Prepared for

Olin Corporation
and
Mallinckrodt US LLC

REMEDIAL INVESTIGATION / FEASIBILITY STUDY (RI/FS)

FREDERICKSON INDUSTRIAL PARK
FREDERICKSON, WASHINGTON

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Project Number GR4631

28 March 2012

EXECUTIVE SUMMARY

This *Remedial Investigation/Feasibility Study (RI/FS) Report* (RI/FS Report) has been prepared by Geosyntec Consultants on behalf of Olin Corporation and Mallinckrodt US LLC (the Companies) to summarize the phased investigations and past remedial activities, and guide remediation of carbon tetrachloride (CTC) in groundwater at and downgradient of the Frederickson Industrial Park in Frederickson, Washington. Per Model Toxics Control Act (MTCA) and Chapter 173-340-200 of the Washington Administrative Code (WAC), the Site is defined to be anywhere hazardous substances have come to be located, and thus includes both on- and off-property areas. For this RI/FS Report, the Property refers to the area contained within the property boundaries of the Frederickson Industrial Park. This RI/FS Report is being submitted to the Washington Depart of Ecology (Ecology) in accordance with the requirements of Agreed Order No. DE 97TC-S121 (AO) established between the Companies and Ecology on 12 May 1997, and associated correspondence of May 11, 2011 in which Ecology agreed that sufficient data have been collected to complete the remedial investigation and prepare the RI/FS Report for the Site.

Site Background

The Property encompasses 527 acres of land south of 176th Street East and east of Canyon Road East in the Fredrickson area of Pierce County, Washington. The Property is situated approximately 10 miles south of Tacoma and 8 miles southwest of Puyallup, and is located in unincorporated County area surrounded by a mixture of industrial, residential and commercial properties.

From 1935/1936 through 1976, the Property was operated as an explosives manufacturing and processing plant under various ownerships. From 1976 to 1986, the Property was conveyed through a series of transactions to several owners related to the lumber industry (e.g., timber cutting, lumber milling, and related storage purposes). During the period of 1987 to 1990, the Property was developed as an industrial park to facilitate its sale. In the course of Property development, investigations were conducted and residual debris and waste were removed, as detailed in this report.

While there was no known use of CTC in any of the past Property manufacturing processes, CTC was suspected to have been used in limited volume as an industrial cleaning solvent and as a fire extinguishing compound during powder plant operations (1936 -1976). Disposal pits were reportedly used to burn and dispose of waste paper, fugitive powder, barrels, scrap metal, laundry wastes, rags, and wood products. CTC was initially discovered in on-Property monitoring wells in 1988. Consequently, several investigations were conducted at the Property, confirming the presence of CTC in the groundwater, both on- and off-Property. While off-Property CTC concentrations were below the United States Environmental Protection Agency's (USEPA's) 5 µg/L Maximum Contaminant Level (MCL), some locations exceeded cleanup levels established under the authority of the Washington State Statute, Revised Code of Washington (RCW) (70.105D), MTCA and Chapter 173-340 WAC, the MTCA Cleanup Regulation.

In 1990, the Property was purchased by Boeing, the current owner. Boeing graded, constructed and currently operates an aircraft parts manufacturing facility on the Property. In 1994, Centrum Properties Corporation entered into Agreed Order No. DE 94TC-S217 with Ecology to conduct a phased remedial investigation and feasibility study to address the CTC contamination at the Property, with Phase I of the RI/FS completed in 1995. Olin and Mallinckrodt are the successors of former owners of the Property. In 1997, the Companies entered into AO No. DE 97TC-S121 requiring the Companies to complete the RI/FS and to devise and implement a permanent solution regarding the impact of CTC in affected domestic drinking water wells.

Numerous site investigations have been conducted at the Site over the past twenty-five years, including, but not limited to:

- an Ecology site inspection (1988);
- an environmental site assessment (1989);
- multiple source area excavations and removal actions between 1989 and 1991;
- several rounds of groundwater monitoring (from 1988 to 1995);
- a Phase I RI/FS (from 1994 to 1995);
- a Phase II RI/FS (1998 through 2007) that included a soil gas investigation (1999), an evaluation of potential plume impacts on water supply (2000), installation of several new monitoring wells (2000 to 2002), and three rounds of groundwater sampling (2000, 2001 and 2002);
- implementation of permanent solutions for CTC-affected domestic drinking water wells from 2002 to 2007; and,
- an Additional RI Scope of Work (2008 - 2011). Key aspects of this work included: i) confirming that the energetic compounds perchlorate, RDX and TNT are not present in the Site groundwater, and that CTC is the only constituent of concern at the Site; and ii) completion of CTC delineation in surface water, sediment, and groundwater.

Through these investigations and remedial activities, the Companies have permanently mitigated the human health risk pathway, and have collected sufficient data on-Property and off-Property to appropriately delineate CTC impacts and satisfy the objectives of the RI, such that it is appropriate to prepare this RI/FS Report. Ecology concurred with the Companies' recommendation that sufficient data exist to prepare the RI/FS Report in a letter dated 11 May 2011.

RI/FS Objectives

The objectives of this RI/FS are to:

- characterize the on-Property and off-Property extent of the CTC groundwater plume;
- determine and confirm any existing potential source areas of CTC;
- acquire the information necessary for the selection of a cleanup action;
- document implementation of permanent solutions for domestic wells impacted by CTC;
- recommend cleanup standards (i.e., cleanup levels and point(s) of compliance) for the Site;
- develop and evaluate cleanup action alternatives capable of achieving the cleanup standards for the Site;
- analyze the technical equivalency of the cleanup action alternatives, in terms of the MTCA threshold criteria and additional criteria, such as permanence, reasonable restoration time frame, sustainability, and adequate consideration of public concerns;
- prepare comparative cost estimates (to an approximate accuracy of plus 50 percent to minus 30 percent) for the various cleanup action alternatives, and identify the most cost-effective cleanup action alternative to achieve the cleanup standards; and,
- identify the cleanup action alternative (preferred alternative) that satisfies the MTCA criteria, provides for a permanent solution to the maximum extent practicable, provides for a reasonable restoration time frame, and considers public concerns.

Conceptual Site Model (CSM)

The Conceptual Site Model (CSM), which explains how CTC may have been released into the subsurface at the Site, and how it has behaved in terms of fate, transport and distribution over time, can be summarized as follows:

- Between 1936 (i.e., initial powder plant operations) and 1991 (i.e., completion of final removal actions), CTC appears to have infiltrated from operational areas to the underlying water table. The purpose of the removal actions in 1989 and 1991 was to address source areas in the former operational areas;

- Within the former operational areas of the Site, infiltration of precipitation and north-northwest horizontal flow of groundwater caused the initial migration of CTC within Aquifer A;

- CTC was last detected in Aquifer C in November 1990 at wells Y-2 and Y-5 (now abandoned) at concentrations of 2.8 µg/L and 0.7 µg/L, respectively. CTC has not been detected in any of the current Aquifer C wells since they were installed in 2000;

- Groundwater flow is primarily horizontal to the north-northwest from the Site toward Clover Creek;

- Adjacent to Clover Creek (on both sides), groundwater flow is upward, resulting in discharge to Clover Creek;

- CTC has not been detected in surface water or sediment in Clover Creek; and,

- Since 1991, the mass of CTC dissolved in groundwater has been subject to various fate and transport mechanisms, destructive and non-destructive, that have influenced the observed distributions. CTC concentrations along the flow path have been declining and will continue to decline under the influence of the following mechanisms: i) advective-based dispersion; ii) recharge of groundwater that does not contain CTC; iii) sorption to aquifer solids; and iv) abiotic and biotic CTC transformation reactions. A concentration trend analysis of monitoring well CTC data clearly shows declining CTC concentrations in all wells over time. Based on the CSM and the available CTC groundwater chemistry data, it is apparent that CTC concentrations in groundwater are declining and that the extent of CTC in groundwater is expected to continue to shrink through natural processes until all groundwater in the Site is below the MTCA Cleanup Level for CTC.

Potential Risk Pathways and Cleanup Levels

Potential exposure pathways were evaluated for CTC at the Site, including pathways involving CTC in soil, soil-gas, groundwater, surface water and sediment. The results of this evaluation concluded that:

- There are no unacceptable potential exposures associated with CTC in soil, as CTC concentrations are all below levels that would pose risk to human health or groundwater;

- There are no unacceptable potential indoor air exposures related to vapor intrusion from CTC in soil, soil-gas or groundwater;

- There are no unacceptable potential exposures associated with CTC in groundwater, as the drinking water pathway is incomplete as a result of implementation of permanent solutions regarding the CTC-affected domestic drinking water wells, and due to prevailing use limitations; and

- There are no unacceptable potential exposures associated with CTC in surface water or sediment, as CTC concentrations are below method reporting limits in these media, groundwater CTC concentrations in adjacent wells do not exceed the surface water screening criterion for consumption of organisms only, and groundwater CTC concentrations are declining with time so it is very unlikely that groundwater with CTC concentrations greater than this criterion will discharge to the creek in the future. Furthermore, this section of the creek is not currently and is not likely to be used in the future as a source for potable water supply, based on the availability of municipal supply.

Consistent with MTCA regulations, the highest beneficial use of groundwater at the Site has been determined to be drinking water. Since surface water is not and will not likely be used for drinking water, the most stringent Applicable or Relevant and Appropriate Requirement (ARAR) for CTC in groundwater is 0.63 µg/L, which is the MTCA Method B standard formula value.

Development and Detailed Analysis of Remedial Alternatives

Following an initial identification and screening of potentially-applicable remedial technologies and process options, three remedial alternatives were developed. These included:

- **Alternative 1: Site-wide Monitored Natural Attenuation (MNA) –** This alternative would consist of monitoring and documenting that the naturally-occurring processes that have been reducing CTC concentrations will continue to occur until such time that CTC in groundwater meets the MTCA cleanup level for CTC. The natural processes were described above in the CSM section. As part of evaluation of the MNA alternative, a site-specific attenuation rate constant was estimated to be 0.095 per year based historical monitoring well data for on-Property and off-Property areas. It is anticipated that CTC would be below the MTCA cleanup level (0.63 µg/L) at all wells within 28 years. The estimated present value cost of Alternative 1 is $555,000.

- **Alternative 2: Site-wide Groundwater Extraction and Treatment (P&T) –** This alternative would consist of installation of two groundwater extraction wells, pumping at a combined rate of approximately 300 to 400 gallons per minute (gpm) to remove CTC in excess of 0.63 µg/L from groundwater. Extracted groundwater would be conveyed to a new groundwater treatment system located on Site (on Boeing property). Approximately 3,400 feet (ft) of conveyance piping would be required to connect the extraction wells to the treatment system. Most of this conveyance piping would need to be installed in public rights-of-way beneath or beside roadways. Treatment would be accomplished using a granular activated carbon adsorption unit. Treated water would most likely be conveyed to the nearest surface water feature (location to be determined) and discharged under applicable permit(s). It is anticipated that CTC would be below the MTCA cleanup level (0.63 µg/L) at all wells within 18 years. The estimated present value cost of Alternative 2 is $4,143,000.

- **Alternative 3: Permeable Reactive Barrier (PRB) –** This alternative would consist of installation of an in-situ flow-through treatment barrier containing reactive media (e.g., zero-valent iron) that would reduce CTC to concentrations below the MTCA cleanup level. The PRB would be situated within the northern Property boundary downgradient of the former process area. The PRB would be designed to span the width of the plume above the 0.63 μg/L CTC contour, which is approximately 1,200 ft. At the proposed location, the depth to the bottom of Aquifer A is approximately 110 ft. The reactive barrier would be installed from approximately 30 ft below ground surface (bgs) to approximately 110 ft bgs. Groundwater from the Site would flow through the PRB, and the CTC would be reduced to comply with the MTCA cleanup level. It is anticipated that CTC would be below the MTCA cleanup level (0.63 μg/L) at all wells within 28 years. The estimated present value cost of Alternative 3 is $6,871,000.

Each of these Alternatives was subjected to a detailed evaluation, per the two categories of cleanup action requirements under WAC 173-340-360: (i) threshold requirements and (ii) additional requirements.

The threshold requirements (WAC 173-340-360(2)(a)) included: i) Protect Human Health and the Environment; ii) Comply with Cleanup Standards; iii) Comply with Applicable State and Federal Laws; and iv) Provide for Compliance Monitoring. All three Alternatives were found to comply with these threshold requirements.

The additional requirements (WAC 173-340-360(2)(b)) included: i) Use Permanent Solutions to the Maximum Extent Practicable; ii) Provide for Reasonable Restoration Time Frame; and iii) Consider Public Concerns. Each of the Alternatives were rated based on these criteria and had differing scores, with MNA gaining the highest score, followed by P&T and PRB. MNA was also determined to be the lowest cost remedy.

Consistent with WAC 173-340-360(3)(e), a disproportionate cost analysis (DCA) was performed for the three Alternatives to determine which of these cleanup action alternatives is protective to the maximum extent practicable, and to determine if the incremental costs of higher cost remedies (i.e., P&T or PRB versus MNA) are proportionate to their anticipated incremental benefits. The DCA evaluation criteria included protectiveness, permanence, cost, long-term effectiveness, management of short-term risks, implementability, and consideration of public concerns. The results of the DCA indicated that the incremental benefits (if any) of the P&T and PRB remedies would be highly disproportionate to the incremental costs versus MNA, and as such, the DCA selects the MNA remedy, which was both the highest scoring and lowest cost remedy.

As a further evaluation metric for the Alternatives (although not required under MTCA), the sustainability of the three Alternatives was also evaluated using commercially-available sustainability evaluation software developed by the United States Government, in collaboration with industry, environmental consultants, and state regulators. The results of this analysis showed that:

- CO_2 emissions were approximately 45 and 525 times greater for P&T and PRB, respectively, compared to MNA;

- Energy consumption was approximately 67 and 75 times greater for P&T and PRB, respectively, compared to MNA; and

- The safety/accident risk metric was approximately 8 and 19 times greater for P&T and PRB, respectively, compared to MNA (meaning MNA would be much safer to implement).

Through this RI/FS process, Alternative 1 (MNA) has been found to be consistent with Ecology expectations and requirements for cleanup action alternatives, and is superior to Alternatives 2 (P&T) and 3 (PRB) based on the MTCA evaluation criteria, cost and sustainability. As such, Alternative 1 – MNA is proposed as the recommended alternative for the Site.

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AFCEE	United States Air Force Center for Engineering and the Environment
AO	Agreed Order
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
CAP	Corrective Action Plan
CAS	Columbia Analytical Services
CCC	Clover/Chambers Creek
CFR	Code of Federal Regulations
CLARC	Cleanup Levels and Risk Calculation
CO_2	Carbon Dioxide
CRA	Conestoga, Rovers & Associates
CSM	Conceptual Site Model
CTC	Carbon Tetrachloride
CUL	Cleanup Level
DCA	Disproportionate Cost Analysis
Ecology	Washington Department of Ecology
ft	Feet
GAC	Granular Activated Carbon
gpm	gallons per minute
IDW	Investigation Derived Waste
ITRC	Interstate Technology and Regulatory Council
LCA	Lifecycle Cost Analysis
MCL	Maximum Contaminant Level
MNA	Monitored Natural Attenuation
MTCA	Model Toxics Control Act
NO_x	Nitrous Oxides
NRWQC	National Recommended Water Quality Criteria
O&M	Operations and Maintenance
P&T	Pump and Treat
PCB	Polychlorinated Biphenyls

PM_{10}	Particulate Matter
PRB	Permeable Reactive Barrier
PV	Pore Volume
R	Retardation Factor
RCW	Revised Code of Washington
RDX	Research Department Explosive
RI/FS	Remedial Investigation and Feasibility Study
SOW	Scope of Work
SO_x	Sulfur Oxides
SRT	Sustainable Remediation Tool
SSL	Soil Screening Level
TEE	Terrestrial Ecological Evaluation
TNT	Trinitrotoluene
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
VAS	Vertical Aquifer Sampling
VI	Vapor Intrusion
VOC	Volatile Organic Compound
WAC	Washington Administrative Code
WSCP	Water Supply Conceptual Plan

1 INTRODUCTION

This *Remedial Investigation/Feasibility Study (RI/FS) Report* (RI/FS Report) has been prepared by Geosyntec Consultants on behalf of Olin Corporation and Mallinckrodt US LLC (the Companies) to summarize the phased investigations and guide remediation of carbon tetrachloride (CTC) in groundwater at the Frederickson Industrial Park in Frederickson, Washington (**Figure 1-1**). Per Model Toxics Control Act (MTCA) and Chapter 173-340-200 of the Washington Administrative Code (WAC), the Site is defined to be anywhere hazardous substances have come to be located, and thus includes both on- and off-Property areas. For this RI/FS Report, the Property refers to the area contained within the property boundaries of the Frederickson Industrial Park. This RI/FS Report is being submitted to the Washington Department of Ecology (Ecology) in accordance with the requirements of Agreed Order No. DE 97TC-S121 (AO) established between the Companies and Ecology on 12 May 1997, and associated correspondence of May 11, 2011 in which Ecology agreed that sufficient data have been collected to complete the remedial investigation and prepare the RI/FS Report for the Site.

1.1 Site Overview & History

The Property encompasses 527 acres of land south of 176th Street East and east of Canyon Road East in the Fredrickson area of Pierce County, Washington. The Property is situated approximately 10 miles south of Tacoma and 8 miles southwest of Puyallup, and is located in unincorporated County area surrounded by a mixture of industrial, residential and commercial properties. The Property is accessible from Canyon Road East and from 176th Street East.

From 1935/1936 through 1976, the Property was operated as an explosives manufacturing and processing plant under various ownerships. From 1976 to 1986, the Property was conveyed through a series of transactions to several owners related to the lumber industry (e.g., timber cutting, lumber milling, and related storage purposes). During the period of 1987 to 1990, the Property was developed as an industrial park to facilitate its sale. In the course of Property development, investigations were conducted and residual debris and waste were removed. Detailed accounts of debris and waste removal are provided in Section 2 of this RI/FS Report.

While there was no known use of CTC in any of the past Property manufacturing processes, CTC was suspected to have been used in limited volume as a potential industrial cleaning solvent and as a fire extinguishing compound during powder plant operations (1936-1976). Disposal pits were reportedly used to burn and dispose of waste paper, fugitive powder, barrels, scrap metal, laundry wastes, rags, and wood products. CTC was initially discovered in on-Property monitoring wells in 1988. Consequently, several investigations were conducted at the Site, and have confirmed the presence of CTC in the groundwater, both on- and off-Property. While off-Property CTC concentrations were below the United States Environmental Protection Agency's (USEPA's) 5 µg/L Maximum Contaminant Level (MCL), some locations exceeded cleanup levels established under the authority of the Washington State Statute, Revised Code of

Washington (RCW) (70.105D), MTCA and Chapter 173-340 WAC, the MTCA Cleanup Regulation. For example, several domestic drinking water wells to the northwest of the Property contained concentrations of CTC exceeding the former MTCA Method B value (0.337 µg/L)[1] for groundwater, but were below the MCL.

In 1990, the Property was purchased by Boeing, the current owner. Boeing graded, constructed and currently operates an aircraft parts manufacturing facility on the Property. In 1994, Centrum Properties Corporation entered into Agreed Order No. DE 94TC-S217 with Ecology to conduct a phased remedial investigation and feasibility study at the Site, with Phase I of the RI/FS completed in 1995. Olin and Mallinckrodt are the successors of former owners of the Property. In 1997, the Companies entered into AO No. DE 97TC-S121 requiring the Companies to undertake the following remedial actions at the Site:

- devise and implement a permanent solution regarding the impact of CTC in affected domestic drinking water wells; and
- design and implement a work plan to provide a basis for completion of the RI/FS.

As specified in the AO, the Phase II RI/FS is to be conducted in accordance with MTCA, WAC-173-340-350, and the State remedial investigation and feasibility study requirements, as appropriate.

Starting in 1998, the scope of work described in the *Phase II RI/FS Work Plan* was implemented. In 1998, the Companies submitted the *Water Supply Conceptual Plan* (WSCP) which provided the proposed approach to provide for a permanent remedial action regarding CTC-affected domestic wells. The implementation of the WSCP is discussed in detail in Section 2.1.2.3. In addition to submittal and implementation of the WSCP, multiple technical memoranda related to site investigation activities and other RI/FS tasks were submitted to Ecology pursuant to the AO and the *Phase II RI/FS Work Plan*. These memoranda are summarized in Section of 2.1.1 of this RI/FS Report.

In early 2007, communications between the Companies and Ecology centered on Ecology's requests for further investigation to address potential data gaps in soil and groundwater, and to expand groundwater characterization activities to include the energetic compounds perchlorate, TNT and RDX in order to complete the RI process. In response to these communications, the Companies submitted a work plan titled *Additional RI Scope of Work* (SOW) to Ecology on 7 March 2008. The SOW described the work tasks that were developed in consultation with Ecology for the completion of the RI at the Site. Ecology approved the SOW in March 2008.

In May 2010, the Companies proposed modifications to the implementation sequence of the Additional RI SOW (Geosyntec, 2010a), primarily to conduct groundwater sampling in advance of installing the proposed new monitoring wells. This was conducted to confirm the suitability

[1] In May 2011, the MTCA Method B value for CTC in groundwater was revised to a value of 0.63 µg/L.

of proposed monitoring well installation locations, and to assess the presence of the energetic compounds in groundwater. Ecology approved the re-sequenced scope of work on 7 May 2010. The results of the June 2010 groundwater monitoring event, confirmed that CTC is the only chemical of concern for the Site (Geosyntec, 2010b). Ecology concurred with this conclusion in an email dated 10 November 2010. The final tasks of the Additional RI SOW were completed in March 2011, as acknowledged by Ecology's letter dated 11 May 2011. This RI/FS Report is being completed in accordance with the requirements of the 1997 AO and the 11 May 2011 correspondence from Ecology, in order to determine the preferred remedy for remediation of CTC in groundwater at the Site.

1.2 Objectives of the RI/FS

The primary objective of this RI/FS is to identify and implement an appropriate remedy for CTC in groundwater. The specific objectives of this RI/FS are to:

- characterize the on-Property and off-Property extent of the CTC groundwater plume;
- determine and confirm any existing potential source areas of CTC;
- acquire the information necessary for the selection of a cleanup action;
- document implementation of permanent solutions for domestic wells impacted by CTC;
- recommend cleanup standards (i.e., cleanup levels and point(s) of compliance) for the Site;
- develop and evaluate cleanup action alternatives capable of achieving the cleanup standards for the Site;
- analyze the technical equivalency of the cleanup action alternatives, in terms of the MTCA threshold criteria and additional criteria, such as permanence, reasonable restoration time frame, sustainability, and adequate consideration of public concerns;
- prepare comparative cost estimates (to an approximate accuracy of plus 50 percent to minus 30 percent) for the various cleanup action alternatives, and identify the most cost-effective cleanup action alternative to achieve the cleanup standards; and
- identify the cleanup action alternative (preferred alternative) that satisfies the MTCA criteria, provides for a permanent solution to the maximum extent practicable, provides for a reasonable restoration time frame, and considers public concerns.

Based on the information presented in this RI/FS, a final remedial action alternative will be selected for implementation at the Site.

1.3 Report Organization

The remainder of this RI/FS is divided into the following sections:

- Section 2 – Site Characterization and Remediation, which includes a review of: (i) site conditions, (ii) the nature and extent of CTC contamination, (iii) site risk and exposure pathway evaluation, and (iv) review of past site remediation activities.
- Section 3 – Cleanup Standards.
- Section 4 – Identification and Screening of Remedial Technologies.
- Section 5 – Identification and Detailed Analysis of Cleanup Action Alternatives.
- Section 6 – References.

2 SITE CHARACTERIZATION & REMEDIATION

The following sections provide: i) a summary of Site activities conducted from 1988 through 2011, including investigations, submittals of data reports, agency correspondence, remedial actions and domestic water supply connections (Section 2.1); ii) a review of Site conditions, including site geology, site hydrogeology, surface water features, and local land and resource use (Section 2.2); iii) a summary of the nature and extent of chemical impacts at the Site by media (i.e., soil, groundwater, surface water, and sediment) and an analysis of CTC concentration trends over time in groundwater (Section 2.3); and iv) a Site risk and exposure pathway evaluation (Section 2.4).

2.1 Summary of Site Activities – Investigations and Remedial Activities

2.1.1 Site Investigations, Data Reports and Relevant Correspondence

Numerous site investigations and remedial activities have been conducted at the Site over the past twenty-five years. From 1988 to 1998, main activities included:

- an Ecology site inspection (1988);
- a report on groundwater sampling (1989);
- a summary of the environmental investigation for contaminated wastes and remedial actions (1989);
- an environmental site assessment (1990);
- Multiple source area excavations and removal actions between 1989 and 1991, as summarized in Section 2.1.2.1;
- Several rounds of groundwater monitoring (from 1988 to 1995); and
- a Phase I RI/FS (from 1994 to 1995).

The *Phase II RI/FS Work Plan* (Conestoga Rovers & Associates [CRA], 1998) provides a detailed summary of these activities.

Starting in 1998, the scope of work described in the *Phase II RI/FS Work Plan* was implemented. Activities from 1998 through 2011 have included:

- a Phase II RI/FS (1998 through 2007) that included a soil gas investigation (1999), an evaluation of potential plume impacts on water supply (2000), installation of several new monitoring wells (2000 to 2002), and three rounds of groundwater sampling (2000, 2001 and 2002);

- Implementation of permanent solutions for CTC-affected domestic drinking water wells from 2002 to 2007; and

- Completion of the Phase II RI/FS (2008 - 2011).

