. Estimates of groundwater flowrate for the site have ranged between 0.1 and 0.5 foot/day. Aspect Consulting is performing a slug test analysis to better estimate hydraulic conductivity; however, site flow conditions likely occur on a micro scale that is not currently characterized. We are conservatively assuming an average flowrate of 0.5 foot/day.
- Reaction rate of vinyl chloride. This was measured by Environmetal Technologies during design of the Market Street Property iron wall, in which a field half-life of 2.8 hours was measured.
- Minimum groundwater residence time in the wall. Based on the above vinyl chloride half-life, and the assumption that influent vinyl chloride concentrations will be 240 ug/L and the effluent concentration will be 3 ug/L (the site cleanup level), the required residence time in a wall containing 40% iron by volume will be 18 hours. The residence time in a 2-foot thick wall at the above groundwater flowrate is 39 hours.
- Sorptive capacity of GAC for chemicals in groundwater at the site. The main chemical of concern is p-dichlorobenzene, but other chemicals such as 1,2,4-trichlorobenzene are present at concentrations that will compete with p-dichlorobenzene for sorption sites. The Freundlich isotherm constants for p-dichlorobenzene are K = 121 and 1/N = 0.47, and for 1,2,4-trichlorobenzene are K = 157 and 1/N = 0.31. Assuming influent concentrations of 9 mg/L 1,2,4-trichlorobenzene and 0.3 mg/L 1,4-dichlorobenzene, these values result in predictions for the lifetime of a 2-foot thick wall with 10 percent GAC to be greater than 100 years; however, this calculation does not take into account competitive sorption effects.
- Vulnerability of the wall to foul or otherwise encounter reduced performance in *in-situ* conditions. Considerations include:
 - Biofouling of GAC;
 - Mineral precipitation on GAC and/or iron. A laboratory study (Koeber 2001) found reduced sorptive capacity when iron and GAC were mixed; the researchers hypothesized that iron precipitated on the GAC surface.

BENCH-SCALE TEST DESIGN

The purpose of the bench-scale test is to measure the sorptive capacity of GAC for the site-specific contaminant mixture and to evaluate the potential for fouling or reduced performance under long-term operation under site conditions. We propose operating two columns for 3 months and a third control column for 2 days. The control column will be

operated to measure losses due to sorption on column equipment, volatilization, or other reactions not due to GAC or iron. If significant losses in the control column are detected, the control column will be operated longer to determine if they are temporary (e.g., short-term sorption to column equipment, sand, or dilution with clean pore water) or long-term (e.g., volatilization or biotic reactions).

Each column will be two feet long, with sample ports at the entrance, in the middle (at a distance of 1 foot from the entrance), and at the exit. The composition of each column will be as follows:

■ Column A: 5% GAC/95% Sand by volume.

■ Column B: 5% GAC/40% Iron/55% Sand by volume.

■ Column C: 100% Sand by volume.

The flowrate through each column will be 10 feet/day. With samples collected after 1 foot of column length, this will result in evaluation of sorption capacity in the 3-month test period equivalent to 20 years of operating under in-situ conditions (for 0.5 foot/day groundwater flow, 10% GAC, 2-foot wall thickness). If breakthrough is detected at the middle sampling port before the test is completed, samples will then be collected from the exit sampling port.

Each column will be constructed of two 1-foot sections of capped 4-inch Schedule 40 PVC pipe. The columns will be initially filled with clean water to saturate the materials. A pressure gauge will be installed at the entrance of columns A and B to measure if any plugging of the column (indicated by a gradual buildup of backpressure) occurs. Columns will be mounted vertically. Schematics of Columns A, B, and C are presented on Figure 1.

Water will be pumped from wells JT-8 (75% by volume) and IP-10 (25% by volume) into a 55 gallon drum. Water from JT-8 contains worst-case concentrations of chlorinated benzenes, while water from IP-10 contains worst-case concentrations of vinyl chloride. A drum liner will be placed above the liquid, and dedicated tubing for filling and emptying the drum will be placed through the liner and sealed, to minimize volatilization of VOCs from the drum and dissolution of oxygen into the drum. Based on the design flowrate of 10 feet/day, we expect each column to be run at 7.8 mL/min, or 2.6 gal/day. Continuous operation of two columns will consume 36 gal/week; therefore, the drum will be refilled at a minimum of once per week.

During operation, the following parameters will be monitored:

- One sample (2 40-mL vials) will be collected from the entrance and midpoint of each column (or the exit, if breakthrough has occurred at the midpoint) for analysis for VOCs by EPA Method 8260. Samples will be collected from Columns A, B, and C after 2 days of operation. Samples will be collected from columns A and B after 1 week, 2 weeks, 4 weeks, 8 weeks, and 12 weeks of operation.
- After 12 weeks of operation, one water sample will be collected from the entrance and exit of Columns A and B and analyzed for PCBs by EPA Method 8082 (ultra low level) and chloride.
- After 2 day, a water sample from the entrance and exit of Columns A, B, and C will be collected and field-analyzed for dissolved oxygen, pH, conductivity, and temperature. These parameters will also be measured after 4 weeks, 8 weeks, and 12 weeks at the entrance and exit of Columns A and B.

After 12 weeks, the columns will be dismantled and inspected for mineral precipitation and biofilm buildup. A sample of GAC from each column will be analyzed for total VOCs.

Attachments:

Figure 1 - Column Schematics

APPENDIX B

Laboratory Certificates of Analysis Environmental Services Network, NW Analyical Resources, Inc. (to be included in Final Report)