Documents submitted to Ecology pursuant to the AO and the *Phase II RI/FS Work Plan* from 1998 through 2011 are summarized below:

- **January 1998. *Water Supply Conceptual Plan* (CRA, 8/1/98).** The Water Supply Conceptual Plan (WSCP) provided the proposed approach to provide for a permanent remedial action regarding the impact of CTC-affected domestic wells. The WSCP indicated that the preferred remedial alternative was to extend existing water mains to all potentially affected residences having CTC concentrations above the MTCA Method B cleanup value. The WSCP was approved in 1998 by Ecology. The implementation of the WSCP (2000 through 2007) is described in detail in Section 2.1.2.3.

- **August 1999. *Task 5: Technical Memorandum No. 1* (CRA, 8/1/99).** An initial round of soil gas and groundwater data was collected to produce a "snapshot" of existing conditions. Based on these data, the locations of 6 proposed monitoring wells and 2 sets of nested piezometers were finalized, as well as the proposed monitoring network for an additional two rounds of groundwater/hydraulic monitoring.

- **February 2000. *Technical Memorandum No. 2* (CRA, 2/4/00).** This report presented a definition of aquifer and aquitard layers on- and off-Property, based on the review of Site-specific and published data. The report concluded that groundwater from the Site would not likely be hydraulically captured by the known water purveyors in the vicinity of the Site (located 3 to 4 miles from the Site), based on the hydrogeologic data (e.g., geologic, aquifer parameter and pumping rate data) available to CRA at the time.

- **March 2001. *Task 8: Groundwater Investigation (Update)* (CRA, 3/27/01).** This report documented the monitoring well installations (6 wells and 2 nested piezometers), hydraulic monitoring, and groundwater sampling data. Sixteen residential wells and 23 monitoring wells were sampled for volatile organic compounds (VOCs) to define the extent of the CTC plume. Results confirmed that CTC was the only VOC of concern and concentrations had remained similar to historic levels since 1986. CTC extended to the north to Clover Creek and vertically to about 125 and 95 feet (ft) below ground surface (bgs), under the Property and at Clover Creek, respectively.

- **February 2002. *Task 8: Groundwater Investigation (Update: Use of Existing Residential Wells as Long–Term Monitoring Points)* (CRA, 2/1/02).** This report documented the compilation of residential well information, survey of new monitoring wells and existing residential wells, and evaluated the groundwater discharge area at Clover Creek. The report identified 8 residential wells (to be used in lieu of installing additional monitoring wells) for monitoring purposes to define the east, west and northern (northwest of Clover Creek) edges of the CTC plume. The report also proposed to collect surface water samples for CTC analyses from Clover Creek at 4 locations.

- **April 2003. *Task 8: Groundwater Investigation (Update-Third Round Monitoring Program Results)* (CRA, 4/23/03).** This report documented the installation of a new monitoring well north of Clover Creek (requested by Ecology), hydraulic conductivity testing, third and final round groundwater monitoring event required by the *Phase II RI/FS Work Plan*, and an update on connections to Tacoma City water (see Section 2.1.2.3 for a summary of connection activities). Groundwater sampling was done in 15 of the 19 wells sampled during the second round, 3 additional private wells, new monitoring well MW-7 (north of Clover Creek), 4 surface water locations, and 7 private wells in the vicinity of MW-7 due to the presence of CTC in this well. Based on the third round results, 2 additional properties were identified as requiring hook-up to the City water system for a total of 15 properties.

- **April 2007. *Response to Ecology's letter report dated January 10, 2007* (CRA, 4/12/07).** A PowerPoint Presentation entitled "RI/FS and Domestic WSCP Project Update" was conducted by CRA to Ecology in Tacoma on March 1, 2007. The presentation provided responses to the comments by Ecology in their 10 January 2007 letter. The responses included a summary of the history of the Property, descriptions of the completed tasks in the RI/FS Work Plan (delineation of CTC, an update of the efforts involved in the access agreements, and connections to City water as part of the domestic WSCP). The responses also presented the rationale for the installation of 7 additional monitoring wells.

- **March 2008. *Additional RI Scope of Work* (Olin letter dated 3/7/08 from David M. Share, Olin to Laura Klasner of Ecology).** This letter described the activities developed in consultation with Ecology to complete the RI and included securing access agreements, existing well inventory and inspection (identify any repairs), installation of 7 additional wells and vertical aquifer sampling (VAS), groundwater sampling (twice during the first year-spring and summer), surface water sampling at 4 locations in Clover Creek (during low flow conditions), a groundwater upwelling investigation (to assess groundwater discharge to Clover Creek), sediment sampling in Clover Creek, review of wellhead protection zones (including modeling), and preparation of reports. The Additional RI Scope of Work and revised RI/FS schedule was approved by Ecology on March 18, 2008.

- **May 2008. *Well Inspection Results* (CRA, 5/21/08).** This report presented the results of the existing well inspection. Twenty four wells were inspected: 17 were identified as being in good condition and suitable for groundwater sample collection during the RI. Four wells were in good condition but were suspected of having sediment accumulation or blockages. One well could not be located, while two wells were no longer available for sampling due to damage, but were described as not being critical to the groundwater sampling network.

- **September 2008.** ***Management of Investigation Derived Waste-Brazier Site, Tacoma, Washington*** **(CRA, 9/9/08).** This document provided additional information regarding the proposed management of investigation derived waste (IDW) associated with the additional activities proposed to complete the RI. The additional activities correspond to those listed in the March 7, 2008 “Additional RI Scope of Work” and included the installation of additional monitoring wells and groundwater sampling both on and downgradient of the Boeing Property. The document provided specific protocols for the handling and management of the IDW, which are consistent with 40 CFR262.34.

- **November 2009.** ***Private Property Access; Request for Ecology Assistance*** **(Olin (McClure), 11/16/09).** This letter provided an update regarding the Companies’ activities to secure access for monitoring well installation at the Additional RI Scope of Work locations and requested Ecology assistance where access was still needed. As noted in the letter update, the Companies expended significant effort and resources to attempt to secure the necessary access agreements and permits for well installations, but were unable to secure access to any private property for monitoring well installations.

- **May 2010.** ***Proposed Sequencing of Additional Remedial Investigation Activities*** **(Geosyntec, 5/6/10).** This technical memorandum submitted to Ecology provided the rationale to revise the Additional RI SOW such that the first round of groundwater sampling would be conducted prior to installation of the new monitoring wells proposed in the SOW letter. Ecology provided concurrence with the revised implementation approach on 7 May 2010.

- **August 2010.** ***Additional RI – First Groundwater Monitoring Event Results, Frederickson Industrial Park Site, Pierce County, WA*** **(Geosyntec, 8/19/2010).** This letter report submitted to Ecology presented the results of the first groundwater monitoring event conducted in June 2010. A total of 21 groundwater monitoring wells were sampled for CTC and the three energetic constituents prescribed in the SOW – perchlorate, (research demolition explosive (RDX), and trinitrotoluene (TNT). In addition, one private well (i.e., the Pierce Well) was sampled and analyzed for CTC. Based on the results of the sampling event, the letter report concluded that CTC is the only constituent of concern at the Site. In addition, the letter report recommended that the number of monitoring wells to be installed at the Site be reduced from eight to one (MW-13) based on the declining CTC concentrations observed throughout the study area. Ecology provided concurrence with the recommendations and conclusions contained in the August 2010 letter in a letter dated 30 August 2010.

- **September 2010.** ***Updated Schedule for Additional Remedial Investigation Activities, Frederickson Industrial Park Site, Pierce County, WA*** **(Geosyntec, 9/24/2010).** This letter submitted to Ecology provided an update on the Additional RI SOW implementation schedule. It confirmed that sediment and surface water sampling at Clover Creek would occur in October 2010. It also estimated that the second groundwater monitoring event would occur in the first quarter of 2011 after installation of MW-13 was completed. The proposed groundwater upwelling investigation would occur during the second groundwater sampling event. Ecology provided concurrence with the updated schedule in an email dated 27 September 2010.

- **November 2010.** ***Additional RI – Surface Water & Sediment Sampling Event Results, Frederickson Industrial Park Site, Pierce County, WA*** **(Geosyntec, 11/9/2010).** This letter report submitted to Ecology presented the results of the Additional RI surface water and sediment sampling event for the Site. A total of four surface water samples and four sediment samples were collected at Clover Creek and analyzed for CTC; all the results were non-detect. Based on the results of the sampling, the letter recommended that the groundwater upwelling investigation be eliminated from the SOW. Ecology concurred with the recommendation in an email dated 10 November 2010. The schedule to conduct the second groundwater sampling event in the first quarter of 2011 was confirmed.

- **March 2011.** ***Additional RI - Second Groundwater Monitoring Event Results and Installation of Monitoring Well MW-13, Frederickson Industrial Park Site, Pierce County, WA*** **(Geosyntec, 3/31/2011).** This letter report submitted to Ecology described the installation of monitoring well MW-13 and presented the results of the second groundwater monitoring event conducted in February 2011. A total of 22 groundwater monitoring wells, including MW-13, were sampled for CTC. Based on the results of the second groundwater sampling event, the letter concluded that sufficient data were available to prepare the RI/FS Report. Ecology concurred with the recommendation in a letter dated 11 May 2011.

The data acquired through the aforementioned activities form the basis of the information presented in Sections 2.2, 2.3, and 2.4.

2.1.2 Site Remediation Activities

Source Excavations and Removals

Based on past documentation (e.g., *Phase II RI/FS Work Plan*), multiple source area excavations and removals occurred in 1989 and 1991, and are summarized below. A potential source of CTC to groundwater was not definitively identified during the source excavations and removals. However, even though the documented source area excavations and removals targeted multiple constituents and were not specific to CTC, it was previously concluded, based on subsequent soil, soil gas and groundwater data showing very low and declining CTC concentrations, these removals effectively abated the potential source of CTC impacts to the subsurface at these areas.

September 1989. JMR Enterprises excavated an extensive amount of debris (e.g., metal, barrels, concrete rubble, etc.) from dump sites on Lots 7, 9, and 10. Figure 2.5 of the RI/FS Work Plan (copy provided in Appendix A) shows the locations of the Centrum Development Plan lots. The area excavated was approximately 0.4 acres on Lot 7, and 4 acres each on Lots 9 and 10. AHR (1989) estimated that the following material was excavated and processed from these areas (primarily from Lots 9 and 10):

- 58,000 pounds of barrels (approximately 1,100 barrels);
- 57,000 pounds of metal waste/debris;
- 5,000 cubic yards of concrete rubble;
- 3,000 cubic yards of soil from the barrel dump; and,
- 15,000 cubic yards of soils sifted and sorted for debris removal.

AHR also reported that removal work done by Crosby & Overton and JMR Enterprises included:

- removal of 225,000 pounds of petroleum products, wood preservatives, paints, and miscellaneous related debris;
- removal of four bunker fuel storage tanks from the boiler house; and
- removal of five underground diesel, gasoline and oil storage tanks.

Following the debris excavation, AHR excavated 13 test pits at the bottom of the debris pits. One soil sample from each trench was analyzed for VOCs, polychlorinated biphenyls (PCBs) and metals. Soil excavated from the barrel dump was also analyzed for VOCs, PCBs, and metals. The test pit soil data were non-detect for CTC and other VOCs with the exception of low-level detections of chlorobenzene in one test pit and trichloroethylene in two test pits. The test pit soil data were summarized in Table 2.2 of the RI/FS Work Plan (copy provided in Appendix A).

October/November 1991. Approximately 7,120 cubic yards of soil with petroleum at concentrations greater than the MTCA Cleanup Levels (CUL) (200 mg/kg) were excavated from 20 locations at the Property during October and November 1990. Soil removed from the remedial excavations was stockpiled on-Property. Excavation of soil with petroleum concentrations greater than the CCL was completed successfully in 17 of the 20 remedial excavations. Further removal of soil from two of the three incomplete remedial excavations was not completed because existing facilities required demolition[2]. Bioremediation of the stockpiled soil was scheduled for the spring and summer of 1991. Based on subsequent reports, it appears that the excavated soils were disposed off-Property in late 1992 and early 1993 after attempts to reach cleanup goals via bioremediation were not successful.

Groundwater Extraction & Treatment

In January 1990, AHR began to operate a groundwater extraction and treatment system. Groundwater was initially extracted from well 11-A, and was later switched to well 11-D (locations shown in **Figure 2-1**). The pumping rates for the extraction wells reportedly ranged from 60 to 90 gallons per minute (gpm). The water was treated by air stripping and reportedly discharged to the ground surface. The system was taken out of operation in July 1990, shortly after Boeing purchased the property (AHR, 1990).

Domestic Water Supply Connections

From 2002 to 2007, the Companies devised and implemented permanent solutions regarding the CTC affected domestic drinking water wells, as required by the AO. During these efforts, the Companies proceeded with abandonment of domestic water supply wells and providing connections to a municipal water supply pipeline with Ecology's knowledge and understanding that the elimination of direct exposure pathways should be addressed before submittal of the RI/FS report. As a result, the Companies secured access agreements with impacted property owners, provided connections to the municipal water supply system and decommissioned existing wells when agreed to by the owner.

Thirteen properties were connected to public water. These efforts toward completing this AO requirement are described below:

- The Ramsey property was connected prior to initiation of the study by a contractor on behalf of the owners;

[2] Ecology provided comments on the Draft RI/FS Report on 7 October 2011. One of the comments addressed the potential need for an institutional control for on-Property soils. In a 26 January 2012 email, Ecology requested that the Companies provide additional information on prior TPH remediation activities to confirm that all contaminated soil at the Site has been remediated and thus eliminate the requirement for an environmental covenant for the Property soil. On 22 February 2012, the Companies submitted to Ecology a technical memorandum titled "*Overview of Total Petroleum Hydrocarbons (TPHs) Distribution at the Frederickson Industrial Park, Frederickson, Washington*." The technical memorandum is provided in Appendix E of this RI/FS Report. Subsequent to submittal of the technical memorandum, it was determined that Boeing, the current Property owner, would conduct a limited TPH investigation to determine whether TPH is present in soil at concentrations that exceed current MTCA cleanup levels.

- Four hookups were completed in July 2002 by Ollala Hills Excavating and included: Catchpole, Lemay #2, Looker, and WGW Inc. (Wetherbee). At the WGW Inc. property the property side pipe was stubbed as the house was razed for development;

- Five hookups were completed by Northwest Cascade, including Arthur, Bowman, WGW Inc. (former Kuhuski), Rennie and Campbell. Connections to the Arthur, Bowman and WGW Inc. properties were completed between March and June 2006. Connection to the Rennie and Campbell properties were completed in January and March 2007, respectively. Connection to the Rennie property required that water service pipe be run under a railway right-of-way (completed in August 2006), and the addition of a residential booster station to compensate for estimated pressure losses due to the significant distance between the water meter and the house. It is noted that low water pressure along 176th Street resulted in residential booster stations also being required at the Campbell and WGW Inc (former Kuhuski) properties. All of the booster stations were installed in November - December 2006;

- Arrangements for three hookups were made by the property owners, including: Lemay #1, Wheeler (former Wilcox), and Coleman. These hookups were completed in mid to late 2003, February 2006, and April 2006, respectively;

- The time between the first (2002) and second (2006) round of hookups resulted from the time required to secure agreements with the second group of property owners, access for the railroad crossing, and a change in ownership in the case of the former Kuhuski and former Young properties;

- The Companies installed a 2,100 foot municipal water main extension along 176th Street, east of Canyon Road;

- The Canyon Trails, LLC (former Young) property was to have been included in the second round of hookups; however, the new owners determined that the water service was no longer required as the house has been demolished; and,

- At the Shotwell property, a hookup was not required since the location was no longer used as an operating pit and a water source was therefore not required.

Eight well closures were also completed at seven properties in accordance with the wishes of the property owners. All work was completed in accordance with Washington State regulations, and is summarized as follows:

- Closure of the Shotwell property shallow and deep wells took place in February, 2002; and,

- Closure of wells at Canyon Trails, LLC (former Young), WGW Inc. (Wetherbee), WGW Inc. (former Kuhuski), Bowman, and Ramsey were completed between June and

December 2006. The Campbell (old well only) was closed in November 2007. It is noted that at the Campbell property, the "new" well was not abandoned and has been used for irrigation and livestock (llamas).

2.2 Site Conditions

The Site is located within the Clover Creek Subbasin, which occupies the southeastern portion of the Clover/Chambers Creek (CCC) Basin **(Figure 1-1)**. Detailed descriptions of the regional and site-specific conditions have been presented previously (Brown & Caldwell, 1985; CRA, 1998; CRA, 1999; CRA, 2000; CRA, 2001; CRA, 2002; CRA, 2003; Geosyntec, 2010; and, Geosyntec, 2011). **Figure 2-1** depicts the area of interest, including Property boundaries, the monitoring well network, locations of existing and decommissioned domestic wells, surface water features, and local streets. This section provides a summary of the Site conditions pertinent to remedy evaluation and recommendation.

2.2.1 Site Geology

Five geologic/hydrogeologic cross-sections were originally presented in *Technical Memorandum No. 2* (CRA, 2000) to illustrate the stratigraphic/hydrostratigraphic framework of the area surrounding the Site. The geologic/hydrogeologic cross-sections extend from the Property to distances approximately 4 miles north and 3 miles east and west of the Property. The area covered by the cross-sections includes the length and width of the CTC plume. The data (well and boring logs) used to develop the cross-sections were provided in Appendix A of *Technical Memorandum No. 2* (CRA, 2000). The locations of the cross-sections are shown on Figure 3.1 of *Technical Memorandum No. 2*. Geologic/hydrogeologic cross-sections A-A' (north to south), B-B' (north to south), C-C' (north to south), D-D' (west to east), and E-E' (west to east) are presented on Figures 3.2, 3.3, 3.4, 3.5, and 3.6, respectively. Copies of Figures 3.1 through 3.6 are provided in Appendix A of this RI/FS Report.

Regionally, the geologic/stratigraphic units were designated as "Layers" by Brown and Caldwell (1985). A layer is a grouping of deposits, both vertically and horizontally, which were deposited at approximately the same time, under similar environmental conditions and which exhibit the same general physical and hydrologic characteristics. Major water-transmitting or producing zones are glacial layers A, C, and E, which are identified as Aquifers. Interglacial Layers B and D retard or inhibit the flow of groundwater, and are identified as Aquitards. Layers A through C are pertinent to this RI/FS. Further details for Layers D and E are provided in the Brown and Caldwell report.

The following subsections provide abbreviated descriptions of the layers with emphasis on lithology and hydraulic properties. More detailed regional descriptions of these layers can be found in *Technical Memorandum No. 2* (CRA, 2000).

Layer A

Layer A is primarily glacial in origin and includes all materials stratigraphically above the Kitsap Formation. Regionally, Layer A varies from approximately 30 to 350 ft thick, with an average thickness of 200 ft. The average saturated thickness of Layer A is on the order of 150 ft.

The most recent deposits included within Layer A are peat and alluvium. Peat deposits consist of partly decayed organic matter and are found scattered throughout the surface of the CCC Basin. These deposits are associated with swamps and marshes. The alluvium consists of sand, gravel, silt, and clay recently deposited at the bottom of creeks and streams. No peat deposits within Layer A have been identified within the Property area. Layer A at the Property is comprised entirely of alluvial deposits.

Vertical and horizontal movement of groundwater is highly influenced by the presence/absence of lower permeability till materials that exist in some areas.

Layer B

Layer B is a widespread interglacial unit consisting mainly of clay, silt, and fine sand with included vegetation. Beneath the Property, Layer B has not been identified in deep wells. Layer B has been identified at off-Property wells.

Layer C

Layer C consists of glacial drift aquifer material that serves many of the region's water supply wells. Layer C is well represented in test holes and water wells throughout the CCC Basin. Layer C in the vicinity of the Site is typically approximately 120 ft thick. Where overlain by fine-grained deposits of Layer B, Layer C can be expected to have a reasonable degree of protection from direct surface contamination.

2.2.2 Site Hydrogeology

In the vicinity of the Site, the major water producing zones or aquifers are glacial Layers A and C, while interglacial Layer B generally inhibits groundwater flow and is therefore considered an aquitard. The hydrogeologic characteristics of these three layers are described as follows:

Aquifer A

Aquifer A is the uppermost unit in the area of the Site with an average saturated thickness of 80 to 100 ft near the Site. Aquifer A in this area consists primarily of sands and gravels. The average hydraulic conductivity of the materials comprising Aquifer A is on the order of 1.4×10^{-2} cm/sec (40 ft/day) (CRA, 2000). A representative transmissivity value for Aquifer A is approximately 4,000 ft^2/day.

Aquifer A is unconfined and groundwater flow at the Site is predominantly to the north and northwest. The average regional horizontal hydraulic gradient is 0.005 ft/ ft. Groundwater flow direction for Aquifer A is discussed in more detail in Section 2.3 of this document.

Aquitard B

Aquitard B consists primarily of the Kitsap Formation, an interglacial deposit of clay, silt and fine sand with occasional gravel lenses. Where identified, the thickness of Aquitard B is approximately 20 ft. Hydraulic conductivity values for Aquitard B range from less than $3.5x10^{-4}$ cm/sec (1 ft/ day) to $4.6x10^{-3}$ cm/sec (13 ft/ day), with an average value of $1.4x10^{-3}$ cm/sec (4 ft/ day) (CRA, 2000).

Aquifer C

Aquifer C is regionally extensive, although its properties are highly variable. It consists primarily of a sequence of stratified sand and gravel, although discontinuous layers of silt and clay and intermittent till lenses are scattered throughout. The average hydraulic conductivity of the materials comprising Aquifer C is on the order of $5x10^{-3}$ cm/sec (15 ft/day). The average saturated thickness of Aquifer C in the general area of the Site is 120 ft. Therefore, a representative transmissivity value for Aquifer C is approximately 1,800 ft^2/day.

As described in *Technical Memorandum No. 2* (CRA, 2000), Groundwater flow within this unit is predominantly to the north and northwest. The average regional horizontal hydraulic gradient is 0.01 ft/ ft.

2.2.3 Surface Water (Clover Creek)

The nearest surface water feature to the Site is Clover Creek, which is located approximately a half mile north of the Property (**Figure 2-1**). Clover Creek originates from a spring located approximately 0.7 miles to the northeast of the Property and flows westward within the area of interest until it discharges into Lake Steilacoom (located about 10 miles from the study area). Throughout most of its length, Clover Creek is a discharge zone for Aquifer A (i.e., gaining stream). To date, two sets of surface water samples (2002 and 2010) and one set of sediment samples (2010) have been collected from Clover Creek for analysis of CTC. CTC analytical results for the surface water and sediment samples are discussed in Section 2.3.

2.2.4 Land and Resource Use

The Property is located within the Pierce County Urban Growth Area and development is governed under their Frederickson Community Plan. Land use and zoning is industrial for the Property. Pierce County zoning maps indicate commercial zoning for all areas north of the Property, although there are some residential areas within this area that appear to pre-date the county zoning. **Figure 2-2** shows the Land Use Designations for the Property and surrounding area as presented in the Frederickson Community Plan. The designation "Employment Center" refers to a zoning area that is reserved for the development of industrial areas to meet the needs of a growing jobs-based economy. Specifically, the zoning designation allows for a concentration of low to high intensity office parks, manufacturing, other industrial development, or a combination of activities. It may also include commercial development as a part of the center as long as the commercial development is incidental to the employment activities of the center and supports and serves the needs of the workforce.

Aside from the two industrial buildings on the Property, the only presently occupied buildings within the Site are relatively new commercial buildings on the southeast and northeast corners of Canyon Road East and 176th Street East. In addition, there are two residential buildings adjacent to the Property. The locations of these buildings are shown in **Figure 2-1**. The buildings within the Site are connected to the local water purveyor, Tacoma Water.

Per MTCA regulation, WAC 173-340-720(1)(a):

> *"The department has determined that at most sites use of groundwater as a source of drinking water is the beneficial use requiring the highest quality of groundwater and that exposure to hazardous substances through ingestion of drinking water and other domestic uses represents the reasonable maximum exposure. Unless a site qualifies under subsection (2) of this section for a different groundwater beneficial use, groundwater cleanup levels shall be established using this presumed exposure scenario and be established in accordance with subsection (3), (4) or (5) of this section."*

Based on the WAC, the groundwater in the vicinity of the Site is considered a potential source of drinking water even though the properties within the area of interest are connected to the local water purveyor, Tacoma Water, and there is a County restriction on future well installations within the area of interest. Exposure pathways are discussed in detailed in Section 2.4.1 of this report. The service area of Tacoma Water is shown in **Figure 2-3**.

Natural resources in the area of the Site include surface water, soils, flora, and fauna. The waters of Clover Creek are occasionally used for fishing and other recreational activities, but topography and poor accessibility limit the use of the creek in the vicinity of the Site.

2.3 Nature and Extent of Contamination

2.3.1 Chemicals of Concern

Historical groundwater sampling data indicated that CTC was the only VOC of concern in groundwater (CRA, 2001, 2002 and 2003). As part of the *Additional RI Scope of Work,* Ecology required that the Companies sample for the following three energetic constituents: perchlorate, RDX, and TNT. These three constituents were added to the analyte list for the Additional RI SOW first groundwater sampling event which occurred in June 2010. As reported in the *Additional RI – First Groundwater Monitoring Event Results* letter report (Geosyntec, 2010), all the samples for perchlorate were non-detect or well below the MTCA Method B standard of 11 μg/L. For RDX and TNT, all samples were non-detect at levels below their respective MTCA Method B standards. Thus, it was concluded that the only constituent of concern for the Site is CTC, and that the analyte list for future monitoring events would be limited to CTC. Ecology concurred with this conclusion in an email dated 10 November 2010.

2.3.2 Soil

The locations where soil samples have been previously collected at the Property and analyzed for CTC, whether collected from test pits, trenches, soil borings or surface soils are presented in Figure 2.5 of the *Phase II RI/FS Work Plan* (Copy provided in Appendix A). As summarized in the *Phase II RI/FS Work Plan* Tables 2.1 through 2.5 (Copies provided in Appendix A), and as shown on Figure 2.5, CTC was not detected in any of the soil samples analyzed for VOCs.

A soil gas survey was performed in April 1999 to attempt to identify potential sources of CTC in soil. The soil gas survey was conducted in five areas identified in the *Phase II RI/FS Work Plan* (CRA, 1998) as potential CTC source areas. The five areas were depicted on Figure 4.2 of the *Phase II RI/FS Work Plan* (Copy provided in Appendix A). The results of the soil gas survey were reported in the *Task 5: Technical Memorandum No. 1* (CRA, 1999). The soil gas data for each of the five sample areas exhibited very low soil gas detections of CTC as shown in Figures 5.1 through 5.5 of *Task 5: Technical Memorandum No. 1* (CRA, 1999), copies of which are provided in Appendix A.

The soil gas concentrations were used to calculate bulk soil and pore water concentrations of CTC; details of the calculation process are provided in *Technical Memorandum No. 1* (CRA, 1999). Conservatively, the highest soil gas detection was used to calculate the bulk soil and pore water concentrations. Based on the highest soil gas detection (Area 5 at 0.1863 μg/L), the estimated bulk soil concentration of CTC was approximately 0.09 μg/kg. The calculated result is less than the generic Soil Screening Levels (SSLs) calculated by USEPA (USEPA, 2011), which are designed to be protective of human exposure pathways (i.e., ingestion, inhalation, and migration to groundwater). The lowest SSL for CTC was 0.17 μg/kg, based on migration to groundwater. The estimated pore water concentration of CTC was estimated to be approximately 0.15 μg/L, less than the MTCA Method B value of 0.63 μg/L.

Based on the extensive nature of the investigation for potential CTC sources at the Property, including historical soil investigations and the soil gas survey program, the *Technical Memorandum No. 1* (CRA, 1999) concluded that the soils in the former process areas are not acting as sources of CTC. It was concluded that excavation activities conducted as part of remediation during Property redevelopment, while not specific to CTC, likely served to remove any CTC in soil at these areas that may have been present at concentrations capable of acting as an ongoing source. *Technical Memorandum No. 1* also concluded that the results of the soil gas survey proposed the elimination of Task 7 (i.e., source area soil investigation) from the RI/FS

Work Plan. In a letter dated 20 September 1999, Ecology indicated their approval of the basic concept of the investigation work, and Task 7 was eliminated from the RI/FS Work Plan.

2.3.3 Groundwater

Several groundwater sampling events occurred as part of the *Phase II RI/FS Work Plan* and the Additional RI Scope of Work. A summary of groundwater CTC concentrations at existing on- and off-Property monitoring wells from 1985 to February 2011 is presented in **Table 2-1**; in addition to the groundwater data presented in **Table 2-1** for existing monitoring wells, historical CTC data from abandoned on-Property monitoring wells are provided in Table 2-8 of the *Phase RI/FS Work Plan* (copy provided in Appendix A). Well screen information (i.e., top of screen, bottom of screen, aquifer interval screened, etc.) for the monitoring wells is provided in **Table 2-2**. The last of three groundwater sampling events conducted under the *Phase II RI/FS Work Plan* occurred in November 2002 with the results reported in the letter report titled *Task 8 Groundwater Investigation: Update – Third Round Monitoring Program Results* (CRA, 2003). The extent of CTC in Aquifer A in 2002 is shown in Figure 2 of the letter report (CRA, 2003); a copy of the figure is provided in Appendix A of this RI/FS. In 2002, the extent of the CTC plume at a contour concentration of 0.3 µg/L encompassed monitoring Well MW-7 (located to the north of Clover Creek), while the 3.0 µg/L CTC contour was believed to extend to Clover Creek (Figure 2, CRA, 2003).

The Additional RI first groundwater sampling event occurred in June 2010, approximately 8.5 years after the November 2002 sampling event. For the June 2010 sampling event, 21 monitoring wells were sampled and the samples submitted to Columbia Analytical Services (CAS) for CTC analysis. In addition, the Pierce Well was sampled and analyzed for CTC. Of the wells sampled, nineteen are screened in Aquifer A and three are screened in Aquifer C. The CTC data are summarized in **Table 2-1**; the analytical reports were provided in Attachment A of the *Additional RI – First Groundwater Monitoring Event Results* letter report (Geosyntec, 2010). **Figure 2-4a** presents the locations, individual well CTC results, and CTC contours for the Aquifer A wells for June 2010. Of note, while the MTCA Method B value for CTC in groundwater was revised in May 2011 from 0.337 µg/L to 0.63 µg/L, concentration contouring in **Figures 2-4a** and **2-6a** have been maintained at 0.3 and 3.0 µg/L, to allow for more direct comparison of current CTC conditions versus the 2002 data, and to demonstrate that the CTC plume is shrinking over time. **Figure 2-4b** presents the locations and CTC results for the Aquifer C wells in June 2010; CTC concentrations for Aquifer C were not contoured as there were no CTC detections. The June 2010 Aquifer C results are consistent with historical Aquifer C data at wells MW-2, MW-6, P1-D, and P2-D[3].

[3] There exist historic Aquifer C data from abandoned monitoring wells Y-2 and Y-5. The first sampling event (July 1990) resulted in non-detect concentrations at both wells. The subsequent sampling event occurred four months later in November 1990. The CTC concentrations at Y-2 and Y-5 were 2.8 and 0.7 µg/L, respectively. Given the length of time that has passed since these two wells were sampled, in

Water level data collected during the June 2010 groundwater monitoring event are presented in **Table 2-2**; water level contours for Aquifer A are shown in **Figure 2-5**. Similar to historical monitoring events, groundwater flow in June 2010 in Aquifer A was apparently to the north-northwest, generally towards Clover Creek. Near Clover Creek, upward vertical hydraulic gradients were observed at the P1 and P2 well clusters. At the P1 cluster, an upward vertical gradient of 0.02 ft/ft exists between the shallow and intermediate screen intervals. At the P2 cluster, the upward vertical gradient between the shallow and intermediate well screens is approximately 0.024 ft/ft. Consistent with previous evaluations, the data indicate that groundwater at these screen intervals discharges to Clover Creek from both sides of the creek.

Based on results from the June 2010 round of groundwater monitoring, it was recommended (with Ecology concurrence) that an additional monitoring well located along the centerline of the plume downgradient of the former Property was necessary[4]. The location of MW-13 is shown in **Figure 2-1**. Installation of MW-13 occurred from January 31 through February 4, 2011. During well installation, vertical aquifer sampling (VAS) occurred at ten foot intervals from 55 ft bgs (depth of groundwater) to 140 ft bgs (bottom of Aquitard A) in order to determine the optimal elevation for the screen interval. The VAS results for CTC are presented in **Table 2-3**. The two highest CTC concentrations, 0.90 and 0.77 µg/L, were observed at depths of 109 ft and 118 ft bgs, respectively. Drilling and VAS was stopped at 140 ft bgs based on lithologic changes indicating that the bottom of Aquifer A had been reached, and based on the non-detect CTC result for the VAS sample collected at 139 ft bgs. Based on the results from the VAS and borehole logs, the screen interval was set from 110 to 120 ft bgs. Development of the well occurred on February 7, 2011. The well was sampled as part of the second groundwater monitoring event on February 10, 2011. Details of the MW-13 installation are provided in the letter report titled *Additional RI – Second Groundwater Monitoring Event Results* (Geosyntec, 2011).

For the Additional RI second groundwater sampling event conducted in February 2011, twenty-two monitoring wells were sampled and analyzed for CTC by CAS. Of the wells sampled, nineteen are screened in Aquifer A and three are screened in Aquifer C. **Figure 2-6a** presents the locations, CTC results, and the February 2011 CTC contours for the Aquifer A wells. **Figure 2-6b** presents the locations and CTC results for the Aquifer C wells; CTC concentrations for Aquifer C were not contoured as there were no CTC detections. The CTC data from the second groundwater sampling event are summarized in **Table 2-1**; the analytical reports were provided in Attachment B of the *Additional RI – Second Groundwater Monitoring Event Results* letter report (Geosyntec, 2011).

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conjunction with the non-detect data at MW-2 (located within the facility footprint), P1-D, P2-D, and MW-6, it is concluded that CTC is not currently impacting Aquifer C.

[4] The original *Additional RI Scope of Work* proposed that eight new monitoring wells be installed to complete delineation of the CTC plume in Aquifers A and C. As noted, the results of the first groundwater sampling event supported a modification to the scope of work that eliminated all but one of the proposed monitoring wells.

The CTC data collected from MW-13 provided information that refined the distribution of CTC, as depicted in **Figure 2-6a**. Compared to the CTC contours presented in **Figure 2-4a**, the CTC data from MW-13 indicates that the area enclosed within the 3 µg/L CTC contour is smaller than depicted in August 2010 and 2002.

Water level data collected during the second groundwater monitoring event are presented in **Table 2-2.** Water level contours for Aquifer A are shown in **Figure 2-7**. Similar to past monitoring events, groundwater flow in Aquifer A is apparently to the north-northwest, generally towards Clover Creek. Near Clover Creek, upward vertical hydraulic gradients from the intermediate to the shallow well screens were observed at the P1 and P2 well clusters. At the P1 cluster, an upward vertical gradient of 0.021 ft/ft was calculated for February 2011 (consistent with 0.020 ft/ft in June 2010) between the intermediate and shallow screen intervals. In February 2011, there was a small downward vertical gradient of 0.003 ft/ft between the intermediate and deep screen intervals. The magnitude of the gradient was consistent with the 0.008 ft/ft magnitude observed in June 2010. At the P2 cluster, the upward vertical gradient between the intermediate and shallow well screens was approximately 0.029 ft/ft (consistent with 0.024 ft/ft in June 2010). Similar to the P1 cluster, there was a downward vertical gradient between the intermediate and deep screen intervals with a magnitude of 0.027 ft/ft; in June 2010, the downward gradient between the intermediate and deep screen intervals was 0.052 ft/ft. It is important to note that while there is some component of downward flow in the lower reaches of Aquifer A, CTC has been consistently non-detect in Aquifer C wells P1-D and P2-D. Furthermore, based on the absence of CTC at all screen intervals at well P1 (located to the north of Clover Creek), and declining CTC concentrations at well MW-7, it is concluded that groundwater in Aquifer A primarily discharges to Clover Creek from both sides of the creek.

In summary, the most recent CTC groundwater data have refined and fully delineated the distribution of CTC in groundwater. The following conclusions regarding the distribution of CTC in groundwater were confirmed:

- The current extent of CTC in Aquifer A (i.e., 2010/2011) occupies a smaller footprint than the extent measured in November 2002, suggesting that the CTC plume is naturally attenuating;
- The extent of the 3.0 µg/L CTC contour in Aquifer A is more limited than previously estimated;
- The extent of the 0.63 µg/L CTC contour in Aquifer A does not extend to Clover Creek;
- The presence of CTC in groundwater is limited to Aquifer A (i.e., CTC is not present in Aquifer C);
- Hydraulic data and the orientation of the CTC distribution confirm that groundwater at the Site flows in a north-northwest direction; and,

- Based on the analysis of vertical gradients measured along Clover Creek at the P1 and P2 well clusters, in conjunction with CTC data at these two wells, it is concluded that Aquifer A groundwater predominantly discharges to Clover Creek from both sides of the creek.

These conclusions are revisited in Section 2.3.5 where a summary of the conceptual site model (CSM) is provided.

2.3.4 Surface Water & Sediments

A surface water and sediment sampling event was conducted October 6, 2010 in accordance with the procedures described in *Addendum 2 to the Sampling and Analysis Plan* (Geosyntec, 2010). The four sample locations along Clover Creek are depicted in **Figure 2-1**. The location for SW/SD-4 was originally to the west of the railroad but was moved east of the railroad due to poor access conditions on the west side of the railroad. The updated location was approved by Ecology via email on 28 September 2010. Surface water and sediment samples were submitted to CAS and analyzed for CTC. The sediment samples were also analyzed for total organic carbon (TOC) content. The results of the surface water and sediment samples are presented in **Tables 2-4** and **2-5**, respectively; the analytical reports were provided in Attachment 1 to the letter report titled *Additional RI – Surface Water & Sediment Sampling Event Results Frederickson Industrial Park Site, Pierce County, WA* (Geosyntec, 2010b). A narrative of the sampling event was provided in Attachment 2 to the referenced report.

CTC concentrations in all surface water and sediment samples were non-detect. The surface water data are consistent with the CTC data from four surface water samples that were collected from Clover Creek in November 2002; the 2002 surface water samples were also non-detect for CTC. The lack of detections for CTC in surface water and sediment is consistent with the very low and declining CTC concentrations observed in off-Property groundwater. Based on the absence of CTC in surface water (in 2002 and in 2010) and sediment, and the declining groundwater CTC concentrations, the Companies proposed to Ecology (Geosyntec, 2010b) that no further surface water or sediment samples be collected. Ecology concurred with the recommendation on 10 November 2010. The surface water and sediment data indicate that CTC is not impacting surface water and sediments near the Site.

2.3.5 Summary of Conceptual Site Model

The information presented in Section 2 forms the basis of the CSM. The former operational areas of the Property are shown in Figure 2.2 of the *Phase II RI/FS Work Plan* (copy provided in Appendix A). CTC was suspected to have been used in connection with the powder plant operations from 1936 to 1976. Disposal pits were reportedly used to burn and dispose of waste paper, fugitive powder, barrels, scrap metal, laundry wastes, rags, and wood products. Based on the observance of CTC in groundwater, it is believed that a portion of the CTC present in the soil of former operational areas infiltrated to the underlying water table (i.e., Aquifer A). As described in Section 2.1.2.1, multiple source area excavations occurred in 1989 and 1991. Based on subsequent soil and soil-gas investigations (see Section 2.3.1), these removal actions appeared to remove any long-term sources of CTC to groundwater that may have been present in these areas.

The distribution and migration of CTC at the Site are controlled by the following factors that comprise the CSM:

- Between 1936 (i.e., initial powder plant operations) and 1991 (i.e., completion of final removal actions), CTC appears to have infiltrated from operational areas to the underlying water table. The purpose of the removal actions in 1989 and 1991 was to address source areas in the former operational areas;

- Within the former operational areas of the Property (e.g., as shown in Figures 2.2 and 4.2 of the *Phase II RI/FS Work Plan* (copies provided in Appendix A)), infiltration of precipitation and north-northwest horizontal flow of groundwater described in Section 2.3.3, caused the initial migration of CTC within Aquifer A;

- CTC was last detected in Aquifer C in November 1990 at wells Y-2 and Y-5 (now abandoned) at concentrations of 2.8 µg/L and 0.7 µg/L, respectively. CTC has not been detected in any of the current Aquifer C wells since they were installed in 2000;

- Groundwater flow is apparently horizontal to the north-northwest from the Site toward Clover Creek;

- Adjacent to Clover Creek (on both sides), groundwater flow predominantly discharges to Clover Creek;

- CTC has not been detected in surface water or sediment in Clover Creek, indicating that it is likely attenuating before groundwater discharges to surface water; and,

- Since 1991, the mass of CTC dissolved in groundwater has been subject to various fate and transport mechanisms, destructive and non-destructive, that have influenced the observed distributions of CTC. CTC concentrations along the flow path have been declining and will continue to decline under the influence of the following mechanisms: (i) advective-based dispersion, (ii) recharge of groundwater that does not contain CTC, (iii) sorption to aquifer solids, and (iv) abiotic and biotic CTC transformation reactions.

Based on the CSM and the available CTC groundwater chemistry data, it is apparent that CTC concentrations in groundwater are declining and that the extent of CTC in groundwater is expected to continue to shrink, as further discussed in Section 2.3.6.

2.3.6 Concentration Trend Analysis for CTC

Figure 2-8 shows the concentration trends for CTC in Aquifer A through February 2011 at the on- and off-Property monitoring wells. It is apparent from the time-trend data that the CTC concentrations in Aquifer A have consistently declined over time. Within the former process area, CTC concentrations at several wells have steadily declined over the past 10 to 20 years. For example, CTC concentrations at BMW-18 (screened in the upper portion of Aquifer A) have decreased from a concentration of 14 µg/L in November 1992 to 4.5 µg/L in February 2011. Downgradient of BMW-18, there are three wells (11-CL, HLA-1, and 11-BL) screened in the lower portion of Aquifer A. Each of these wells also shows a downward trend in CTC concentrations over the past 20 years of monitoring, indicating that the CTC plume has been undergoing natural attenuation since completion of the source area removal actions conducted in 1989 and 1991.

CTC concentrations have also declined in the off-Property monitoring wells. CTC concentrations in February 2011 at wells P2-I and P2-S were half of the concentrations measured in November 2000. At MW-7, CTC concentrations declined from 1.3 µg/L in November 2002 to less than 0.5 µg/L[5] in June 2010 and February 2011. The 2.0 µg/L concentration observed at MW-13 is consistent with the concentration distribution and trends in the other off-Property wells. As shown in **Figure 2-8**, the Shotwell domestic well (now abandoned) was located approximately 700 ft downgradient of MW-13. This well was last sampled in April 1999 and had a CTC concentration of 4.6 µg/L. Thus, using the Shotwell domestic well as a point of comparison, the 2.0 µg/L concentration observed at MW-13 indicates that CTC concentrations within the central axis of the plume have declined more than 50% in the past twelve years. The percent reduction estimated for MW-13 is similar to the percent reductions observed at the other off-Property wells, indicating that natural attenuation is effectively addressing CTC impacts associated with the Site.

The CTC concentration trend analysis is consistent with the CSM where it was hypothesized that CTC concentrations along the flow path have been decreasing and will continue to decrease under the influence of the mechanisms noted previously. The CTC concentration trend analysis is consistent with the CSM, where it was hypothesized that CTC concentrations along the flow path have been decreasing and will continue to decrease through mechanisms such as abiotic hydrolysis (as documented in the scientific literature by Jeffers et al [1996] and Amonette et al [2008]), and anaerobic biodegradation (see pathways/references depicted in **Figure 2-9**), which can occur in anaerobic microhabitats within bulk aerobic aquifers.

[5] The results were above the Method Detection Limit (MDL) but below the Method Reporting Limit (MRL) and thus the values are estimated (i.e., j-flagged).

2.4 Site Risk & Exposure Pathway Evaluation

2.4.1 Groundwater

Potential exposure pathways and receptors for CTC in Site groundwater could include:

- Contact (dermal, incidental ingestion, inhalation of vapors) by utility workers;
- Volatilization to indoor air;
- Groundwater ingestion as drinking water; and,
- Migration of groundwater into surface water and sediment at Clover Creek, resulting in potential exposure of aquatic organisms and human consumption of marine organisms.

Because the depth to groundwater is greater than 15 ft bgs on-Property and up to 30 ft bgs off-Property, incidental contact, ingestion, and inhalation exposure to groundwater during subsurface construction or other utility type work is unlikely and this exposure pathway is not considered complete.

Based on the analysis summarized on Section 2.4.3 and presented in detail in Appendix B, there is no risk to indoor air from volatilization. As such, VI does not appear to be a complete exposure pathway.

The drinking water pathway for CTC in groundwater was eliminated by the installation of a public water supply line to 13 of the 15 homes within the plume footprint that previously used private drinking water wells; the drinking water wells at the two remaining homes were decommissioned. Thus, there are currently no drinking water well users within the CTC plume area and there are no known planned uses of the groundwater for future drinking water supply. Moreover, since the Site resides within a Pierce County Urban Growth Area, the installation of any new groundwater use wells are prohibited unless an application is first filed and approved by the local water purveyor, providing a mechanism to prevent human exposure to CTC via groundwater during remedy implementation[6]. In addition, WAC 173-160-171(3)(b)(v) states that new water wells shall not be located within “one hundred feet from all other sources or potential sources of contamination except for solid waste landfills.” WAC 173-160-171(3)(c) further states that “all public water supply well locations shall be approved by the department of health or the local health jurisdiction or other department of health designee.”

[6] This requirement is stipulated in the Pierce County Comprehensive Plan, as codified in Title 19A of the Pierce County Code. Section 19A.90.070 addresses the prohibition of new water wells.

Therefore, in accordance with WAC 173-340-720(2), groundwater at, or potentially affected by, the Site is not considered drinking water at this time and is not a reasonable future source of drinking water. The drinking water pathway is, therefore, incomplete.

The groundwater to surface water migration pathway is considered incomplete, based on the empirical data collected at the Site. Although CTC concentrations in groundwater monitoring wells P-2S and P-2I exceed the lowest surface water screening criteria (NRWQC [Clean Water Act] Human Health – Fresh Water), CTC concentrations were below method reporting limits in surface water and sediment samples obtained in October 2010, as discussed in Section 2.3.4. These results indicate that CTC is attenuating prior to reaching Clover Creek. The lower section of Clover Creek is listed as a domestic beneficial use (WAC 173-201A-602); however, the section of the creek adjacent to and downgradient of the Site is not listed for beneficial use. Furthermore, this section of the creek is not currently and is not likely to be used in the future as a source for domestic water supply, based on the availability of municipal supply. Groundwater concentrations in monitoring wells P-2S and P-2I do not exceed the surface water screening criteria for consumption of organisms only. Applicable or relevant and appropriate requirements (ARARs) and cleanup levels are discussed in Section 3.

2.4.2 Soil

Potential exposure pathways and receptors for CTC in Property soil could include:

- Contact with CTC in soil (dermal, incidental ingestion, or inhalation) by visitors, workers, and potential future residents or other Property users;
- Contact with CTC in soil (dermal, incidental ingestion, or inhalation) by terrestrial wildlife; and
- Leaching to groundwater.

Evaluation of the terrestrial ecological evaluation (TEE) criteria was conducted pursuant to WAC 173-340-7490. Per WAC 173-340-7490 (2), if there is a release of a hazardous substance to the soil at a site, one of the following actions is required to comply with MTCA TEE procedures:

(a) Document an exclusion from any further terrestrial ecological evaluation using the criteria in WAC 173-340-7491;

(b) Conduct a simplified terrestrial ecological evaluation as set forth in WAC 173-340-7492; or

(c) Conduct a site-specific terrestrial ecological evaluation as set forth in WAC 173-340-7493.

The Site qualifies for the exclusions outlined in WAC 173-340-7491(1) given that residual CTC concentrations detected in soil are contained within the former process areas beneath clean fill, pavement, and buildings. Future land use is anticipated to be consistent with current land use. However, the exclusion requires the use of a restrictive covenant to ensure that the current land use remains the same while residual chemical concentrations are in place. As noted above, either a simplified TEE or a site-specific TEE may also be conducted to comply with the TEE procedures.

Based upon an evaluation of the simplified and the site-specific TEE approaches, it was concluded that the presence of CTC in soil will not pose an ecological risk. Under the simplified TEE, there are two criteria that allow the conclusion that CTC will not adversely affect ecological receptors. They are the following:

- **173-340-7492 (2)(b) – Pathway Analysis:** The evaluation may be ended if there are no potential exposure pathways from soil contamination to soil biota, plants or wildlife. Only exposure pathways for priority chemicals of ecological concern listed in Table 749-2 at or above the concentrations provided must be considered. Presently, CTC is not a priority chemical of ecological concern, and thus the analysis can be ended with the conclusion that any residual concentrations of CTC present at the site do not represent an ecological concern.
- **173-340-7492 (2)(c) – Contaminant Analysis:** The evaluation may be ended if no hazardous substance listed in Table 749-2 for which a value is listed is, or will be, present in the soil. Once again, since CTC is not listed in Table 749-2, the evaluation can be ended.

Under a site-specific TEE (173-340-7493), the evaluation can be ended in the problem formulation step where the chemicals of ecological concern are considered. WAC 173-340-7493 (2)(a)(i) states that the person conducting the evaluation may eliminate hazardous substances from further consideration where the maximum or the upper ninety-five percent confidence limit soil concentration found at the site does not exceed ecological indicator concentrations described in Table 749-3. Using the same rationale as above, CTC is eliminated from consideration since it is not listed in Table 749-3. Using either the simplified TEE or the site-specific TEE, the ecological requirements for the Site can be addressed without requiring a restrictive covenant.

As noted in Section 2.3.2, there is no evidence of the presence of CTC in the Property soils exceeding SSLs within the former process areas. Thus, there are no unacceptable potential exposures associated with CTC in soil.

2.4.3 Soil Gas (Potential Vapor Intrusion Pathway)

According to the Department of Ecology Draft Guidance for Evaluating Vapor Intrusion[7] (Ecology, 2009), remedial investigations and feasibility studies should include "an evaluation to determine if vapor intrusion is unacceptably impacting indoor air quality whenever volatile hazardous substances are present in the subsurface at a site." The Draft Guidance recommends a tiered evaluation approach, beginning with a preliminary assessment and progressing through Tier 1, 2, and 3 assessments depending on results of each analysis. Appendix B to this RI/FS presents the results of the Preliminary and Tier 1 assessments that were conducted by Geosyntec on behalf of the Companies to evaluate the potential for subsurface CTC vapors related to the Site to migrate into the indoor air of occupied buildings (i.e., vapor intrusion; VI) at or near the Site.

Based on the analysis presented in Appendix B, no unacceptable indoor air exposures were identified during the evaluation.

2.4.4 Surface Water and Sediments

Potential exposure pathways and receptors for CTC in surface water in Clover Creek could include:

- Exposure by aquatic receptors to surface water impacted by CTC; and,
- Ingestion by Site visitors of aquatic organisms affected by surface water impacted by CTC.

As noted in Section 2.3.4, there is no evidence of the presence of CTC in surface water in Clover Creek, thus there is no risk associated with the potential exposure pathways and receptors to surface water in Clover Creek. There is low risk for potential bioaccumulation resulting from concentrations below method detection limits, because analytical method detection limits for surface water are over one order of magnitude lower than the surface water screening criteria, and CTC also was not detected in sediment, as discussed below.

Potential exposure pathways and receptors for CTC in sediment in Clover Creek could include:

- Exposure of benthic organisms to CTC in the biologically active zone of sediment;
- Ingestion by aquatic organisms of benthic organisms impacted by CTC in sediment; and,
- Ingestion by Site visitors of marine organisms impacted by CTC in sediment.

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[7] Department of Ecology; Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action; Washington State Department of Ecology, Toxics Cleanup Program, Publication no. 09-09-047, Review Draft, October 2009. http://www.ecy.wa.gov/programs/tcp/policies/VaporIntrusion/vig.html.

As noted in Section 2.3.4, there is no evidence of the presence of CTC in Site sediments, thus there is no risk associated with the potential exposure pathways and receptors to sediment in Clover Creek.

3 CLEANUP STANDARDS

3.1 Cleanup Standards

Cleanup standards consist of two components:

- Cleanup levels (chemical concentrations); and
- Points of compliance (at which the cleanup levels must be met).

Typically, preliminary cleanup standards are developed during the RI, proposed cleanup standards for remedial alternative evaluation are presented in the FS, and final cleanup standards are established during the corrective action plan (CAP) development process to be prepared following completion of the FS. Due to the combined nature of this document, the cleanup standards presented are the proposed cleanup standards for remediation at the Site. The cleanup standards proposed in this RI/FS Report were developed in accordance with WAC 173-340-700 through -730.

3.1.1 Identification of ARARS

MTCA requires that all cleanup actions comply with applicable state and federal laws (WAC 173-340-360(2)). MTCA defines applicable state and federal laws to include “legally applicable requirements” and “relevant and appropriate requirements.” MTCA’s requirements are substantially the same as CERCLA Section 121 where remedial actions are required to achieve ARARs. Per CERCLA, ARARs are defined as any legally applicable or relevant and appropriate standard, requirement, criterion, or limitation that has been promulgated under federal or state environmental laws. For convenience, this RI/FS Report uses the ARAR terminology in the development of cleanup standards and the subsequent evaluation of cleanup action alternatives.

This section presents the proposed ARARs and the “to-be-considered” regulations (TBCs) that have been identified for remediation of the Site. ARARs are determined on a case-by-case basis for each site. TBCs are advisory or guidance documents that are not legally binding and do not have the same status as ARARs. However, TBCs may be used in evaluating the cleanup alternatives and are included in the evaluation of ARARs.

CERCLA identifies three categories of ARARs: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs include health- or risk-based numerical values or methodologies applied to Site-specific conditions. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment. Location-specific ARARs set restrictions on activities based on Site characteristics or the surrounding environment. Action-specific ARARs include technology-based requirements for hazardous waste management. The proposed ARARs for the Site are presented in **Table 3-1**.

3.1.2 Cleanup Levels

Section 2.4 of this RI/FS Report evaluated potential Site risks and exposure pathways. The regulations implementing MTCA, Chapter 173-340 WAC, require groundwater cleanup levels to be based on the highest beneficial use of the water under current and future conditions. The regulations presume that the highest beneficial use of groundwater at any site will be drinking water, per WAC 173-340-720(1). Therefore, groundwater in the vicinity of the Site is considered as a potential source of drinking water, although, the groundwater ingestion pathway is considered incomplete based on use and availability of municipal water supply (Tacoma Water). For soil and soil gas, it was concluded that there were no unacceptable exposures to CTC. Hydraulic data for the Site indicates groundwater is discharging to Clover Creek; however, CTC was not detected in surface water and sediments, suggesting no unacceptable exposures to CTC.

Based on evaluation of potential exposure pathways, the development of cleanup levels for CTC are limited to groundwater and groundwater to surface water pathways, as follows:

- Potential future drinking water beneficial use;
- Groundwater to surface water pathway: Acute or chronic effects to aquatic organisms resulting from exposure to constituents in groundwater discharging to adjacent marine surface water; and,
- Human ingestion of organisms contaminated by releases of affected Site groundwater to adjacent surface water.

Groundwater cleanup criteria were developed based on the exposure pathways above, to be adequately protective of human health and aquatic organisms, and of humans that ingest these organisms. MTCA Method B groundwater and surface water cleanup levels were compiled in accordance with WAC 173-340-720(4) and WAC 173-340-730(3), including:

- Federal and state Maximum Contaminant Levels (MCLs) for drinking water;
- Standard MTCA Method B cleanup levels for carcinogens and non-carcinogens protective of human health, obtained from Ecology's Cleanup Levels and Risk Calculation (CLARC) database; and,
- MTCA Method B fresh surface water cleanup levels protective of aquatic organisms and human health (WAC 173-340-730[3]), including:
    - Water quality criteria published in the Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A);
    - Water quality criteria based on the protection of aquatic organisms (acute and chronic criteria) and human health published under Section 304 of the Federal Clean Water Act; and,

- Concentrations established under the National Toxics Rule (Code of Federal Regulations [CFR] Title 40, Part 131).

The groundwater cleanup levels are presented in **Table 3-2**.

The selection process requires that the most stringent cleanup level from the groundwater and surface water ARARs be selected. Of the cleanup levels, Section 304 of the CWA is the most stringent with a CTC criterion of 0.23 µg/L[8] based on human health consumption for water and organisms. The NTR criterion is 0.25 µg/L for the same receptor. However, because CTC has not been detected in surface water near and directly downgradient of the Site and surface water is not and will not likely be used for drinking water, the most stringent CWA and NTR values for protection of human health are 1.6 and 4.4 µg/L, respectively, based on consumption of organisms. Therefore, for this RI/FS Report the most stringent ARAR for CTC in groundwater is 0.63 µg/L, which is the MTCA Method B standard formula value (**Table 3-2**).

3.1.3 Points of Compliance

The point of compliance is defined by MTCA as the point or points where cleanup levels shall be achieved (WAC 173-340-200). The compliance monitoring points for groundwater will be approved by Ecology and presented in a forthcoming CAP for the Site. A standard point of compliance is proposed for this Site, which includes the Property as well as the outer extent of the plume boundary to the depth of Aquifer A (WAC 173-340-720(8)(b)).

3.2 Area and Volume of Groundwater above Cleanup Levels

Site-specific conditions, the nature and extent of the CTC groundwater plume, and the cleanup standards were taken into consideration to estimate the areal extent and volume of groundwater to be addressed by potential cleanup actions.

Figure 3-1 illustrates the estimated areal extent of the CTC plume exceeding the MTCA cleanup level of 0.63 µg/L in February 2011. The area of the CTC plume in groundwater is approximately 120 acres. An estimated aquifer thickness of 90 ft and an effective porosity of 30 percent were used to calculate the pore volume of 1.05 billion gallons of groundwater exceeding the 0.63 µg/L isoconcentration contour for CTC.

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[8] The criterion is based on the Environmental Protection Agency's q1* values as contained in the Integrated Risk Information System (IRIS) as of May 17, 2002.

4 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

WAC 173-340-350(8)(b) states that "An initial screening of alternatives to reduce the number of alternatives for the final detailed evaluation may be appropriate. The person conducting the feasibility study may initially propose cleanup action alternatives or components to be screened from detailed evaluation." During the initial screening stage, the preliminary analysis may eliminate potential alternatives based on two typical criteria. First, alternatives that clearly do not meet the minimum requirements specified in WAC 173-340-360 may be eliminated. This includes those alternatives for which costs are clearly disproportionate under WAC 173-340-360 (3)(e). Second, alternatives that are not technically feasible for site conditions may also be eliminated.

The identification and screening of remedial technologies and process options described in this section was conducted in accordance with the substantial requirements of WAC 173-340-350(8)(b). As a first step, a wide range of potential remedial approaches were assembled for initial screening on the basis of technical implementability and potential effectiveness given Site conditions. The technologies and process options considered included groundwater extraction and treatment, in-situ chemical, biological or thermal treatment, and monitored natural attenuation (MNA). **Table 4-1** presents the results of the identification and initial screening of remedial technologies and process options. On the basis of the initial screening, several process options were eliminated from further consideration, including:

- Vapor intrusion monitoring;
- Extraction trench;
- Permeability enhancements;
- Vacuum-enhanced extraction;
- Air sparging;
- In-well air stripping; and,
- Thermal treatment.

The rationale for elimination of these process options is provided in **Table 4-1**.

As a next step, remedial technologies and process options deemed potentially effective in the initial screening process were further evaluated based on permanence, effectiveness, implementability (technical and administrative), and cost (capital and operations & maintenance (O&M)). **Table 4-2** presents the evaluation of technology process options. An assessment of each process option's potential to achieve the cleanup standards as a stand-alone option was considered. On the basis of this evaluation, process options were either retained or rejected for detailed comparative analysis in Section 5. Three process options were not retained for alternative development, including:

- Enhanced bioremediation;
- Chemical oxidation; and,
- Chemical reduction.

Comments supporting the elimination of these process options are provided in **Table 4-2**. The remaining remedial technologies/process options were retained for cleanup alternative development, as discussed in Section 5.

5 DEVELOPMENT AND DETAILED ANALYSIS OF CLEANUP ACTION ALTERNATIVES

In this section, three cleanup action alternatives are assembled using the remedial technologies and process options that were retained from the initial screening process. The MTCA criteria used to evaluate the cleanup action alternatives are presented in context of the current Site conditions. A detailed analysis of the cleanup action alternatives using the MTCA criteria is then presented. Based on the detailed analysis, the recommended alternative is identified.

5.1 Cleanup Action Alternative Development

The three alternatives developed for the Site are presented in **Table 5-1**, and listed below:

- Alternative 1: Site-wide MNA;
- Alternative 2: Site-wide groundwater extraction and treatment; and,
- Alternative 3: Permeable Reactive Barrier (PRB).

These alternatives represent an appropriate range of cleanup approaches capable of achieving the Site cleanup standards presented in Section 3.

5.2 MTCA Evaluation Criteria

WAC 173-340-360(2) specifies the minimum requirements for cleanup actions. There are two basic categories of cleanup action requirements: (i) threshold requirements, and (ii) additional requirements. Sections 5.2.1 and 5.2.2 discuss the components of the threshold and additional requirements, respectively. It is important to note that the regulations acknowledge (WAC 173-340-360(2)) that "the department recognizes that some of the requirements contain flexibility and will require the use of professional judgment in determining how to apply them at particular sites."

5.2.1 MTCA Threshold Requirements

The threshold requirements for cleanup actions performed under MTCA are listed in WAC 173-340-360(2)(a), and indicate that a cleanup action shall:

- **Protect Human Health and the Environment –** Cleanup actions must ensure that both human health and the environment are protected during and after cleanup action implementation. As stated in WAC 173-340-702(5), "*Cleanup actions that achieve cleanup levels at the applicable point of compliance under Methods A, B, or C (as applicable) and comply with applicable state and federal laws shall be presumed to be protective of human health and the environment.*"

- **Comply with Cleanup Standards –** Compliance with cleanup standards requires that cleanup levels are met at the applicable points of compliance. The proposed cleanup standards for the Site were developed in accordance with WAC 173-340-720/730 and are presented in Section 3 of this RI/FS Report.

- **Comply with Applicable State and Federal Laws –** Cleanup actions conducted under MTCA must comply with applicable state and federal laws. The term "applicable state and federal laws" (i.e., ARARs) includes legally applicable requirements and those requirements that Ecology determines to be relevant and appropriate as described in WAC 173-340-710. The ARARs for the Site were presented in **Table 3-1**.

- **Provide for Compliance Monitoring –** The cleanup action must allow for compliance monitoring in accordance with WAC 173- 340-410. Compliance monitoring consists of protection monitoring, performance monitoring, and confirmational monitoring.

5.2.2 Additional MTCA Requirements

The additional requirements for cleanup actions performed under MTCA are listed in WAC 173-340-360(2)(b). The regulation requires that when selecting from cleanup action alternatives that fulfill the threshold requirements, the selected action shall:

- **Use Permanent Solutions to the Maximum Extent Practicable –** WAC 173-340-730(3)(b) states "To determine whether a cleanup action uses permanent solutions to the maximum extent practicable, the disproportionate cost analysis specified in (e) of this subsection shall be used. The analysis shall compare the costs and benefits of the cleanup action alternatives evaluated in the feasibility study." As defined by MTCA, "Practicable" means capable of being designed, constructed and implemented in a reliable and effective manner including consideration of cost. When considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs of the alternative are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives. The criteria for conducting the disproportionate cost analysis (DCA) are described in Section 5.2.3.

- **Provide for Reasonable Restoration Time Frame –**WAC 173-340-360(4) describes the requirements and procedures for determining whether a cleanup action provides for a reasonable restoration time frame. The factors to be considered during the evaluation include the following [WAC 173-340-360(4)(b)]:

  (i) Potential risks posed by the site to human health and the environment;

  (ii) Practicability of achieving a shorter restoration time frame;

  (iii) Current use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site;

(iv) Potential future use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site;

(v) Availability of alternative water supplies;

(vi) Likely effectiveness and reliability of institutional controls;

(vii) Ability to control and monitor migration of hazardous substances from the site;

(viii) Toxicity of the hazardous substances at the site; and,

(ix) Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the site or under similar site conditions.

- **Consider Public Concerns –** Per WAC 173-340-600, public participation is considered an integral part of Ecology's responsibilities under MTCA. The goal of this requirement is to provide the public with timely information and meaningful opportunities for participation that are appropriate for each site. As part of the process, Ecology will consider public comments submitted during the RI/FS process during its selection of the preliminary cleanup action alternative. This preliminary selection is subject to further public review and comment when the proposed remedy is published by Ecology in a draft CAP.

5.2.3 MTCA Disproportionate Cost Analysis Procedure & Criteria

As required per WAC 173-340-360(3)(e), the MTCA DCA is an analysis that is performed on the cleanup action alternatives that meet the threshold requirements. The purpose of the DCA is to determine which of these cleanup action alternatives is protective to the maximum extent practicable. To make this determination, the costs and benefits of the alternatives are quantified using the DCA criteria described below. The alternatives are then ranked from most to least permanent based on the benefit scorings. To facilitate comparison of the alternatives, WAC 173-340-360(3)(e)(ii)(B) states that "The most practicable permanent solution evaluated in the feasibility study shall be the baseline cleanup action alternative against which cleanup action alternatives are compared." Typically, the low cost alternative is set as the baseline alternative. The other cleanup alternatives are then compared against the baseline to determine if their incremental costs are not disproportionate to their potential incremental benefits.

The evaluation criteria for the DCA are specified in WAC 173-340-360(3)(f), and include protectiveness, permanence, cost, long-term effectiveness, management of short-term risks, implementability, and consideration of public concerns. It is typical to more heavily weight the evaluation criteria associated with the primary objectives of the cleanup action. For example, criteria pertaining to protection and permanence are weighted more heavily than criteria such as implementability or consideration of public concerns. The MTCA criteria used in the DCA and the weighting factors ascribed to the criteria are described below.

Protectiveness

Protectiveness is defined in WAC 173-340-360(3)(f)(i) as the "Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and offsite risks resulting from implementing the alternative, and improvement of the overall environmental quality." Although protectiveness is one of seven criteria to be considered, a weighting factor of 30% was used in the numeric benefit analysis given that protection of human health and the environment is one of the primary objectives of the cleanup action.

Permanence

Permanence is defined in WAC 173-340-360(3)(f)(ii) as "The degree to which the alternative permanently reduces the toxicity, mobility or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment processes, and the characteristics and quantity of treatment residuals generated." A weighing factor of 20 percent was used in the numeric benefit analysis. Given the emphasis placed by Ecology on the permanence of cleanup actions, this criterion was given the second highest weighting factor.

Cost

Cost is defined in WAC 173-340-360(3)(f)(iii) as "The cost to implement the alternative, including the cost of construction, the net present value of any long-term costs, and agency oversight costs that are cost recoverable. Long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining institutional controls. Cost estimates for treatment technologies shall describe pretreatment, analytical, labor, and waste management costs. The design life of the cleanup action shall be estimated and the cost of replacement or repair of major elements shall be included in the cost estimate." The costs of the three cleanup action alternatives were used to determine whether an alternative's cost was disproportionate to potential incremental benefits. As such, no weighting factor was applied to this category to estimate the numeric benefits.

Long-Term Effectiveness

Long-term effectiveness is defined in WAC 173-340-360(3)(f)(iv) as including "the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: Reuse or recycling; destruction or detoxification;

immobilization or solidification; on-site or offsite disposal in an engineered, lined and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring." A weighting factor of 20 percent was assigned to the long-term effectiveness criterion based on the importance of achieving final environmental cleanup without the need for future actions to ensure protection of human health and the environment.

Management of Short-Term Risks

Management of Short-Term Risks is defined in WAC 173-340-360(3)(f)(v) as "The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks." A weighting factor of 10% was assigned to the Management of Short-Term Risks. This criterion is weighted relatively low given the ability to satisfactorily mitigate most short-term risks with implementation of appropriate engineering controls.

Implementability (Technical and Administrative)

Implementability is defined in WAC 173-340-360(3)(f)(vi) as the "Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary offsite facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current or potential remedial actions." Similar to short-term risk, a weighting factor of 10% was assigned to the numeric benefit analysis. Compared to protectiveness, permanence, and long-term effectiveness, this criterion is considered less critical to the overall cleanup action objectives.

Consideration of Public Concerns

Consideration of Public Concerns is described in WAC 173-340-360(3)(f)(vii) to account for "Whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site." The weighting factor used for this criterion was 10 percent based on the observation that public concerns are typically related to protectiveness and permanence, and as such, public concerns are implicitly accounted for in these two previous criteria.

5.3 MTCA Threshold Requirement Evaluation of Cleanup Action Alternatives

5.3.1 Alternative 1 – Site-Wide Monitored Natural Attenuation (MNA)

This section describes the MNA alternative and evaluates whether it satisfies the MTCA Threshold Requirements for a cleanup action.

<u>Technical Description & Cost</u>

Natural attenuation is the process by which natural processes clean up or attenuate contaminants in groundwater. The term "monitored natural attenuation," refers to the reliance on natural processes to achieve site-specific remedial objectives, with on-going monitoring. Natural attenuation processes include a variety of physical, chemical, and/or biological processes that, under favorable conditions, reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These processes include biodegradation; dispersion; dilution; sorption; volatilization; and chemical or biological stabilization, transformation, or destruction of contaminants (USEPA, 1999).

Section 2.3.6 presented a concentration trend analysis for CTC in groundwater at the Site. The concentration trends for CTC in Aquifer A through February 2011 at the on- and off-Property monitoring wells are shown in **Figure 2-8**. Since 1991, subsequent to completion of the source area removal actions, the mass of CTC dissolved in groundwater has been subject to various fate and transport mechanisms, destructive and non-destructive, that have influenced the observed distributions of CTC. The CTC concentrations along the flow path have been decreasing and will continue to decrease under the influence of the following mechanisms: (i) advective-based dispersion, (ii) recharge of groundwater that does not contain CTC, (iii) sorption to aquifer solids, and (iv) abiotic and biotic CTC transformation reactions.

The time trend data were analyzed to estimate an average site-specific degradation rate constant. Degradation rate constants were calculated for the wells with a sufficient number of CTC detections to perform the analysis, as further described in Appendix C. The rate constants were estimated using methods outlined in *Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies* (USEPA, 2002). The site-specific degradation rate constant was estimated to be 0.097 per year based on the average of the individual well rate constants. Assuming a MTCA cleanup level for CTC of 0.63 µg/L, it is anticipated that individual monitoring wells will achieve the cleanup standard between 3 years (i.e., P2-S) and 28 years (i.e., BMW-18).

Capital costs associated with implementation of Alternative 1 are low. The alternative proposes to make use of the existing monitoring well network to evaluate remedial progress and performance. Yearly O&M costs will consist of expenses associated with groundwater monitoring and reporting. The present value of this alternative is estimated to be $555,000 based on a discount rate of 7% and a monitoring period of 28 years[9]. **Table 5-2** provides a breakdown of the cost estimate.

Compliance with Threshold Requirements

Alternative 1 was evaluated against the four minimum threshold requirements specified under MTCA. It was concluded that Alternative 1 satisfies the four threshold requirements as described below:

- **Protect Human Health and the Environment –** Human health and the environment will be protected during remedy implementation and upon achievement of the Site Cleanup Standards. As described in Section 2, there are presently no unacceptable risks to human health or the environment. Specifically, the drinking water pathway for CTC in groundwater was eliminated by the installation of a public water supply line to 13 of the 15 homes within the plume footprint that previously used private drinking water wells; the drinking water wells at the two remaining homes were decommissioned. Further, there are no unacceptable risks associated with soil or soil vapor gas. Lastly, CTC has not been detected in either surface water samples or sediment samples. As such, CTC discharge to surface water or sediments does not appear to present unacceptable risk.

  Based on the CTC concentration trend analysis in groundwater, it is estimated that the Site Cleanup Standards will be achieved in thirty years or less at the on-Property well with the current highest CTC concentration (e.g., BMW-18). Off-Property wells are anticipated to reach Cleanup Standards in much shorter time frames (i.e., 5 to 15 years).

  Therefore, Alternative 1 is consistent with WAC 173-340-702(5) that states *“Cleanup actions that achieve cleanup levels at the applicable point of compliance under Methods A, B, or C (as applicable) and comply with applicable state and federal laws shall be presumed to be protective of human health and the environment.”*

- **Comply with Cleanup Standards –** Site Cleanup Standards are anticipated to be achievable under Alternative 1. As noted under the previous requirement, the CTC concentration trend analysis indicates that Site Cleanup Standards will be likely be met off-Property within 15 years and on-Property within 28 years. Therefore, it was concluded that Alternative 1 satisfies this threshold requirement.

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[9] USEPA policy on the use of discount rates for RI/FS cost analyses is stated in the preamble to the NCP (55 FR 8722) and in Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20 entitled “*Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis*” (USEPA 1993). Based on the NCP and “*A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*” (USEPA 2000), a discount rate of 7% should be used in developing present value cost estimates for remedial action alternatives during the FS.

- **Comply with Applicable State and Federal Laws –** Based on the analysis of potential ARARs, it is anticipated that Alternative 1 would satisfy the applicable state and federal laws. Therefore, it was concluded that Alternative 1 satisfies this threshold requirement.

- **Provide for Compliance Monitoring –** Alternative 1 will include compliance monitoring, and therefore satisfies this threshold requirement.

The analysis of threshold requirements is summarized in **Table 5-1**. Based on the evaluation, Alternative 1 is considered compliant with the four MTCA Threshold Requirements and thus meets the minimum requirements of an acceptable cleanup action. The permanence and practicality of this Alternative are evaluated in Section 5.5.

5.3.2 Alternative 2 – Site-Wide Pump and Treat

This section describes the pump and treat alternative and evaluates whether it satisfies the MTCA Threshold Requirements for a cleanup action.

<u>Technical Description & Cost</u>

The conceptual layout of a Site-wide pump and treat system is presented in **Figure 5-1**. Extraction Well Number 1 (i.e., EW-01) is located along the plume centerline inside the northern Property boundary. Extraction Well Number 2 (i.e., EW-02) is located along the plume centerline, approximately 750 ft north of MW-13. Each of the two extraction wells would be connected to a groundwater conveyance system that would pump the extracted groundwater to a new treatment system located on Property. Approximately 3,400 ft of conveyance piping would be required to connect the wells to the treatment system. Most of this conveyance piping would need to be installed in public rights-of-way beneath or beside roadways. The on-Property treatment system would consist of a bag filter system, a granular activated carbon (GAC) adsorption unit, and a pressurization pump located on the effluent side of the GAC unit. Treated water would be conveyed to the nearest surface water feature (location to be determined) and discharged under appropriate permit(s).

The desired capture zone width for each extraction well was estimated based on the objective of capturing groundwater containing CTC above the MTCA cleanup level of 0.63 µg/L. The desired capture zone widths for EW-01 and EW-02 are approximately 1,100 ft and 900 ft, respectively. An empirical formula was used to estimate the extraction needed at each well to achieve the design capture width (Javandel and Tsang, 1986):

$$Q = 2 \times W \times B \times v$$

Where,

Q = pumping rate from the well (ft^3/day)

W = capture zone width at point of extraction (ft) = 1100 ft (EW-01) or 900 ft (EW-02)

B = aquifer thickness (ft) = 90 ft (see Section 2.2)

ν = Darcy velocity, conductivity (40 ft/d) × gradient (0.005) (ft/day) = 0.2 ft/day

For EW-01, the pumping rate required to develop a 1,100 ft capture width is approximately 39,600 ft^3/day, or 200 gpm. For EW-02, the pumping rate required to develop a 900 ft capture width is approximately 32,400 ft^3/day, or 170 gpm.

Typically, groundwater extraction of multiple aquifer "pore volumes (*PVs*)" is required to achieve groundwater cleanup for chlorinated solvents, due to their sorption to aquifer materials. The restoration of groundwater requires that sufficient groundwater be flushed through the contaminated zone to remove dissolved contaminants and contaminants that will desorb from the aquifer material. The *PV* represents the actual volume of groundwater present within the pore space of the aquifer. The *PV* is calculated as follows:

$$PV = B \times \eta \times A$$

Where,

B = average thickness of the target plume area (ft)

η = formation porosity

A = area of targeted plume (ft^2)

The area of groundwater containing CTC at concentrations above 0.63 µg/L was estimated to be approximately 5,200,000 ft^2 (120 acres). As described in Section 2.2, the average thickness of the target plume area is approximately 90 ft. Assuming a porosity of 0.3, the *PV* is approximately 140,000,000 ft^3 (1,050,000,000 gallons). Approximately 40% of the *PV* would be addressed by EW-01 and the remainder of the *PV* addressed by EW-02.

At many pump and treat sites, numerous *PV*s must be flushed through the contamination zone to attain cleanup standards (USEPA, 1997). Assuming linear sorption, absence of NAPL or soil source, no biodegradation, and discounting dispersion, the number of *PV*s required for restoration is a function of the retardation factor (*R*), which is the ratio of the groundwater velocity to the dissolved VOC transport velocity. The number of *PVs* is calculated as follows (USEPA 1997):

$$\text{No. of } PVs = -R \times \ln(Cwt/Cwo)$$

Where,

Cwt = cleanup concentration goal for CTC (0.63 µg/L)

Cwo = current groundwater CTC concentration (4.5 µg/L at BMW-18; 2.0 µg/L at MW-13)

Assuming a fractional organic carbon content of 0.0001 for the sandy Aquifer A and CTC partition coefficient of 150 L/kg (USEPA, 1996), *R* is calculated to be approximately 1.1. Using the CTC Cwt = 0.63 µg/L (i.e., MTCA Method B Standard for GW) and CTC Cwo = 4.5 µg/L at BMW-18 and 2.0 µg/L at MW-13), the numbers of *PVs* that would be necessary to be extracted to restore the on- and off-Property portions of the plume are 2.2 and 1.3, respectively. To account for the fact that the extraction wells will also extract water containing CTC at concentrations less than 0.63 µg/L, a safety factor of 2 was applied to estimate the total volume of water to be extracted to achieve the target cleanup level. Thus, it was estimated that EW-01 would have to extract ~4.4 on-Property *PVs* and EW-02 would have to extract ~2.6 off-Property *PVs* to achieve cleanup objectives. At the estimated extraction rates, EW-01 and EW-02 would both operate for approximately 18 years.

Capital costs associated with implementation of Alternative 2 are estimated to be approximately $2,421,000. The alternative proposes to make use of the existing monitoring well network to evaluate remedial progress and performance. Yearly O&M costs are high, and primarily associated with treatment system operator labor, electricity, system maintenance, and groundwater monitoring. The present value of this alternative is estimated to be $4,143,000 based on a discount rate of 7% and an operational period of 18 years. **Table 5-3** provides a breakdown of the cost estimate.

<u>Compliance with Threshold Requirements</u>

Alternative 2 was evaluated against the four minimum threshold requirements specified under MTCA. It was concluded that Alternative 2 satisfies the four threshold requirements as described below:

- **Protect Human Health and the Environment –** Human health and the environment will be protected during remedy implementation and upon achievement of the Site Cleanup Standards. Similar to evaluation of Alternative 1, there are presently no unacceptable risks to human health or environment. Based on the performance evaluation presented, it is estimated that the Site Cleanup Standards will be achieved within approximately 18 years.

  Therefore, Alternative 2 is consistent with WAC 173-340-702(5) that states *"Cleanup actions that achieve cleanup levels at the applicable point of compliance under Methods A, B, or C (as applicable) and comply with applicable state and federal laws shall be presumed to be protective of human health and the environment."*

- **Comply with Cleanup Standards –** Site Cleanup Standards are anticipated to be achievable under Alternative 2. As noted under the previous requirement, the anticipated performance of Alternative 2 will likely result in Site Cleanup Standards being met within 18 years. Therefore, it was concluded that Alternative 2 satisfies this threshold requirement.

- **Comply with Applicable State and Federal Laws –** Based on the analysis of potential ARARs, it is anticipated that Alternative 2 would satisfy the applicable state and federal laws. Therefore, it was concluded that Alternative 2 satisfies this threshold requirement.

- **Provide for Compliance Monitoring –** Alternative 2 will include compliance monitoring, and therefore satisfies this threshold requirement.

The analysis of threshold requirements is summarized in **Table 5-1**. Based on the evaluation, Alternative 2 is considered compliant with the four MTCA Threshold Requirements and thus meets the minimum requirements of an acceptable cleanup action. The permanence and practicality of this Alternative are evaluated in Section 5.5.

5.3.3 Alternative 3 – Permeable Reactive Barrier

This section describes the PRB alternative and evaluates whether it satisfies the MTCA Threshold Requirements for a cleanup action.

<u>Technical Description & Cost</u>

The conceptual layout of the PRB is depicted in **Figure 5-2**. The PRB would be situated along the northern Property boundary downgradient of the former process area. The PRB would be designed to span the width of the plume above the 0.63 µg/L CTC contour, which is approximately 1,200 ft. At the proposed location, the depth to the bottom of Aquifer A is approximately 110 ft. The reactive barrier would be installed from approximately 35 ft bgs, coincidental with the approximate water level depth in this area, to approximately 110 ft bgs. It is anticipated that the PRB would be installed using a vertical hydrofracturing methodology. The permeable zone would be designed to maximize hydraulic conductivity so that groundwater flow will occur through the reactive zone.

The performance of the PRB is anticipated to be similar to Alternative 1 upgradient of the PRB and similar to Alternative 2 downgradient of the PRB. Upgradient of the PRB, the CTC concentrations in groundwater will decline by the same processes controlling MNA. Since the PRB does not increase the flow of groundwater, the rate of CTC reduction upgradient of the PRB will be unaffected by its installation (remedy duration of about 28 years, as estimated for on-Property MNA). Downgradient of the PRB, the CTC mass flux will be reduced by the PRB. It is anticipated that the CTC mass reduction due to the PRB will enhance the attenuation process within the plume immediately downgradient of the PRB. However, the effect of the PRB on the downgradient plume edges is not likely to be significant (i.e., CTC concentrations at the lateral and longitudinal extents of the plume are likely to decline at the same rate as predicted for Alternative 1. The remedial duration of Alternative 3 is likely to range up to 28 years.

Capital costs associated with implementation of Alternative 3 are estimated to be approximately $6,307,000. The alternative proposes to make use of the existing monitoring well network to evaluate remedial progress and performance. Yearly O&M costs are limited to expenses associated with groundwater monitoring. The present value of this alternative is estimated to be $6,871,000 based on a discount rate of 7% and an operational period of 28 years. **Table 5-4** provides a breakdown of the cost estimate.

Compliance with Threshold Requirements

Alternative 3 was evaluated against the four minimum threshold requirements specified under MTCA. It was concluded that Alternative 3 satisfies the four threshold requirements as described below:

- **Protect Human Health and the Environment –** Human health and the environment will be protected during remedy implementation and upon achievement of the Site Cleanup Standards. Similar to the evaluation of the previous two alternatives, there are presently no unacceptable risks to human health or environment. Based on the performance evaluation presented, it is estimated that the Site Cleanup Standards will be achieved within approximately 28 years.

  Therefore, Alternative 3 is consistent with WAC 173-340-702(5) that states *"Cleanup actions that achieve cleanup levels at the applicable point of compliance under Methods A, B, or C (as applicable) and comply with applicable state and federal laws shall be presumed to be protective of human health and the environment."*

- **Comply with Cleanup Standards –** Site Cleanup Standards are anticipated to be achievable under Alternative 3. As noted under the previous requirement, the anticipated performance of Alternative 3 will likely result in Site Cleanup Standards being met within 28 years. Therefore, it was concluded that Alternative 2 satisfies this threshold requirement.

- **Comply with Applicable State and Federal Laws –** Based on the analysis of potential ARARs, it is anticipated that Alternative 3 would satisfy the applicable state and federal laws. Therefore, it was concluded that Alternative 3 satisfies this threshold requirement.

- **Provide for Compliance Monitoring –** Alternative 3 will include compliance monitoring, and therefore satisfies this threshold requirement.

The analysis of threshold requirements is summarized in **Table 5-1**. Based on the evaluation, Alternative 3 is considered compliant with the four MTCA Threshold Requirements and thus meets the minimum requirements of an acceptable cleanup action. The permanence and practicality of this Alternative are evaluated in Section 5.5.

5.4 Sustainability Analysis of Cleanup Alternatives

Environmental concepts such as risk reduction, compliance with regulations, implementability, and cost have typically guided selection, design, and optimization of remedial systems. Recently, inclusion of sustainability metrics to environmental restoration have emerged as part of site management decision making processes (Interstate Technology and Regulatory Council [ITRC], 2011). Sustainability analysis, which incorporates a broader view of environmental and human health impacts through life-cycle assessment (LCA) concepts, can be used to evaluate and minimize the overall environmental burden (environmental footprint) of remedial alternatives (United States Air Force Center for Engineering and the Environment [AFCEE], 2010). Appendix D presents the results of a sustainability analysis of the three cleanup action alternatives for the Site. The sustainability analysis was performed to aid in the detailed evaluation of the three alternatives as presented in Section 5.5.

The sustainability analysis was performed using the commercially available *Sustainability Remediation Tool* (SRT, version 2), which was developed by the AFCEE in collaboration with representatives from the United States military, the USEPA, industry, environmental consultants, and state regulators. Sustainability metrics considered in the analysis include total energy consumed, technology cost, safety/accident risk, and air emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM_{10}).

Appendix D presents the estimated sustainability metrics for the three alternatives. A comparison of the metrics indicates the following:

- CO_2 emissions were approximately 45 and 525 times greater for P&T and PRB, respectively, compared to MNA;
- Energy consumption was approximately 67 and 75 times greater for P&T and PRB, respectively, compared to MNA; and,
- The safety/accident risk metric was approximately 8 and 19 times greater for P&T and PRB, respectively, compared to MNA.

In summary, MNA had the smallest environmental footprint for each sustainability metric, and the best safety metric. The environmental footprints for P&T and PRB were generally similar in magnitude to one another but significantly greater than the MNA environmental footprints. Based on the evaluation, the remedial alternatives ranked, in order of most to least sustainable, as follows: 1) MNA; 2) P&T; and 3) PRB. Complete results and conclusions of the sustainability analysis are provided in Appendix D.

5.5 Disproportionate Cost Analysis

A DCA was performed to determine which of the three cleanup action alternatives is protective to the maximum extent practicable. The estimated benefit of each alternative was quantified using the DCA criteria described in Section 5.2.3. For each cleanup action alternative, rating values ranging from 1 (least favorable) to 5 (most favorable) were assigned for each of the MTCA criteria. **Table 5-1** provides the numeric ratings and corresponding rationale for each alternative and criteria. The conclusions provided in **Table 5-1** are discussed below:

5.5.1 Protectiveness

Each of the three alternatives was determined to be protective of human health and environment. As noted previously, there are presently no unacceptable risks to human health or the environment based on the pathway and receptor evaluation. As such, each alternative was initially given a value of 5 for protectiveness. However, this criterion requires that "on-Property and off-Property risks resulting from implementing the alternative, and improvement of the overall environmental quality" be considered. Based on the greater environmental footprint of Alternatives 2 and 3 compared to Alternative 1 (Section 5.4 and Appendix D), these two alternatives were downgraded in their rating to a value of 4 since these alternatives will have larger impacts to the environment based on sustainability.

5.5.2 Permanence

Each of the three alternatives provides for a reduction in CTC toxicity, mobility, and volume. Alternatives 2 and 3 were given a rating of 4 while Alternative 1 was given a rating of 3. Alternative 2 would achieve CTC mass reduction through the extraction of groundwater at two locations and treatment at an on-Property treatment facility. Operation of the extraction wells would target containment of groundwater containing CTC at concentrations above the MTCA cleanup level of 0.63 µg/L. Alternative 2 did not receive a rating of 5 given the inefficiency of the system (i.e., high volume of extraction compared to the rather small mass of CTC removal and treatment). Alternative 3 would achieve CTC mass reduction through in situ treatment of CTC in groundwater leaving the Property. Alternative 3 did not receive a rating of 5 given that a significant portion of the CTC plume would not be actively targeted for treatment. Alternative 1 achieves mass reduction through ongoing destructive natural attenuation processes such as hydrolysis and anaerobic degradation. In addition, CTC mobility is reduced through sorption to aquifer solids. Toxicity is also reduced via dilution due to dispersion, groundwater recharge, and other physical processes. Alternative 1 is not rated as high as Alternatives 2 and 3 because the percentage of CTC mass that undergoes destruction is expected to be less for Alternative 1 compared to Alternatives 2 and 3.

5.5.3 Cost

Detailed cost estimates were developed for the three alternatives and are presented in **Tables 5-2** through **5-4**. Alternative 1 is estimated to have the lowest NPV (~ $555,000) and was given a rating of 5. Alternative 3 is estimated to have the highest NPV (~ $6,871,000) even though its estimated annual O&M costs are less than Alternative 2 and approximately equal to Alternative

1; Alternative 3 was given a rating of 2. The estimated NPV of Alternative 2 is $4,143,000 and was given a rating of 3. As noted previously, no weighting factor was applied to this criterion in the calculation of each alternatives overall numeric benefit.

5.5.4 Long-Term Effectiveness

Several factors [WAC 173-340-360(3)(f)(iv)] were considered to rate the three alternatives on their long-term effectiveness. The factors and their evaluation with respect to the three alternatives are described as follows:

- Degree of certainty that the alternative will be successful – each alternative is expected to be successful in achieving Site remediation if implemented. It is anticipated that Alternative 2 may be the least efficient of the alternatives given that the performance of the pump and treat system may be limited by lenses of low hydraulic conductivity and/or rate-limited desorption. Under active pumping conditions, these rate-limiting mechanisms will have a greater influence on alternative performance than under the ambient flow conditions present for Alternatives 1 and 3.

- Reliability of the alternative during the period of time CTC may remain at concentrations that exceed cleanup levels – Alternatives 1 and 3 are expected to have a greater degree of reliability than Alternative 2 for the following reasons. First, there is no current unacceptable risk associated with the presence of CTC in groundwater. Given that Alternatives 1 and 3 provide mass reduction in situ, there is limited potential for human exposure to CTC during remedy implementation. In contrast, Alternative 2 requires the extraction, conveyance, treatment, and effluent management of groundwater containing CTC. If an equipment malfunction associated with operation of the pump and treat system occurs, there is the potential for human exposure and/or an environmental impact.

- Magnitude of residual risk with the alternative in place – the residual risk associated with each alternative is anticipated to be within acceptable levels.

Based on these factors, Alternatives 1 and 3 were given a rating of 5 while Alternative 2 was given a rating of 4.

5.5.5 Management of Short-Term Risks

Alternative 1 was given a rating of 5 because it minimizes impacts to human health and the environment in the short term by minimizing invasive activities associated with implementation. In contrast, Alternatives 2 and 3 would involve significant construction activities as part of implementation and would have higher short-term risks. The magnitude of this increased risk was quantified as part of the sustainability analysis presented in Section 5.4. As noted, the safety/accident risk metric accounting for mitigation measures was approximately 8 to 19 times greater for Alternatives 2 and 3, respectively, compared to Alternative 1. Given the magnitude of the increased risks, Alternative 2 was rated a 4 and Alternative 3 was rated a 3.

5.5.6 Implementability (Technical and Administrative)

Alternative 1 is readily implementable and was given a rating of 5.

Alternative 2 is implementable but would be subject to potentially significant (based on past issues) access limitations for extraction wells, conveyance piping and the treatment plant. Furthermore, permitting issues and logistical challenges may occur related to discharge of the treated groundwater. Based on low concentrations of CTC in groundwater, relatively high hydraulic conductivity of the aquifer, and lateral extent of the plume, a relatively high pumping rate of approximately 370 gpm will be required. Alternative 2 would require the removal of substantial amount of water in order to remove a small amount of CTC mass. Overall, Alternative 2 was rated a 4 for implementability.

Alternative 3 is implementable, subject to access limitations and technical challenges. Prior to construction, an access agreement would be required to install the PRB in the proposed location. The proposed depth of the PRB (>100 ft) would present several construction challenges that may not be surmountable. For these reasons, Alternative 3 is rated a 3 for implementability.

5.5.7 Consideration of Public Concerns

It is anticipated that each of the alternatives will address potential concerns the public may have regarding alternative implementation. However, it is anticipated that MNA may be favored by the public on the basis of less construction impact and better sustainability metrics (less energy use and emissions, better safety metric). As such, MNA was rated a 5, whereas P&T and PRB were each rated a 3.

5.5.8 Weighted Ratings & DCA

The absolute ratings above were adjusted using the DCA weighting factors described in Section 5.2.3. **Table 5-5** presents the weighted ratings and the estimated benefit of each alternative. The estimated benefit of Alternative 1 (normalized to a value of 5) is 4.6. The estimated benefits of Alternatives 2 and 3 were each 4.1. Given that Alternative 1 is the highest rated alternative and also the lowest cost alternative, a formal DCA is not required per MTCA. Although not required, the DCA metric of cost per benefit (i.e., cost/benefit) clearly indicates that Alternative 1 is protective to the maximum extent practicable.

5.6 Reasonable Restoration Timeframe Analysis

The MTCA specified factors were considered to determine whether Alternative 1 (i.e., the highest rated alternative based on the DCA) provides for a reasonable restoration time frame. The evaluation factors and analysis are summarized below:

- Potential risks posed by the site to human health and the environment – There are no current or likely future unacceptable risks at the Site, therefore the estimated restoration time frame of 28 years for the highest concentration areas is reasonable.

- Practicability of achieving a shorter restoration time frame – Based on the evaluation of the DCA criteria, it is not practicable to reduce the restoration time frame. As illustrated, the reduced restoration time frame for Alternative 2 requires activities that result in a lower overall benefit rating compared to Alternative 1.

- Current use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site – Based on existing conditions, there are no anticipated effects on current uses that would result during the anticipated restoration time frame.

- Potential future use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site – Based on likely future uses within the plume area, it is unlikely that potential future uses will be negatively impacted by the presence of CTC in the groundwater during the anticipated restoration time frame.

- Availability of alternative water supplies – Connections to Tacoma Water supply are available or present for properties within the footprint of the CTC plume.

- Likely effectiveness and reliability of institutional controls – The Site is located within the Pierce County Urban Growth Area, and thus the installation of any new groundwater use wells are prohibited unless an application is first filed and approved by the local water purveyor. This use restriction is anticipated to be an effective and reliable means to prevent human exposure to CTC in groundwater.

- Ability to control and monitor migration of hazardous substances from the site – Compliance monitoring will be implemented as part of the remedy and will provide adequate data to evaluate whether remediation is progressing as anticipated. It will also provide data to evaluate whether unacceptable migration of the plume is occurring.

- Toxicity of the hazardous substances at the site – CTC concentrations at the Site are relatively close to the proposed MTCA cleanup level of 0.63 µg/L. Given the absence of a complete exposure pathway for groundwater, there are no anticipated negative effects due to CTC toxicity.

- Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the site or under similar site conditions – The CTC time trend analysis and the estimated first-order decay rates indicate that natural processes are reducing the concentrations of CTC at the Site.

Based on this analysis, the estimated restoration time frame for Alternative 1 is considered reasonable.

5.7 Consider Public Concerns

It is anticipated that the public will support the acceptance of Alternative 1 for several reasons:

- There are no unacceptable risks currently at the Site;

- CTC concentrations are declining and will likely be less than MTCA cleanup levels within 10 years at most off-Property locations, and within 28 years on Property (versus 18 years for pump and treat);

- There are no use restrictions imposed by Alternative 1 that are not already present as a result of local government ordinances;

- Alternative 1 does not require construction activities within public right-of-ways and thus will not inconvenience residents or property owners during implementation; and

- Alternative 1 is by far the most sustainable of the three alternatives, consuming substantially less energy, producing substantially less CO_2 emissions, and having by far the best safety/accident risk metric.

Based on absence of construction activities within the public right-of-ways, the public is likely to prefer Alternative 1 to Alternative 2.

5.8 Recommended Cleanup Action Alternative

Based on the analyses presented in this RI/FS Report, the recommended cleanup action alternative for the Site is Alternative 1 - Monitored Natural Attenuation. WAC 173-340-370 states the expectations that Ecology has for the development of cleanup action alternatives under WAC 173-340-350 and the selection of cleanup actions under WAC 173-340-360. The factors pertinent to the recommendation of Alternative 1 are summarized below:

- **WAC 173-340-370(6):** *The department expects that, for facilities adjacent to a surface water body, active measures will be taken to prevent/minimize releases to surface water via surface runoff and groundwater discharges in excess of cleanup levels. The department expects that dilution will not be the sole method for demonstrating compliance with cleanup standards in these instances.* – Based on the non-detect samples for surface water and sediment at Clover Creek during 2002 and 2010, attenuation of the CTC plume to concentrations less than the MTCA cleanup levels is occurring, preventing unacceptable risks to Clover Creek. The attenuation processes are likely to include hydrolysis, anaerobic degradation, and sorption, thus dilution is not the sole mechanism resulting in compliance.

- **WAC 173-340-370(7):** *The department expects that natural attenuation of hazardous substances may be appropriate at sites where:*

  (a) Source control (including removal and/or treatment of hazardous substances) has been conducted to the maximum extent practicable – Source area excavations were conducted in 1989 and 1991. Subsequent source investigations indicated that CTC was not present in soil and soil gas within the former process areas at levels that would impact groundwater.

  (b) Leaving contaminants on-site during the restoration time frame does not pose an unacceptable threat to human health or the environment – There are no current or anticipated future unacceptable risks associated with the presence of CTC at the Site.

  (c) There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site – CTC is known to degrade via hydrolysis and anaerobic biodegradation pathways. The CTC time trend analysis and the estimated first-order decay rates indicate that CTC concentrations are decreasing at significant rates within the plume footprint.

  (d) Appropriate monitoring requirements are conducted to ensure that the natural attenuation process is taking place and that human health and the environment are protected – Compliance monitoring will be performed as part of Alternative 1, thus satisfying this requirement.

- **WAC 173-340-370(8):** *The department expects that cleanup actions conducted under this chapter will not result in a significantly greater overall threat to human health and the environment than other alternatives* – As demonstrated during the DCA and in the sustainability analysis, Alternative 1 minimizes potential risks to human health during remedy implementation and has the smallest environmental footprint of the three alternatives considered in this RI/FS Report.

Based on this review of Ecology expectations for cleanup action alternatives, Alternative 1 is consistent MTCA requirements and thus is proposed as the recommended alternative for the Site.

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TABLES

Table 2-1
Summary of Carbon Tetrachloride Groundwater Data
Frederickson Industrial Park
Frederickson, Washington

Wells	11-BL	11-CU	11-CL	HLA-1	BMW-2	BMW-3	BMW-13R	BMW-18	BMW-19	BMW-22	MW1	MW2	MW3	MW4	MW6	MW7	P1S	P1I	P1D	P2S	P2I	P2D	MW-13
Ground Elevation (MSL)	395.5	403.69	403.69	403.86	406.88	414.74	416.48	409.74	413.12	409.53	413.27	402.77	389.2	465.5	353.58	350.7	335.01	335.67	334.6	340.55	340.65	340.23	394.5
Top of Screen (MSL)	331.5	363.7	329.7	320.9	381.9	381.7	381	375.7	373.6	376	324.8	255.8	299.2	317.9	245.6	310.2	320	272.7	235	320.6	270.7	231.2	284.5
Bottom of Screen (MSL)	321.5	353.7	319.7	310.9	351.9	351.7	351	345.7	343.6	346	314.8	245.8	289.2	307.9	235.6	300.2	310	267.7	225	310.6	265.7	221.2	274.1
Aquifer Zone	A - Lower	A - Upper	A - Lower	A - Lower	A - Upper	A - Upper	A - Upper	A - Upper	A - Upper	A - Upper	A - Lower	C - Upper	A - Middle	A - Middle	C - Upper	A - Upper	A - Upper	A - Lower	C - Upper	A - Upper	A - Lower	C - Upper	Aquifer A
Data																							
Jul-89	ND(1.0)	ND(1.0)	15.7																				
Aug-89	ND(1.0)	ND(1.0)	51.3																				
Sep-89			25.0																				
Jan-90	0.3		9.7																				
Feb-90	15.7		19.8																				
Mar-90	28.7		53.1																				
Apr-90																							
May-90	1.7		6.9																				
Jul-90	0.5	ND(1.0)	10.4																				
Jul-90	ND(1.0)		11.0																				
Nov-90	1.1	ND(1.0)	16.0																				
Oct-92								13.0	ND(1.0)	3.3													
Nov-92	1.0	ND(0.2)	12.0			2.8	ND(0.2)	14.0	ND(0.2)	0.4													
Feb-94						2.0																	
May-94					ND(0.2)			9.3															
Jun-94						0.9		12.0															
Jul-94				9.7																			
Aug-94					ND(0.2)																		
Apr-95																							
Jul-95	4.3			9.9	0.3	0.5		11.0															
Aug-95																							
Apr-99	1.5	ND(0.5)	10.0	12.0	0.25		ND(0.5)	9.6	ND(0.5)	0.7													
Nov-00	2.2	ND(0.2)	12.0	12.0	ND(0.2)	0.55	ND(0.2)	12.0	ND(0.2)	0.94	3.4	ND(0.2)	ND(0.2)	1.1	ND(0.2)		ND(0.2)	ND(0.2)	ND(0.2)	1.5	1.2	ND(0.2)	
Nov-02	1.2	ND(0.2)	8.1	8.1	ND(0.2)	0.65	ND(0.2)	7.5	ND(0.2)	0.48	1.7	ND(0.2)	ND(0.2)	0.88	ND(0.2)	1.3	ND(0.2)	ND(0.2)	ND(0.2)	1.3	1.1	ND(0.2)	
Jun-10	1.0	ND(0.1)	9.4	8.8/9.3	ND(0.1)	***0.35***	ND(0.1)	7.7/7.8	ND(0.1)	***0.16***	1.2	ND(0.1)	ND(0.1)	1.0		***0.11***	ND(0.1)	ND(0.1)	ND(0.1)	0.5	0.64	ND(0.1)	
Feb-11	***0.3***	ND(0.1)	3.1	4.1/4.2	ND(0.1)	***0.16***	ND(0.1)	4.5/4.4	ND(0.1)	ND(0.1)	0.86	ND(0.1)	ND(0.1)	***0.3***		***0.17***	ND(0.1)	ND(0.1)	ND(0.1)	0.71	0.59	ND(0.1)	2.0

Notes:

MSL Feet above mean sea level

0.5 Estimated Value (i.e., concentration greater than method detection limit but less than method reporting limit)

ND(XX) Not-Detected (Method Detection Limit)

Table 2-2
Monitoring Well Construction Information and Groundwater Elevation Data
Fredrickson Industrial Park
Frederickson, Washington

Well	Ground Elevation (ft MSL)	Top of Casing Elevation (MSL)	Top of Screen (MSL)	Bottom of Screen (MSL)	Aquifer	June 2010		February 2011	
						Depth to Water (ft)	Water Level (MSL)	Depth to Water (ft)	Water Level (MSL)
11-BL	395.5	396.08	331.5	321.5	Lower - Aquifer A	38.29	357.79	37.37	358.71
11-CL	403.69	404.55	329.7	319.7	Lower - Aquifer A	43.35	361.20	42.50	362.05
11-CU	403.69	404.67	363.7	353.7	Upper - Aquifer A	34.03	370.64	32.37	372.30
BMW-13R	416.48	416.48	381	351	Upper - Aquifer A	38.53	377.95	38.23	378.25
BMW-18	409.74	412.09	375.7	345.7	Upper - Aquifer A	41.51	370.58	40.94	371.15
BMW-19	413.12	415.66	373.6	343.6	Upper - Aquifer A	42.93	372.73	42.79	372.87
BMW-2	406.88	408.98	381.9	351.9	Upper - Aquifer A	33.94	375.04	33.81	375.17
BMW-22	409.53	412.13	376	346	Upper - Aquifer A	38.94	373.19	38.50	373.63
BMW-3	414.74	416.76	381.7	351.7	Upper - Aquifer A	40.35	376.41	40.53	376.23
HLA-1	403.86	405.81	320.9	310.9	Lower - Aquifer A	44.80	361.01	43.85	361.96
MW-1	413.27	415.79	324.8	314.8	Lower - Aquifer A	41.60	374.19	40.81	374.98
MW-2	402.77	405.18	255.8	245.8	Aquifer C	35.08	370.10	33.91	371.27
MW-3	389.2	391.41	299.2	289.2	Aquifer A	36.92	354.49	36.20	355.21
MW-4	465.5	467.72	317.9	307.9	Aquifer A	116.92	350.80	116.02	351.70
MW-7	350.7	350.12	310.2	300.2	Upper - Aquifer A	25.35	324.77	25.33	324.79
P1-D	334.6	336.87	235	225	Aquifer C	9.21	327.66	9.12	327.75
P1-I	335.67	337.44	272.7	267.7	Lower - Aquifer A	9.44	328.00	9.55	327.89
P1-S	335.01	337.84	320	310	Upper - Aquifer A	10.73	327.11	10.93	326.91
P2-D	340.23	342.78	231.2	221.2	Aquifer C	15.75	327.03	14.55	328.23
P2-I	340.65	343.23	270.7	265.7	Lower - Aquifer A	14.00	329.23	13.85	329.38
P2-S	340.55	343.6	320.6	310.6	Upper - Aquifer A	15.50	328.10	15.66	327.94
Pierce	466.88	----	----	308.9	Aquifer A	120.68	346.20	NS	NS
MW-13	394.5	394.1	284.5	274.1	Aquifer A	NS	NS	52.60	341.90

Notes:
NS = Not sampled
ft MSL = feet above mean sea level

Table 2-3
MW-13 Vertical Aquifer Sampling Carbon Tetrachloride Results
Frederickson Industrial Park
Frederickson, Washington

Depth (Feet)	Sample Type	Sample Date	Result (µg/L)	Lab MRL	Lab MDL	Qualifiers
55		01/31/11	ND (0.096)	0.5	0.096	
66		02/01/11	No Sample	0.5	0.096	
77		02/01/11	ND (0.096)	0.5	0.096	
89		02/01/11	0.56	0.5	0.096	
89	Duplicate	02/01/11	0.46	0.5	0.096	J
99		02/01/11	ND (0.096)	0.5	0.096	
109		02/01/11	0.90	0.5	0.096	
118		02/02/11	0.77	0.5	0.096	
130		02/02/11	0.41	0.5	0.096	J
139		02/02/11	ND (0.096)	0.5	0.096	
EB	Equipment Blank	02/01/11	ND (0.096)	0.5	0.096	
TB	Trip Blank		ND (0.096)	0.5	0.096	

Notes:
MRL = Method Reporting Limit
MDL = Method Detection Limit
ND (XX)= Not Detected (Method Detection Limit)

Laboratory Qualifier:
J = Carbon Tetrachloride detected between the MDL and method reporting limit (MRL: 0.5 µg/L). The reported value is estimated.

Table 2-4
Surface Water Carbon Tetrachloride Results
Frederickson Industrial Park
Frederickson, Washington

Location	Sample Type	Sample Date	Result (µg/L)	Lab MRL (µg/L)	Lab MDL (µg/L)	Qualifiers
SW-4		10/06/2010	ND (0.096)	0.5	0.096	
SW-3		10/06/2010	ND (0.096)	0.5	0.096	
SW-2		10/06/2010	ND (0.096)	0.5	0.096	
SW-1		10/06/2010	ND (0.096)	0.5	0.096	
SW-1	DUPLICATE	10/06/2010	ND (0.096)	0.5	0.096	

Notes:
MRL = Method Reporting Limit
MDL = Method Detection Limit
ND (XX)= Not Detected (Detection Limit)

Table 2-5
Sediment Carbon Tetrachloride and Total Organic Carbon Results
Fredrickson Industrial Park
Fredrickson, Washington

Location	Sample Type	Sample Date	TOC Result (Percent)	CTC Result (μg/kg)	CTC Lab MRL (μg/kg)	CTC Lab MDL (μg/kg)	Qualifiers
SD-4		10/06/2010	3.25	ND (0.36)	2.0	0.36	
SD-3		10/06/2010	33.9	ND (0.36)	3.6	0.36	
SD-2		10/06/2010	2.77	ND (0.36)	1.9	0.36	
SD-1		10/06/2010	1.57	ND (0.36)	1.7	0.36	
SD-1	DUPLICATE	10/06/2010	1.74	Discounted[1]	---	---	

Notes:

CTC: Carbon Tetrachloride
TOC: Total Organic Carbon
MRL = Method Reporting Limit
MDL = Method Detection Limit
ND (XX)= Not Detected (Detection Limit)
[1]- The duplicate sediment analysis for CTC was discounted based on the variation in sample volumes between the primary SD-1 sample and the duplicate SD-1 sample. This variation was attributed to the heterogeneity of the sample matrix (coarse sand and pebble matrix) which resulted in target compound recovery outside acceptable limits.

Table 3-1
Applicable, Relevant and Appropriate Requirements (ARARs)
Fredrickson Industrial Park
Frederickson, Washington

Action	Citation	Requirements	Comments
Construction	29 CFR Part 1910.120 Occupational Safety and Health Standards - Hazardous Waste Operations and Emergency Response	Federal regulation requiring that remedial activities must be in accordance with applicable Occupational Safety and Health Administration (OSHA) requirements.	Applicable to construction phase of remedial alternatives.
	29 CFR Part 1926 Safety and Health Regulations for Construction	Federal regulation requiring that remedial construction activities must be in accordance with applicable OSHA requirements.	Applicable to construction phase of remedial alternatives.
	Pierce County Title 17	County regulations covering construction and infrastructure regulations.	Applicable to construction of treatment system alternatives.
Treatment	42 USC 6902 (RCRA)	Defines Hazardous waste management requirements.	Applies to management of hazardous/dangerous waste. If wastes are accumulated in treatment system they will be managed in accordance with these requirements.
	RCW 70.105D.090 (Model Toxics Control Act)	Defines hazardous waste cleanup policies.	Remedial activities will comply with substantive requirements of ARARS.
	WAC 173-340 (MTCA regulations)	Establishes administrative processes and standards to identify, investigate and clean up facilities where hazardous substances have come to be located.	Applies to any facility where hazardous substance releases to the environment have been confirmed.
	State Hazardous Waste Management Act (HWMA) RCW 70.105	Defines threshold levels and criteria to determine whether materials are hazardous/dangerous waste.	Applies to designation, handling, and disposal of wastes. Treatment system wastes meeting these criteria will be handled and disposed of in accordance with regulatory requirements.
Extraction wells	Well Construction RCW 18.104 WAC 173-160	Requirements that apply to wells and well construction.	Applies to construction of extraction wells for pump and treat alternative.
Transportation	40 CFR 261, 262, 264; 49 CFR 171, 172, 173, 174 Hazardous Materials Transportation	Defines requirements for off-site transportation of wastes.	Applicable to transportation of waste off-site. Applies to treatment alternative. Actions will comply with these requirements.
	WAC 446-50 Transportation of hazardous/dangerous waste	Defines requirements for off-site transportation of wastes.	Applicable to transportation of waste off-site. Applies to treatment alternative. Actions will comply with these requirements.

Table 3-2
Potential Groundwater Cleanup Levels for Carbon Tetrachloride
Frederickson Industrial Park
Frederickson, Washington

	Groundwater Protection (µg/L)			Concentration Protective of Surface Water (µg/L)									
				National Toxics Rule (1)				National Recommended Water Quality Criteria (2)				MTCA Method B Standard Formula Value (3)	
Analyte	Federal & State MCL	MTCA Method B Standard Formula Value		Protection of Aquatic Life - Freshwater		Protection of Human Health (Water & Organisms) (4)	Protection of Human Health (Organisms Only)	Protection of Aquatic Life - Freshwater		Protection of Human Health (Water & Organisms) (4)	Protection of Human Health (Organisms Only)	Protection of Human Health (Consumption of Organism)	
		Carcinogen	Non-Carcinogen	Acute	Chronic			Acute	Chronic			Carcinogen	Non-Carcinogen
Carbon Tetrachloride	5.0	0.63	32	--	--	0.25	4.4	--	--	0.23	1.6	4.94	553

Notes:
(1) Ambient water quality criteria for protection of human health from 40 CFR Part 131d (National Toxics Rule, 2008)
(2) National Recommended Water Quality Criteria (Clean Water Act Section 304, 2006)
(3) Ambient water quality criteria for protection of aquatic life from WAC 173-201A-240
(4) Criterion is not applicable because surface water near and directly downgradient of the Site is not and will not likely be used for drinking water

Most stringent applicable cleanup level (yellow highlight)

Table 4-1
Identification and Initial Screening of Remedial Technologies
Fredrickson Industrial Park
Frederickson, Washington

General Response Action	Remedial Technology	Process Option	Description	Screening Comments	Retained for Process Evaluation
No action	No action	No action	No action	Required for consideration by National Contingency Plan (NCP) (40 CFR Part 300.430)	Yes
Institutional actions	Monitoring	Groundwater and surface water monitoring	Periodic sampling and analyses of groundwater as a means of detecting changes in constituent concentrations in groundwater	Potentially applicable	Yes
		Vapor intrusion (VI) evaluation/monitoring	Evaluation of VI risk in future inhabitable structures within the areal extent of the groundwater VOC plume	Screening level Vapor Intrusion evaluation was conducted. Based on the evaluation, there is no potential pathway of concern for CTC exposure via vapor intrusion	No
	Use restrictions	Institutional restrictions	Restrictions on groundwater use where applicable until risk to groundwater exposure becomes acceptable	Potentially applicable	Yes
		Alternate water supply	May require connection of residential users to local water purveyors	Potentially applicable for future users. Existing residential users connected to municipal water supply	Yes
Collection/ Hydraulic containment	Extraction	Extraction wells	Installation of extraction wells to extract contaminated groundwater and control groundwater migration	Potentially applicable. No existing groundwater extraction wells or treatment at Site. For a short period of time starting in June 1990, an on-Site groundwater extraction and treatment system was operated at approximately 60 to 90 gallons per minute; groundwater was pumped from a single well (first 11-A, then 11-B) and treated via air-stripping. The system was decommissioned in late 1990 when the property was purchased by Boeing	Yes
		Extraction trench	Removal of groundwater by pumping from extraction trenches	Trench depth (>100 ft.) makes this technology impractable	No
Collection/ treatment enhancements	Permeability enhancement	Pneumatic fracturing	Injection of high pressure air to create channels or fractures in subsurface material	Based on the observed site soil lithology, and as confirmed by relatively high yield of the extraction system operated in 1990, permeability enhancements are not required at the site	No
		Hydraulic fracturing	Injection of water, with or without a propping agent, into the subsurface to create permeable channels in subsurface material	Based on the observed site soil lithology, and as confirmed by relatively high yield of the extraction system operated in 1990, permeability enhancements are not required at the site	No
	Extraction enhancement	Vacuum-enhanced extraction	Simultaneous extraction of groundwater and soil vapor from one or more vacuum-enhanced extraction wells. Extracted groundwater and vapor are treated, followed by discharge or reinjection into the subsurface	No evidence of VOCs in vadose zone. Recent, and past, vertical aquifer monitoring during well installation indicates lens of clean water resides above VOC groundwater plume, confirming the absence of impacted vadose zone. Enhanced extraction techniques for the site saturated zone are not necessary based on the yield of the extraction system operated in 1990	No
Monitored natural attenuation	Monitored natural attenuation	Monitored natural attenuation	Long-term monitoring of the natural attenuation and biotic and abiotic degradation/transformation of carbon tetrachloride	Potentially applicable. Time trend analysis of existing monitoring wells indicates declining CTC concentrations throughout the footprint of the plume. Several of the off-Site Aquifer A monitoring wells (e.g., MW-7, P-2S, P-2I, P-1S, P-1I, etc.) are below or close to the MTCA Method B CTC Standard of 0.63 µg/L. The declining trends observed over the past 10 to 20 years are consistent with the occurrence of degradation/transformation processes indicative of ongoing attenuation	Yes

Table 4-1
Identification and Initial Screening of Remedial Technologies
Fredrickson Industrial Park
Fredrickson, Washington

General Response Action	Remedial Technology	Process Option	Description	Screening Comments	Retained for Process Evaluation
In situ treatment	Biological treatment	Enhanced bioremediation	Injection of microbial populations, nutrient sources, electron donors, or other amendments into groundwater through injection wells to enhance biological degradation	Potentially applicable, although the low level concentrations and large areal extent of the plume may limit the effectiveness of this technology	Yes
	Chemical treatment	Chemical oxidation	Injection of oxidants such as permanganate, hydrogen peroxide, or sodium persulfide into groundwater. Oxidation reactions chemically convert constituents to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert	Potentially applicable, although the low level concentrations and large areal extent of the plume may limit the effectiveness of this technology	Yes
		Chemical reduction	Injection of a reducing agent such as nanoscale or microscale zero valent iron into groundwater. Reduction reactions chemically convert constituents to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert	Potentially applicable, although the low level concentrations and large areal extent of the plume may limit the effectiveness of this technology	Yes
	Physical treatment	Air sparging	Injection of air into the saturated zone to volatilize constituents, which are collected in the unsaturated zone by a soil vapor extraction (SVE) system and treated if necessary	Technology is not well suited for low concentration large area groundwater plume	No
		In-well air stripping	Air is injected into the water column to volatilize constituents. Groundwater is circulated in situ, with groundwater entering the well at one screen and discharging through a second screen. Air is collected in the unsaturated zone by a SVE system and treated if necessary. Can be combined with vacuum-enhanced extraction for low permeability applications	Technology is not well suited for low concentration large area groundwater plume	No
	Thermal treatment	Hot water/steam injection	Injection of hot water/steam through injection wells to enhance the recovery of organic constituents. The injected hot water/steam heats the subsurface, volatilizing organic contaminants, with subsequent collection and treatment through a series of vapor extraction wells	Technology is best suited for source removal and not well suited for low concentration large area groundwater plume. Size of VOC plume will lead to significant cost	No
		Electrical resistance heating	A series of electrodes are installed around a central neutral electrode. Volatilized contaminants, produced by the heating of the subsurface surrounding the electrodes, are recovered using vapor extraction wells and subsequently treated at the surface	Technology is best suited for source removal and not well suited for low concentration large area groundwater plume. Size of VOC plume will lead to significant cost	No
		Thermal conduction/desorption	Heat is applied to groundwater through steel wells via thermal conduction and convection processes. Organic contaminants are volatilized through heating, and subsequently collected by a vapor extraction system for ex situ treatment	Technology is best suited for source removal and not well suited for low concentration large area groundwater plume. Size of VOC plume will lead to significant cost	No
		Radio frequency heating	Heating of the treatment zone using a configuration of electrodes to enhance the recovery of organic constituents. The subsurface area targeted for heating is bound by two rows of electrodes that act as ground electrodes. A third row of electrodes is implanted halfway between the ground rows, acting as a capacitor. Electromagnetic energy is applied, directly heating the volume of material contained within the ground electrodes, causing organic contaminants to vaporize. Vapor extraction wells remove contaminant vapors for ex situ treatment	Technology is best suited for source removal and not well suited for low concentration large area groundwater plume. Size of VOC plume will lead to significant cost	No
	Treatment wall	Permeable reactive barrier	Construction of an iron wall, biobarrier, or carbon wall to treat groundwater as it flows through the treatment zone.	Potentially applicable. Treatment wall installation depth may be problematic	Yes

Table 4-2
Evaluation of Process Options
Frederickson Industrial Park
Frederickson, Washington

General Response Action	Remedial Technology	Process Option	Effectiveness [1]	Implementability	Cost	Retained for Alternative Development	Comments
No action	No action	No action	Not effective in meeting RAOs.	Readily implementable.	No capital No O&M	No	
Institutional actions	Monitoring	Groundwater monitoring	Effective method for monitoring changes in groundwater CTC concentrations and thus identifying potential risk exposures. As a stand-alone process option, potential risk exposures (if identified) are not directly mitigated, but instead groundwater monitoring provides the data to assess the need for active exposure prevention measures (e.g., institutional restrictions). Useful for evaluating remedy effectiveness.	Readily implementable.	Low capital Low O&M	Yes	
	Use restrictions	Institutional restrictions	Limits the use of groundwater until groundwater presents no unacceptable risk. Effective immediately once restrictions are in place.	Have been implemented.	Low capital No O&M	Yes	Institutional controls of restricting potable use of local groundwater successfully implemented.
		Alternate water supply	Effective means of preventing use of impacted groundwater by future residential users.	Have been implemented.	Low capital Low O&M	Yes	Potable water supply has been successfully implemented.
Collection/ Hydraulic containment	Extraction	Extraction wells	Effectiveness limited, primarily due to the large areal extent of the low-level CTC plume. It is anticipated that operation of an extraction system would require large volumes of groundwater to be pumped with little mass reduction or overall acceleration of site cleanup.	Potentially implementable. No extraction wells or infrastructure for conveyance and treatment are currently installed. Installation of the system would require access agreements and acquisition of permits with/from land owners/Pierce County. Installation of conveyance piping connecting off-Site wells to an on-Site treatment system would be complicated given the level of off-Site industrial/commercial development and the presence of supporting utilities. In addition, implementation would require groundwater modeling to identify extraction well sites and potential capture zones.	Medium to High capital Medium O&M	Yes	
Monitored natural attenuation (MNA)	Monitored natural attenuation	Monitored natural attenuation	Effective for reducing the volume and toxicity of low-level dissolved CTC in groundwater. Based on observed time trend analyses of CTC concentrations in existing monitoring wells, permanent CTC mass/concentration reduction is occurring and appears likely to meet remedial goals within an acceptable timeframe. The effectiveness of MNA to achieve permanent CTC mass/concentration reduction is considered to be similar to, or better than, the effectiveness of the groundwater extraction process options (i.e., wells) because the remedial timeframes are likely to be similar.	Readily implementable. The existing monitoring well network appears adequate for monitoring of this process option.	Low capital Low O&M	Yes	
In situ treatment	Biological treatment	Enhanced bioremediation	Potentially effective in reducing the volume and toxicity of dissolved CTC in groundwater. Given the low level CTC concentrations in groundwater, it may be difficult to sustain bioremediation activities. Past experience has shown that the energy produced through the biodegradation of low level CTC (and other VOC) concentrations does not provide sufficient motive force to sustain the biodegradation processes.	It may be necessary to conduct laboratory tests to identify the most appropriate biodegradation approach. Amendments readily available - many are food-grade and/or inexpensive. Access agreements would need to be negotiated to inject electron donor and/or other amendments in the targeted areas of the CTC plume. Enhanced bioremediation will likely adversely affect other groundwater quality constituents such as producing dissolved metals, sulfide and/or methane, which may be undesirable and/or regulated.	Medium capital Medium O&M	No	Due to the low level concentrations and large areal extent of the CTC plume, enhanced bioremediation is not considered a viable approach. The ability to sustain bioremediation processes is limited, and the production of other water quality impacts is undesirable.
	Chemical treatment	Chemical oxidation	Potentially effective in reducing the volume and toxicity of dissolved CTC in groundwater. Limits to technology may be the generally low concentrations and the extensive area needed to be treated. The low level of CTC concentrations in the groundwater plume would result in competing chemical reactions limiting effectiveness of technology. Diffuse, widespread nature of CTC groundwater plume makes technology deployment cost prohibitive.	Oxidizing agents readily available. Transportation and storage of large quantities of treatment chemicals requires compliance with appropriate permits and regulations. Potential health and safety hazards involved when handling large quantities of treatment chemicals. Access agreements would need to be negotiated to inject the oxidant in the targeted areas of the CTC plume.	Medium capital Medium O&M	No	Due to the low level concentrations and large areal extent of the CTC plume, chemical oxidation is not considered a viable approach. Oxidation of the CTC may be limited due to competing reactions.
		Chemical reduction	Potentially effective in reducing the volume and toxicity of dissolved CTC in groundwater. Limits to technology may be the generally low concentrations and the extensive area needed to be treated. The low level of CTC concentrations in the groundwater plume would result in competing chemical reactions limiting effectiveness of technology. Diffuse, widespread nature of CTC groundwater plume makes technology deployment cost prohibitive.	Reducing agents readily available. Transportation and storage of large quantities of treatment chemicals requires compliance with appropriate permits and regulations. Potential health and safety hazards involved when handling large quantities of treatment chemicals. Access agreements would need to be negotiated to inject the reductants in the targeted areas of the CTC plume.	Medium capital Medium O&M	No	Due to the low level concentrations and large areal extent of the CTC plume, chemical reduction is not considered a viable approach. Reduction of the CTC may be limited due to competing reactions.
	Treatment wall	Permeable reactive barrier	Construction of an iron wall, biobarrier, or carbon wall to treat groundwater as it flows through the treatment zone.	Potentially applicable. Depth of implementation (>100 ft.) may present difficulties to implementation.	High capital Low O&M	Yes	Retained for alternative development given the potential for low O&M costs.

Footnotes

1 The effectiveness of a process option is evaluated against its ability to: (i) prevent short- and long-term exposures, and (ii) restore the aquifer to below cleanup levels. It should be noted that the evaluation of effectiveness to prevent short-term exposures should not be interpreted to indicate the presence of any current short-term exposure; Site data indicate that there is no potential for short-term exposure. With regard to RAO #3 - Control contaminant migration so contaminant releases from groundwater to surface water do not exceed clean up criteria to human health and the environment - current Site conditions support the conclusion that the CTC plume does not pose a threat to surface water. As such, each of the process options presented in this table are assumed to be capable of achieving RAO #3.

Table 5-1
Summary of Ratings for Detailed Analysis of Cleanup Action Alternatives
Fredrickson Industrial Park
Frederickson, Washington

Alternatives		MTCA Threshold Criteria				Disproportionate Cost Analysis (DCA) Rating = 0 Lowest (Least Favorable) and 5 = Highest (Most Favorable)													
		Protection of Human Health and the Environment	Compliance with Cleanup Standards	Compliance with Applicable State and Federal Laws (i.e., ARARs)	Provision for Compliance Monitoring	Protectiveness	Rating	Permanence	Rating	Cost	Rating	Long-Term Effectiveness	Rating	Management of Short-Term Risks	Rating	Implementability (Technical and Adminstrative)	Rating	Consideration of Plublic Concerns	Rating
1	MNA	Human health and the environment will be protected during remedy implementation and upon achievement of the Site Cleanup Standards.	Complies with cleanup standards.	Complies with potential ARARs.	Provides for compliance monitoring.	Human health and the environment will be protected during remedy implementation and upon achievement of the Site Cleanup Standards.	5	Reduction of CTC mass, mobility, and volume would occur throughout the plume over time due to natural processes. CTC mass reduction expected to be less than other alternatives.	3	Low capital and O&M cost.	5	Given the evidence of ongoing attenuation of the CTC plume, MNA is expected to be successful in achieving site remediation. MNA is expected to be reliable, and the mangnitude of residual risk with the in-place system is anticipated to be within acceptable levels.	5	Alternative minimizes impacts to human health and the environment in the short term by minimizing invasive activities associated with implementation.	5	Readily implementable.	5	Alternative is anticipated to address potential public conerns regarding alternative implementation.	5
2	Pump and Treat	Human health and the environment will be protected during remedy implementation and upon achievement of the Site Cleanup Standards.	Complies with cleanup standards.	Complies with potential ARARs.	Provides for compliance monitoring.	Human health and the environment will be protected during remedy implementation and upon achievement of the Site Cleanup Standards. Technology has greater overall environmental footprint compared to MNA.	4	Reduction of CTC mass, mobility, and volume would occur upon initiation of groundwater extraction, although system may be inefficient (i.e., high volume of extraction compared to the rather small mass of CTC removal and treatment).	4	Medium to high capital and O&M costs. No existing extraction, conveyance, or treatment infrastructure exists. Costs dependent on extent of groundwater plume targeted for pump and treat. O&M timeframe would be long.	3	P&T is expected to be successful in achieving site remediation, but the alternative is anticipated to be the least effecient alternative given that the performance of the P&T system may be limited by lenses of low hydraulic conductivity and/or rate-limited desorption. P&T is expected to be reliable, but the potential exists for contaminat exposure to receptors in the event of equipment malfunction. The mangnitude of residual risk with the in-place system is anticipated to be within acceptable levels.	4	Construction activities and implementation involve impacts to human health and the environment and short term-risks, as quantified in the Sustainability Analysis. This alternative had a medium safety/accident risk metric.	4	Implementable, subject to access limitations for extraction wells, conveyance piping, and treatment plant. Based on low concentrations of CTC in groundwater, relatively high hydraulic conductivity of the aquifer, and lateral extent of the plume, a relatively high pumping rate would be required. The alternative would require the removal of a substaintial amount of water in order to remove a small amount of CTC mass.	4	Alternative is anticipated to address potential public conerns regarding alternative implementation.	3
3	PRB	Human health and the environment will be protected during remedy implementation and upon achievement of the Site Cleanup Standards.	Complies with cleanup standards.	Complies with potential ARARs.	Provides for compliance monitoring.	Human health and the environment will be protected during remedy implementation and upon achievement of the Site Cleanup Standards. Technology has greater overall environmental footprint compared to MNA.	4	Reduction of CTC mass, mobility, and volume would occur for CTC in groundwater leaving property boundary; current off-site CTC would naturally attenuate.	4	Medium to high capital cost. Cost driven by depth of installation and length of PRB required to intercept and treat groundwater plume. O&M costs are low (monitoring only).	2	PRB is expected to be successful in achieving site remediation. PRB is expected to be reliable, and the mangniture of residual risk with the in-place system is anticipated to be within acceptable levels.	5	Construction activities and implementation involve impacts to human health and the environment and short term-risks, as quantified in the Sustainability Analysis. This alternative had the highest safety/accident risk metric.	3	Potentially implementable, subject to access limitations and technical challenges. Required depth of barrier (>100 feet) presents several construction challenges and may not be surmountable.	3	Alternative is anticipated to address potential public conerns regarding alternative implementation.	3

Table 5 - 2
Alternative 1 Cost Estimate
Frederickson Industrial Park
Frederickson, Washington

	Alternative	1
	Description	**Monitored Natural Attenuation**
Implement-Action Costs	Corrective Action Plan	$25,000
	Total Costs	**$25,000**
Yearly OM&M Costs	Performance Monitoring - Labor and Equipment[1]	$10,000
	Performance Monitoring - Analytical[2]	$3,000
	IDW Management[3]	$4,000
	Yearly Performance Monitoring Reports	$10,000
	Project Management	$10,000
	Total OM&M Cost	**$37,000**
Periodic Costs (Years 1-28)	Five Year Review Report - Year 5	$20,000
	Five Year Review Report - Year 10	$20,000
	Five Year Review Report - Year 15	$20,000
	Five Year Review Report - Year 20	$20,000
	Five Year Review Report - Year 25	$20,000
	Well Abandonment and Site Clean Up - Year 28	$250,000
	Remedial Action Report - Year 28	$25,000
Present Value Analysis	Capital Cost (from above)	$25,000
	Annual OM&M Cost (Discount Factor = 7%)	$449,000
	Five Year Review Report - Year 5	$14,000
	Five Year Review Report - Year 10	$10,000
	Five Year Review Report - Year 15	$7,000
	Five Year Review Report - Year 20	$5,000
	Five Year Review Report - Year 25	$4,000
	Periodic Cost - Year 28 Items	$41,000
	Total Present Value of the Alternative[4]	**$555,000**

1. This line item includes the labor necessary to conduct the annual performance monitoring of the Alternative. It is assumed that 22 monitoring wells will be sampled on an annual basis.

2. This line is based on annual sampling of 22 monitoring wells. Including QAC samples, a total of 30 CTC will be analyzed per year at an estimated cost of $100/sample.

3. This line items includes waste characterization and disposal.

4. All costs are +50%/-30%.

Table 5 - 3
Alternative 2 Cost Estimate
Frederickson Industrial Park
Frederickson, Washington

	Alternative	2
	Description	**Site-Wide Pump and Treat**
Construction/Implementation Costs	Corrective Action Plan	$25,000
	Groundwater Extraction System[1]	$448,000
	Groundwater Conveyance System[2]	$411,000
	Treatment System[3]	$250,000
	Effluent Management System[4]	$120,000
	Performance Monitoring System[5]	$60,000
	Electrical, Instrumentation & Controls[6]	$368,000
	General Contractor Mobilization (5% of Material Installation Cost)	$82,850
	Contractor Construction Site/Staging Area (5% of Material Installation Cost)	$82,850
	Surveying (2% of Material Installation Cost)	$33,000
	Engineering Design (10% of Installation Costs)	$186,000
	Permitting/Access & Use Agreements (5% of Installation Costs)	$91,000
	Construction Management & Oversight (12% of Installation Costs)	$223,000
	System Start-Up[7]	$40,000
	Total Installation Costs	**$2,421,000**
Yearly OM&M Costs (Years 1-18)	Operator Labor[8]	$25,000
	Utilities (Electricity)[9]	$30,000
	GAC Replacement[10]	$10,000
	Performance Monitoring - Labor and Equipment[11]	$10,000
	Performance Monitoring - Analytical[12]	$7,600
	Equipment Maintenance[13]	$20,000
	Yearly Performance Monitoring Reports	$20,000
	Project Engineer & Management	$20,000
	Total OM&M Cost	**$142,600**
Periodic Costs (Years 1-18)	Five Year Review Report - Year 5	$20,000
	Five Year Review Report - Year 10	$20,000
	Five Year Review Report - Year 15	$20,000
	Demobilize Treatment System - Year 18	$50,000
	Well Abandonment and Site Clean Up - Year 18	$250,000
	Remedial Action Report - Year 18	$25,000
Present Value Analysis	Installation Cost (from above)	$2,421,000
	Annual OM&M Cost (Discount Factor = 7%)	$1,595,000
	Five Year Review Report - Year 5	$14,000
	Five Year Review Report - Year 10	$10,000
	Five Year Review Report - Year 15	$7,000
	Periodic Cost - Year 18 Items	$96,000
	Total Present Value of the Alternative[14]	**$4,143,000**

See notes on page 2

1. Groundwater Extraction System costs include: (i) installation, development, and testing of the two extractions wells, (ii) installation of extraction well vaults (includes piping, concrete vaults, etc), and (iii) pump and instrumentation installation. Wells are assumed to be 8" diameter, 120 ft deep, and constructed of 304 stainless steel. Installation costs are estimated at $450/ft. Development and testing is estimated at $100,000 per well based on experience at similar site. Extraction well vault installation and pump installation are estimated at approximately $70,000 per well based on costing developed for another site with similar construction features.

2. Groundwater Conveyance System costs were estimated assuming that the conveyance pipe would be 6" HPDE and installed within County right-of-ways and Boeing property. Based on the conceptual design, there is an estimated 3400 feet of piping. Unit costs for pipe installation were estimated at $120/ft and assumes the replacement of asphalt disturbed during installation.

3. Treatment system costs were estimated from non-bonding quotes from equipment retailers and installers. For costing purposes, it was assumed that the treatment plant will be designed for a capacity of 400 gpm, influent CTC concentrations of approximately 3 ppb, and effluent CTC concentrations of non-detect. The costs include a small treatment building to house the equipment. IDW for well sampling will be treated by the system at no extra cost.

4. The Effluent Management System includes the installation of conveyance piping from the treatment system to either municipal sewer hookup or surface water discharge location under permit. It was assumed that a hookup location would be available within 750 feet of the treatment system. The piping from the treatment system to the hookup was assumed to be 8" HDPE.

5. The Performance Monitoring System includes the installation of two new monitoring wells, one located near each of two extraction wells. The wells were assumed to be 2" diameter, PVC, and installed to a depth of 100 ft each. Cost per well was assumed to be $30,000.

6. Electrical, Installation and Controls includes the installation of two local extraction well control panels, instrumentation for the two extraction wells, wiring & conductors for the extraction wells and treatment system, a treatment system control panel, treatment plant instrumentation, power drops at the extraction wells and treatment plant, and installation costs. The estimated costs for the individual components are based on pricing developed for a similar pump and treat system at a different site.

7. System start up costs assumed that system shakedown and startup would take approximately 4 weeks.

8. Operator labor was estimated to be 8 hours per week at $60 per hour.

9. Electricity costs were estimated assuming a cost of $0.18/kW-hr.

10. For 400 gpm and an influent concentration of 3 ppb CTC, the annual replacement costs are estimated to be approximately $10,000.

11. This line item includes the labor necessary to conduct the annual performance monitoring of the Alternative. It is assumed that 24 monitoring wells will be sampled on an annual basis (includes the two new monitoring wells described under Performance Monitoring System).

12. This line is based on annual sampling of 24 monitoring wells, quarterly sampling of the two extraction wells, and monthly sampling of the treatment system influent, midfluent, and effluent. Including QAC samples, a total of 76 CTC will be analyzed per year at an estimated cost of $100/sample.

13. The System is comprised of approximately $400,000 of equipment that is likely to require replacement on a periodic basis. $20,000 per year was allocated for equipment based on a mean replacement cycle of 20 years. Some equipment is expected to last longer than 20 years whereas other equipment may need more frequent replacement.

14. All costs are +50%/-30%.

Table 5 - 4
Alternative 3 Cost Estimate
Frederickson Industrial Park
Frederickson, Washington

	Alternative	3
	Description	**Permeable Reactive Barrier**
Construction/Implementation Costs	Corrective Action Plan	$25,000
	Permeable Reactive Barrier Construction[1]	$3,300,000
	Zero Valent Iron for PRB	$1,000,000
	Performance Monitoring Wells[2]	$120,000
	General Contractor Mobilization (5% of Material Installation Cost)	$221,000
	Contractor Construction Site/Staging Area (5% of Material Installation Cost)	$221,000
	Surveying (2% of Material Installation Cost)	$88,000
	Engineering Design (10% of Installation Costs)	$495,000
	Permitting/Access & Use Agreements (5% of Installation Costs)	$243,000
	Construction Management & Oversight (12% of Installation Costs)	$594,000
	Total Installation Costs	**$6,307,000**
Yearly OM&M Costs (Years 1-28)	Performance Monitoring Labor and Equipment[3]	$12,000
	Performance Monitoring - Analytical[4]	$4,600
	Yearly Performance Monitoring Reports	$10,000
	Project Engineer & Management	$10,000
	Total OM&M Cost	**$36,600**
Periodic Costs (Years 1-28)	Five Year Review Report - Year 5	$20,000
	Five Year Review Report - Year 10	$20,000
	Five Year Review Report - Year 15	$20,000
	Five Year Review Report - Year 20	$20,000
	Five Year Review Report - Year 25	$20,000
	Well Abandonment and Site Clean Up - Year 28	$250,000
	Remedial Action Report - Year 28	$25,000
Present Value Analysis	Installation Cost (from above)	$6,307,000
	Annual OM&M Cost (Discount Factor = 7%)	$443,000
	Five Year Review Report - Year 5	$14,000
	Five Year Review Report - Year 10	$10,000
	Five Year Review Report - Year 15	$7,000
	Five Year Review Report - Year 20	$5,000
	Five Year Review Report - Year 25	$4,000
	Periodic Cost - Year 28 Items	$81,000
	Total Present Value of the Alternative[5]	**$6,871,000**

See notes on page 2

Table 5 - 4
Alternative 3 Cost Estimate
Frederickson Industrial Park
Frederickson, Washington

1. Permeable Reactive Barrier (PRB) with a total length of 1,200 feet. Zero-valent iron (ZVI) installed from 35 ft bgs to 110 ft bgs with 3" of ZVI. Installed using a vertical hydrofracturing method as implemented by GeoSierra.

2. The Performance Monitoring System includes the installation of four new monitoring wells, two located upgradient and two downgradient of the PRB. The wells were assumed to be 2" diameter, PVC, and installed to a depth of 100 ft each. Cost per well was assumed to be $30,000.

3. This line item includes the labor necessary to conduct the annual performance monitoring of the Alternative. It is assumed that 26 monitoring wells will be sampled on an annual basis (includes the four new monitoring wells described under Performance Monitoring System).

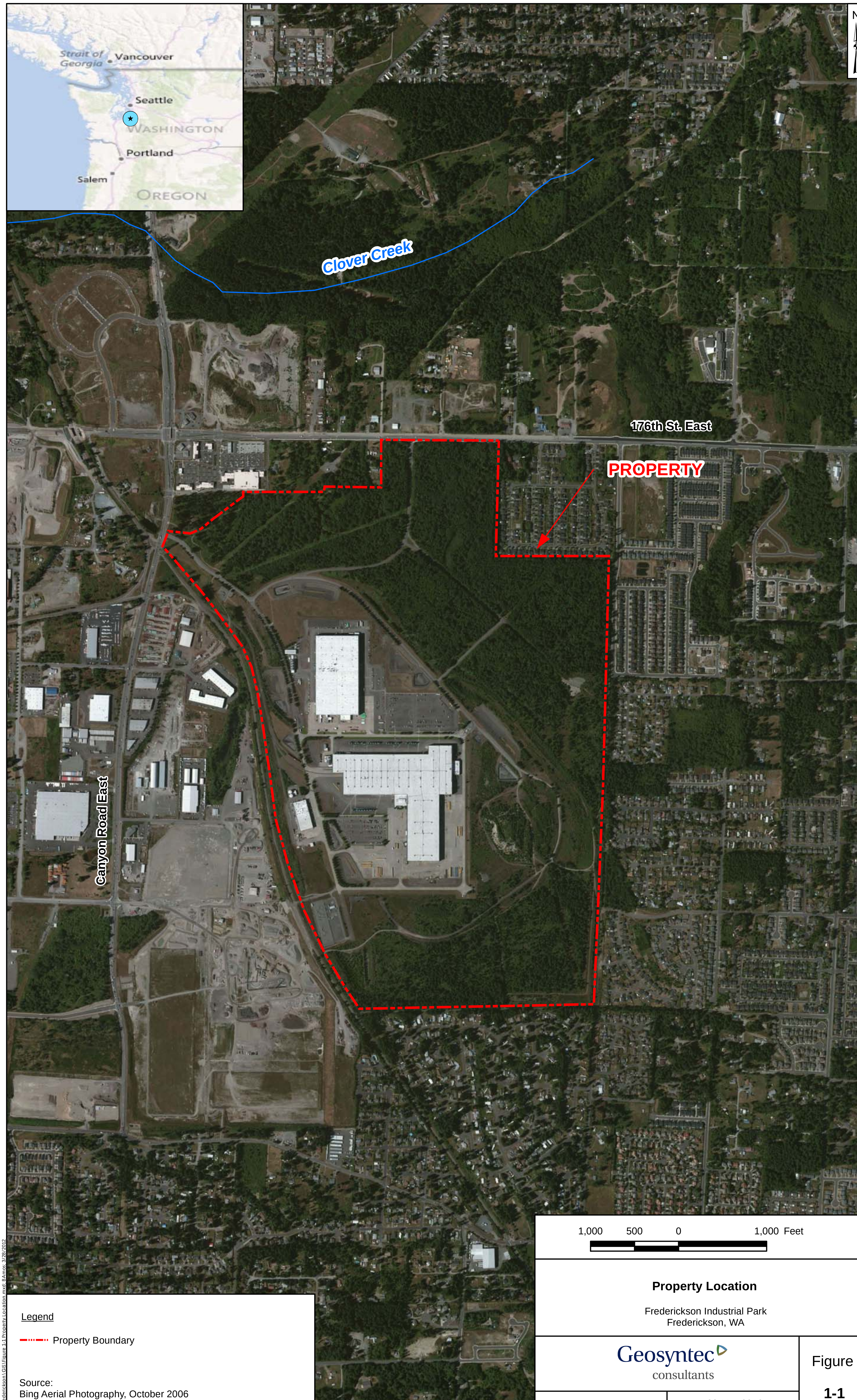
4. This line is based on annual sampling of 22 monitoring wells, and quarterly sampling of the four PRB monitoring wells. Including QAC samples, a total of 46 CTC will be analyzed per year at an estimated cost of $100/sample.

5. All costs are +50%/-30%.

Table 5-5
Disproportionate Cost Analysis
Frederickson Industrial Park
Frederickson, Washington

Criteria	Alternative		
	MNA	**Pump & Treat**	**PRB**
MTCA Threshold Criteria			
1. Protection of Human Health and the Environment	Yes	Yes	Yes
2. Compliance with Cleanup Standards	Yes	Yes	Yes
3. Compliance with ARARs	Yes	Yes	Yes
4. Provision for Compliance Monitoring	Yes	Yes	Yes
Restoration Time Frame	~ 28 Years	~ 18 Years	~ 28 Years
Unweighted Ratings (1 = Least Favorable; 5 = Most Favorable)			
Protectiveness	5	4	4
Permanence	3	4	4
Long-Term Effectiveness	5	4	5
Management of Short-Term Risks	5	4	3
Implementability	5	4	3
Consideration of Public Concerns	5	3	3
Estimated Benefit - Weighted Ratings			
Protectiveness (30%)	1.5	1.2	1.2
Permanence (20%)	0.6	0.8	0.8
Long-Term Effectiveness (20%)	1	0.8	1
Management of Short-Term Risks (10%)	0.5	0.4	0.3
Implementability (10%)	0.5	0.4	0.3
Consideration of Public Concerns (10%)	0.5	0.3	0.3
Benefit Rating	**4.6**	**3.9**	**3.9**
Disproportionate Cost Analysis			
Estimated Cost	$555,000	$4,143,000	$6,871,000
Cost/Benefit	$121,000	$1,062,000	$1,762,000
Cost Disproportionate to Incremental Benefits?	N/A (Baseline)	Yes	Yes
Overall Alternative Ranking	1	2	3
Benefit Increase over Baseline (%)		-15%	-15%
Cost Increase over Baseline (%)		746%	1238%

FIGURES



Legend

Property Boundary

Source:
Bing Aerial Photography, October 2006

Property Location

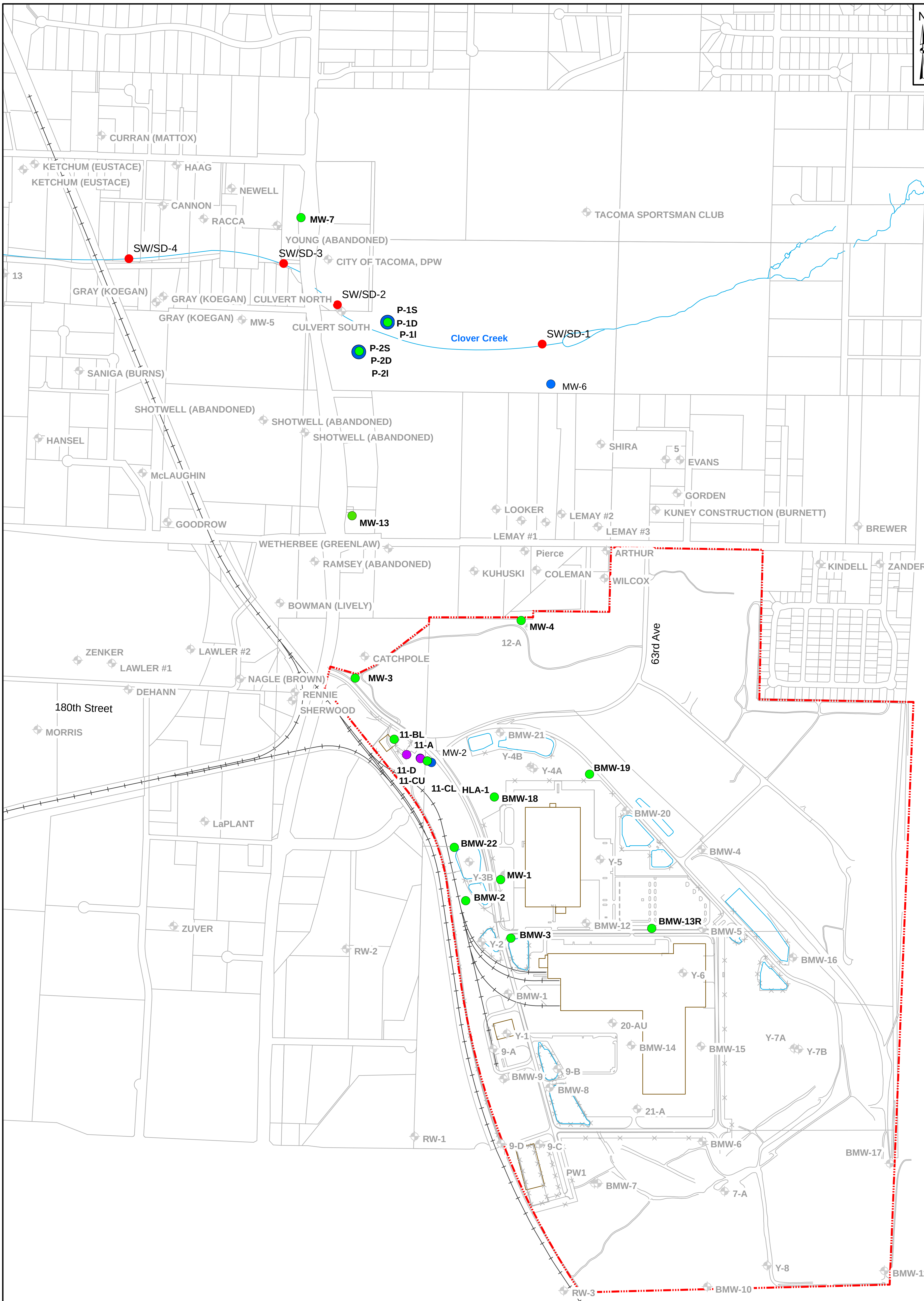
Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Kennesaw, GA | 28-Mar-2012

Figure 1-1

N:\Fredrickson\GIS\Figure 1-1 Property Location.mxd; BAmos; 3/28/2012



Legend

- Aquifer A Monitoring Wells
- Aquifer C Monitoring Wells
- Past Groundwater Extraction Wells
- SW/SD-1 = Surface Water/Sediment Sample Location
- Private/Domestic Wells
- Property Boundary

N:\Frederickson\GIS\Figure 2-1.mxd; BAmos; 3/28/2012

1,000 500 0 1,000 Feet

Site Plan

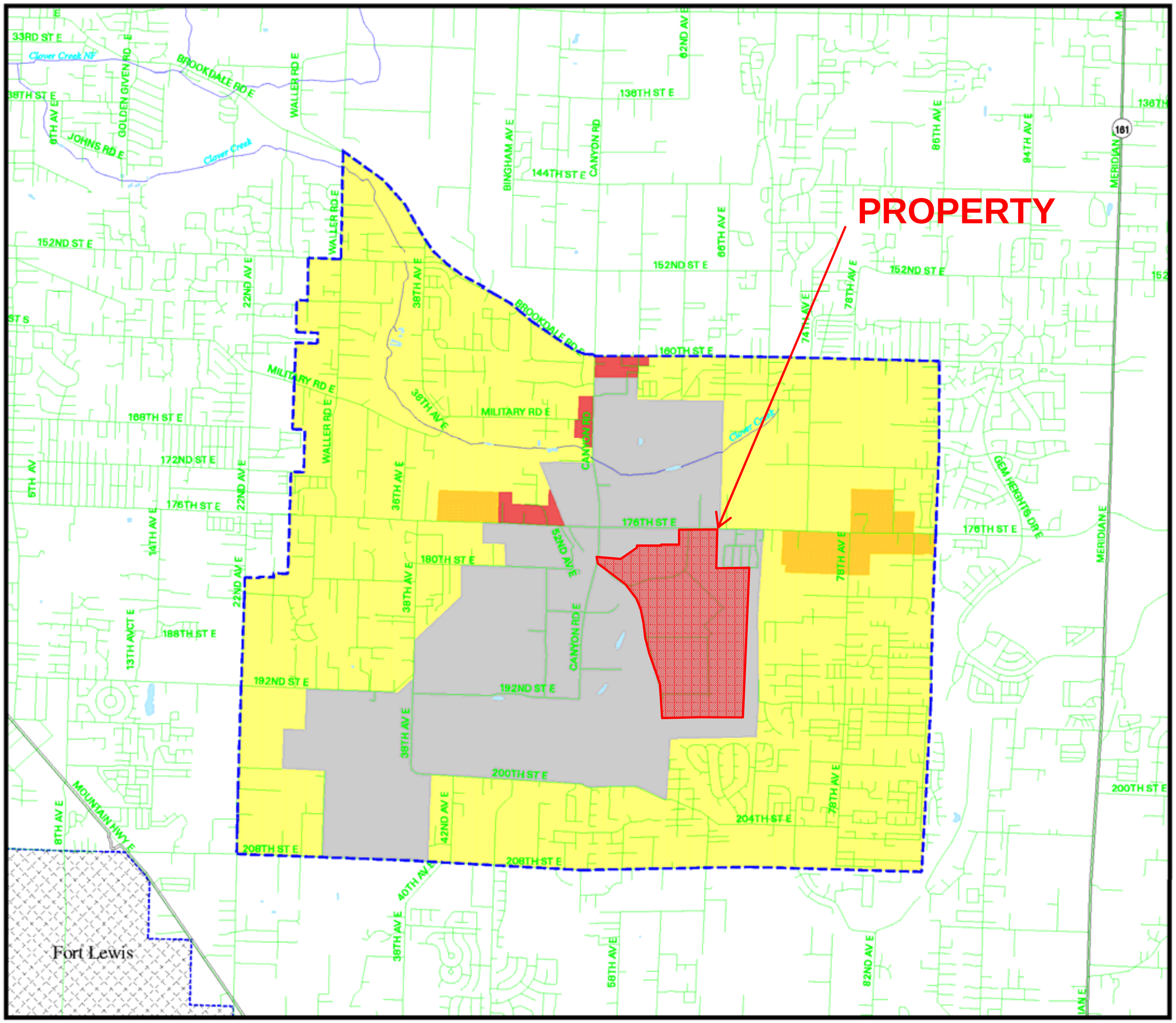
Fredericksson Industrial Park
Frederickson, WA

Geosyntec consultants

Figure **2-1**

Kennesaw, GA

28-Mar-2012



Pierce County, Washington

Land Use Designations

- Employment Center (EC)
- Mixed Use District (MUD)
- High Density Residential District (HRD)
- Moderate Density Single Family (MSF)

Frederickson Community Plan
Adopted October 28, 2003 –Ord. #2003–94S2
Effective December 15, 2003

Frederickson Community Plan Boundary

MILES
0 1

Pierce County
Geographic Information System

Department of Planning and Land Services
Plot Date: August 24, 2004

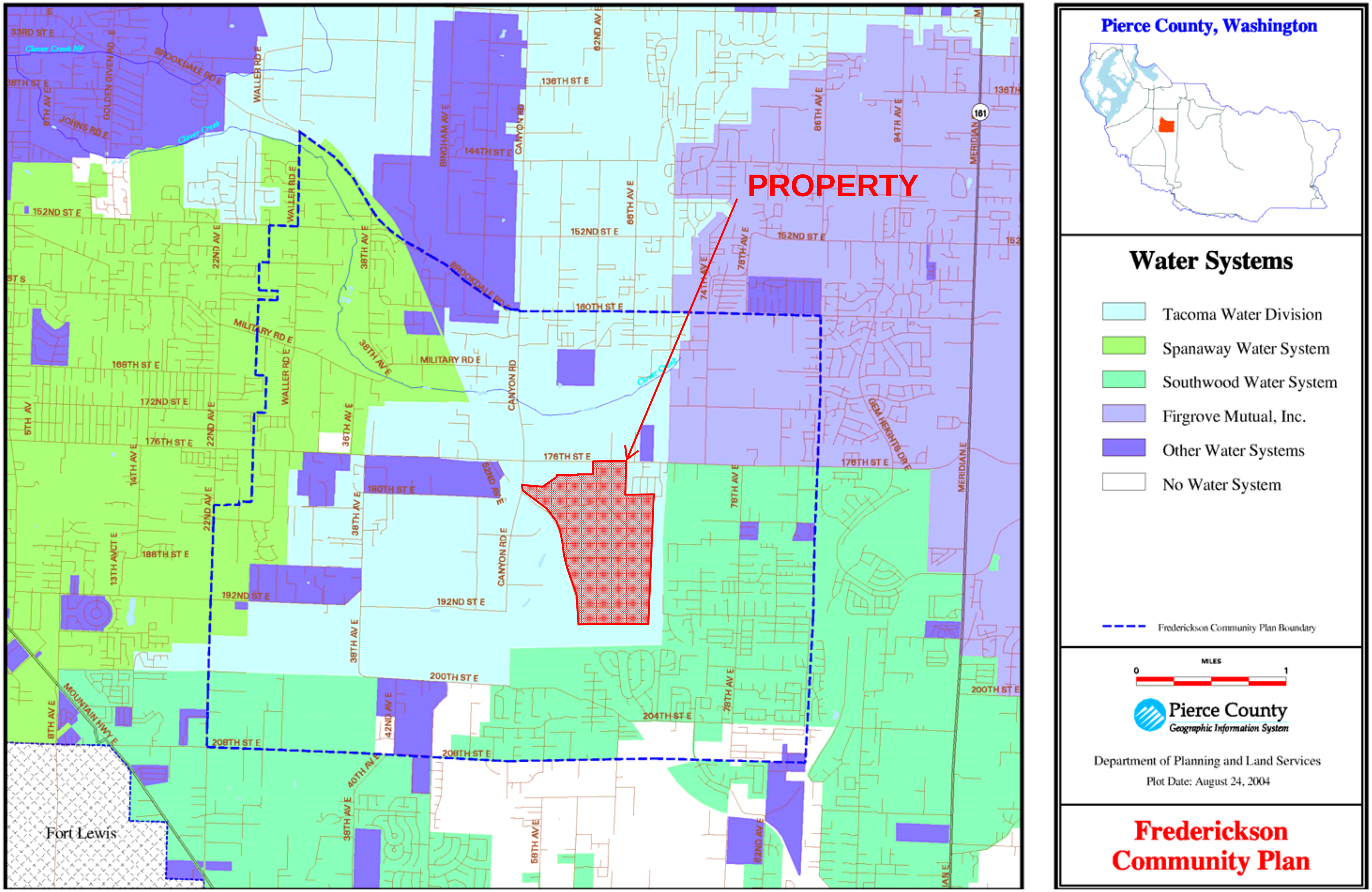
Frederickson Community Plan

Land Use Designations

Fredrickson Industrial Park
Fredrickson, Washington

Geosyntec
consultants

Kennesaw, Georgia	28 March 2012	**Figure 2-2**



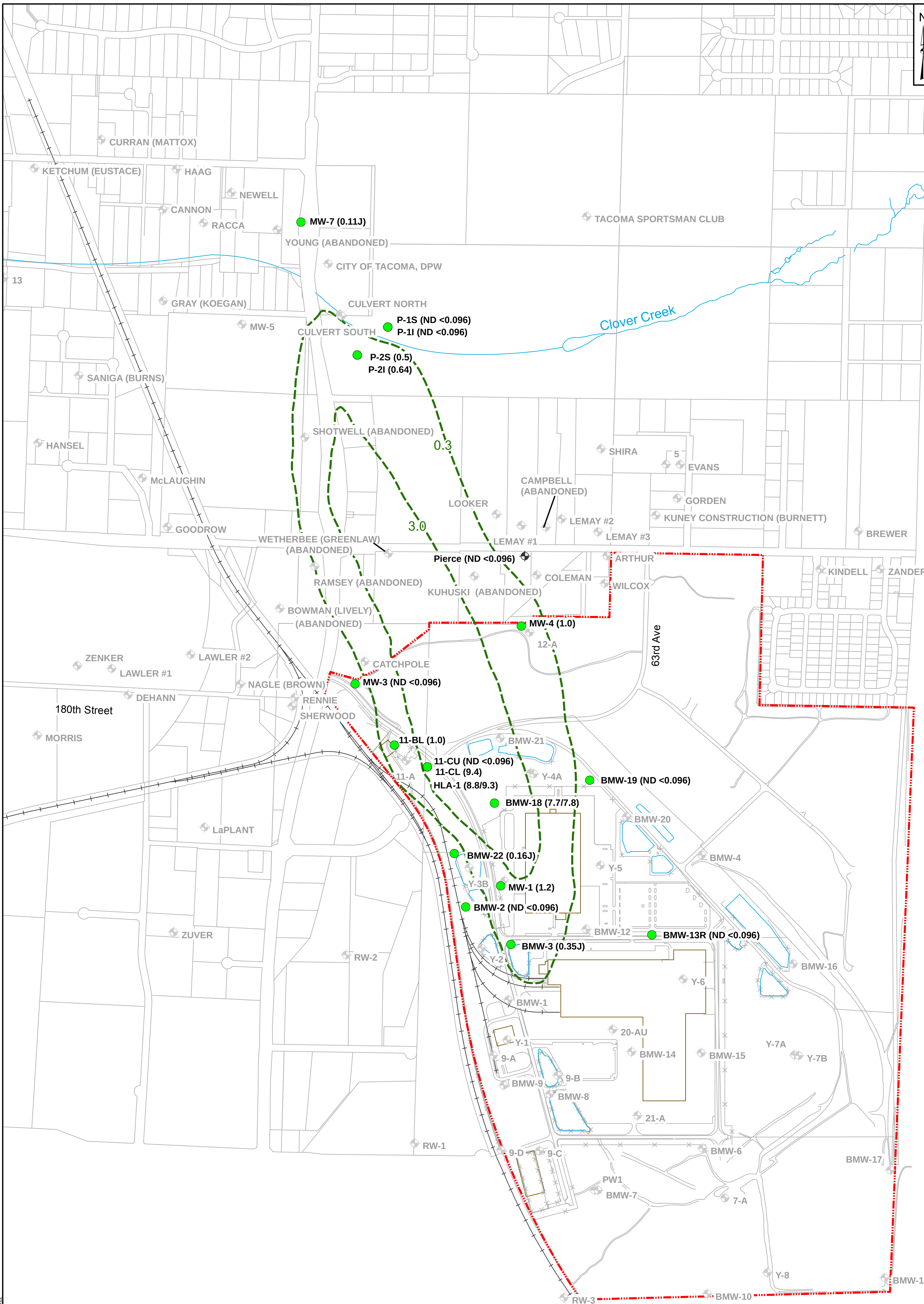
Tacoma Water Service Areas near Site

Frederickson Industrial Park
Frederickson, Washington

Geosyntec consultants

Kennesaw, Georgia | 28 March 2012

Figure 2-3



Legend

- Aquifer A Monitoring Well (CTC Concentration (µg/L))
- Private/Domestic Wells
- June 2010 CTC Contours
- Property Boundary

1,000 500 0 1,000 Feet

Aquifer A Carbon Tetrachloride Groundwater Results
June 2010

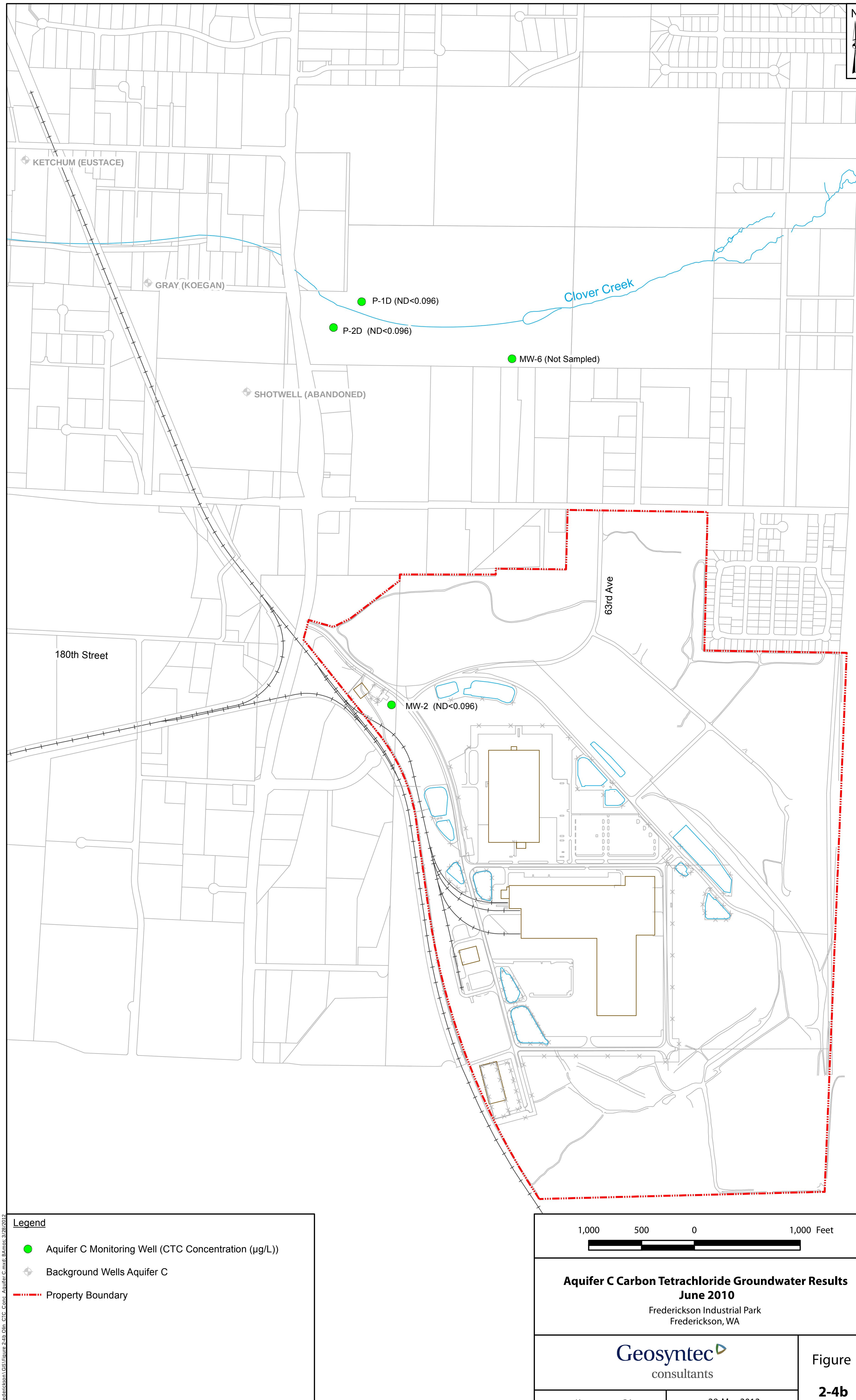
Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Figure
2-4a

Kennesaw, GA | 28-Mar-2012

N:\Fredrickson\GIS\Modified 092911\Figure 2-4a_Qin_CTC_Conc.mxd; BAmos; 3/28/2012



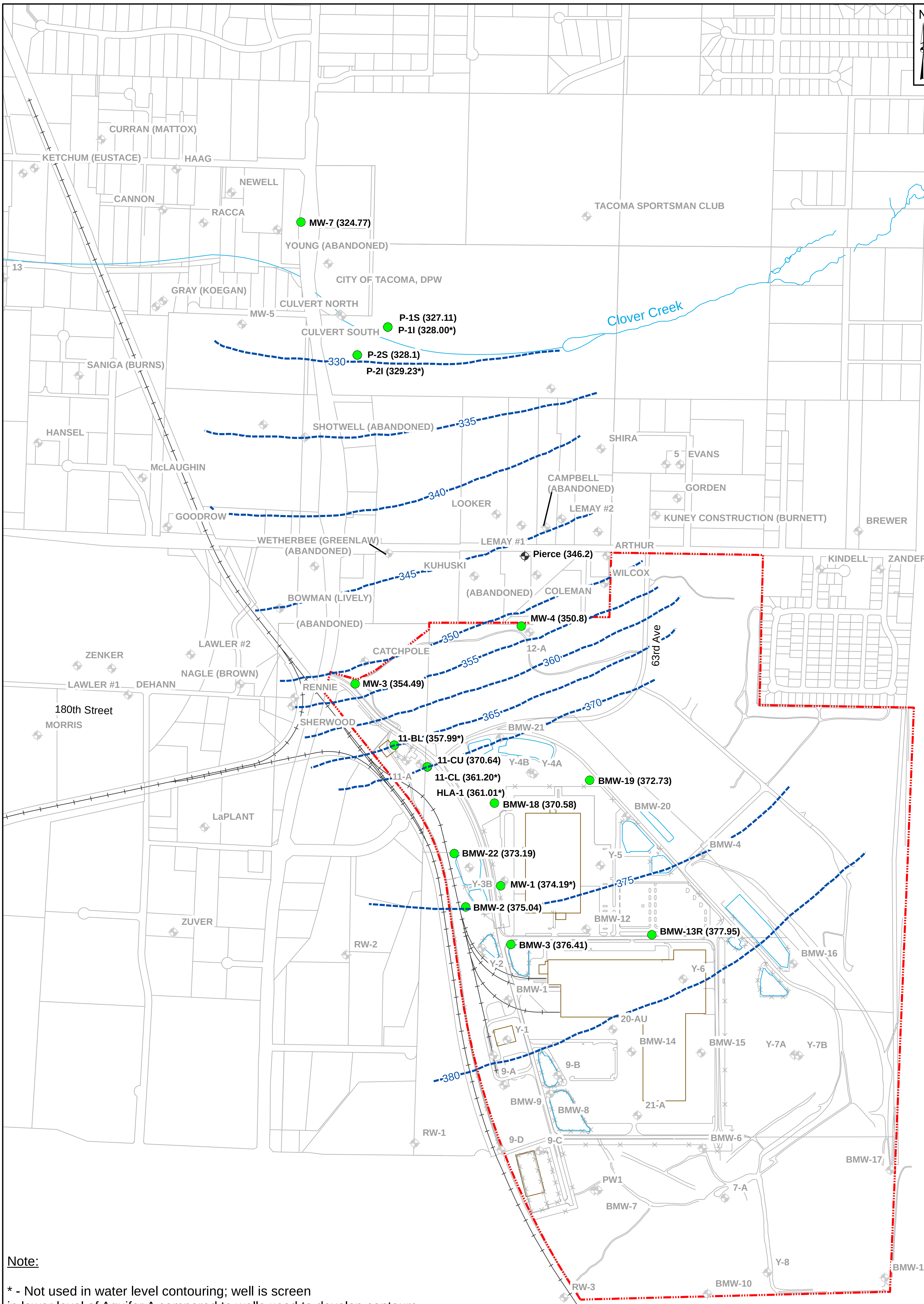
Aquifer C Carbon Tetrachloride Groundwater Results
June 2010

Fredrickson Industrial Park
Frederickson, WA

Geosyntec consultants

Kennesaw, GA | 28-Mar-2012

Figure **2-4b**



Note:

* - Not used in water level contouring; well is screen in lower level of Aquifer A compared to wells used to develop contours.

Legend

- Water Level Contours (ft masl)
- Aquifer A Monitoring Well
- Private/Domestic Wells
- Property Boundary

N:\Fredrickson\GIS\Figure 2-5 Olin_GW_Elev.mxd; BAmos; 3/28/2012

Aquifer A Groundwater Levels
June 2010

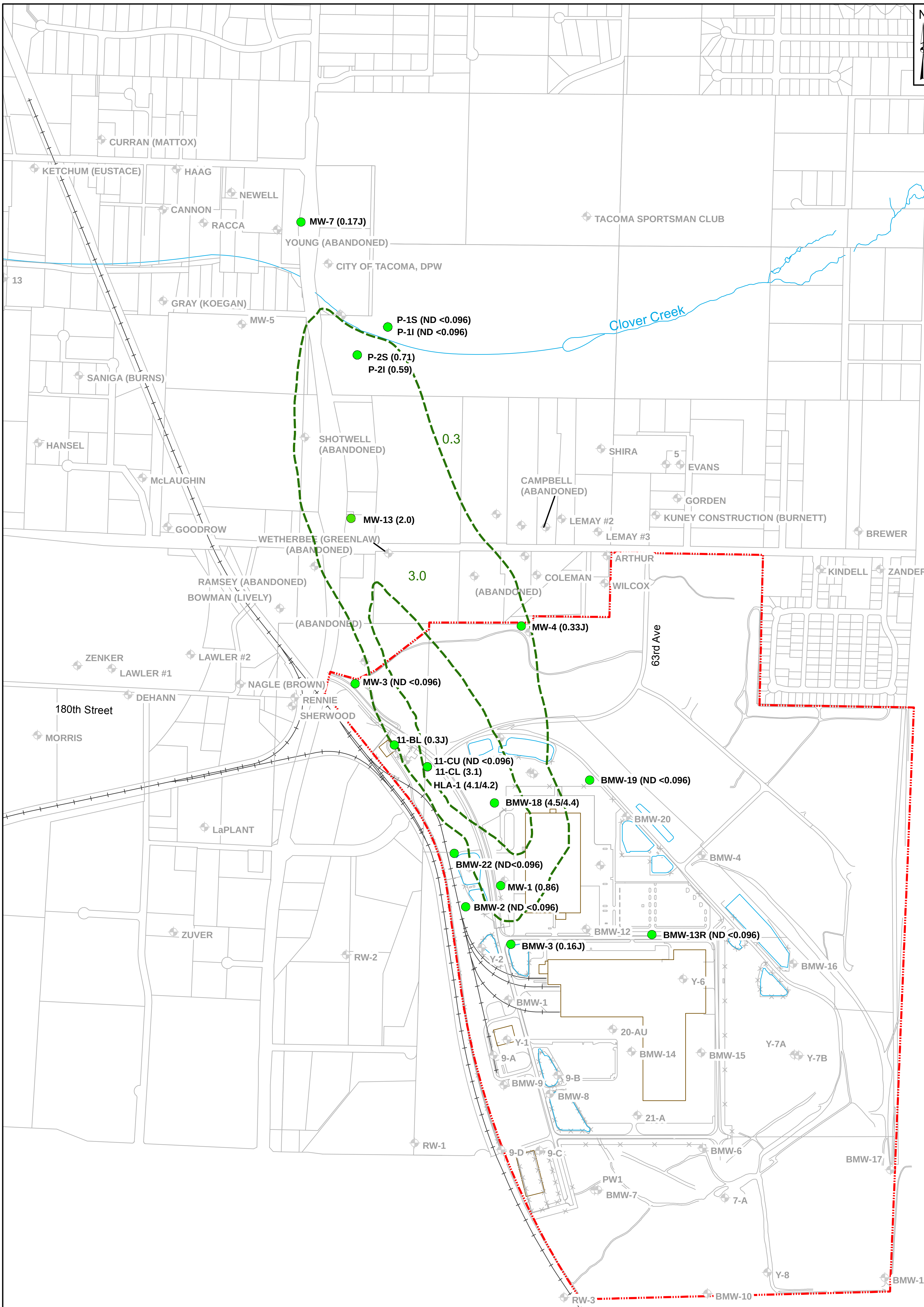
Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Figure **2-5**

Kennesaw, GA

28-Mar-2012



Legend

- Aquifer A Monitoring Well (CTC Concentration (µg/L))
- Private/Domestic Wells
- February 2011 CTC Contours
- Property Boundary

(0.17 J) The results were above the Method Detection Limit (MDL), but below the Method Reporting Limit (MRL) and thus the values are estimated (i.e., j - flagged)

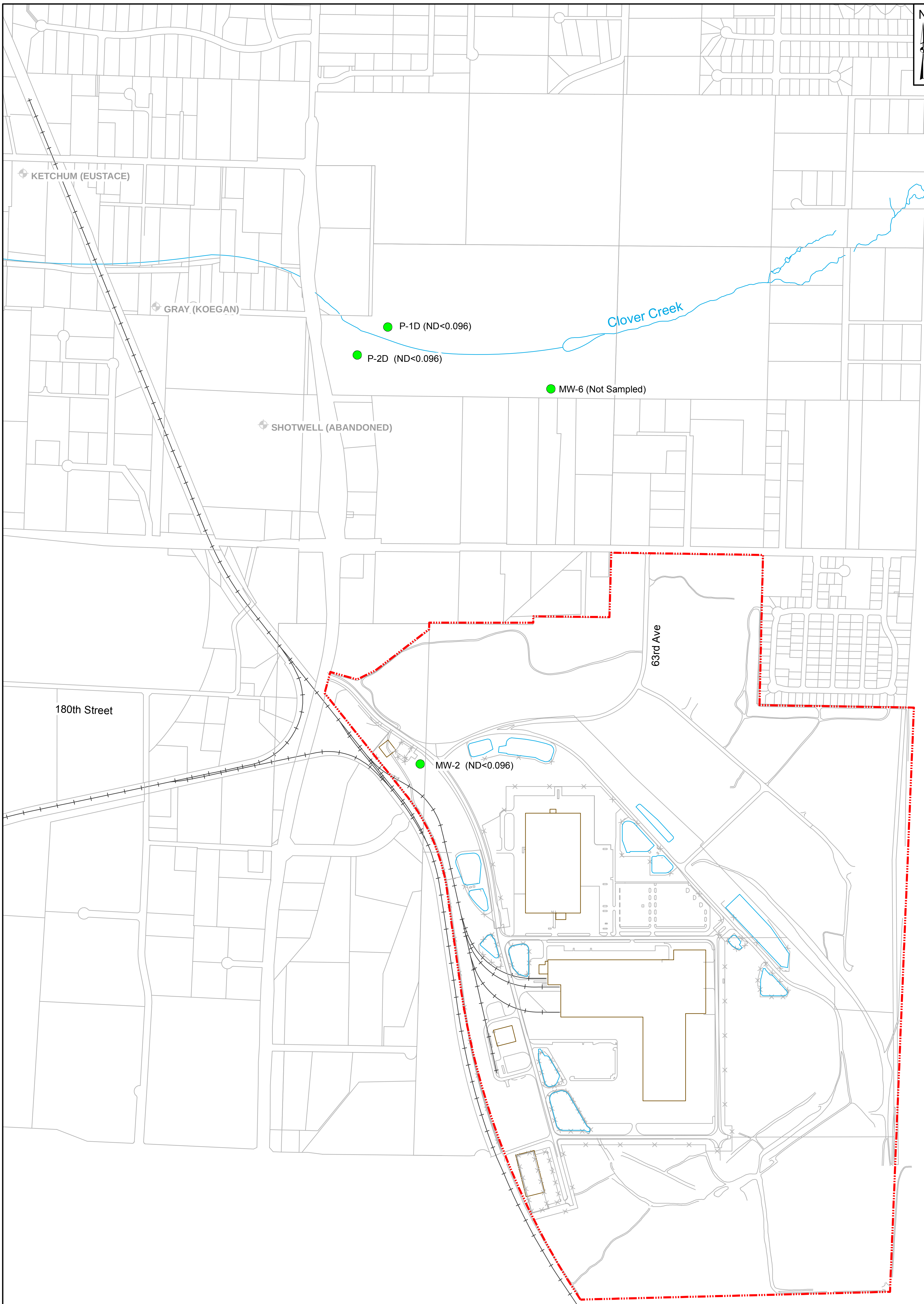
Aquifer A Carbon Tetrachloride Groundwater Results February 2011

Fredericksen Industrial Park
Fredericksen, WA

Geosyntec consultants

Kennesaw, GA | 28-Mar-2012

Figure 2-6a



Legend

- Aquifer C Monitoring Well (CTC Concentration (µg/L))
- Background Wells Aquifer C
- Property Boundary

1,000 500 0 1,000 Feet

Aquifer C Carbon Tetrachloride Groundwater Results
February 2011

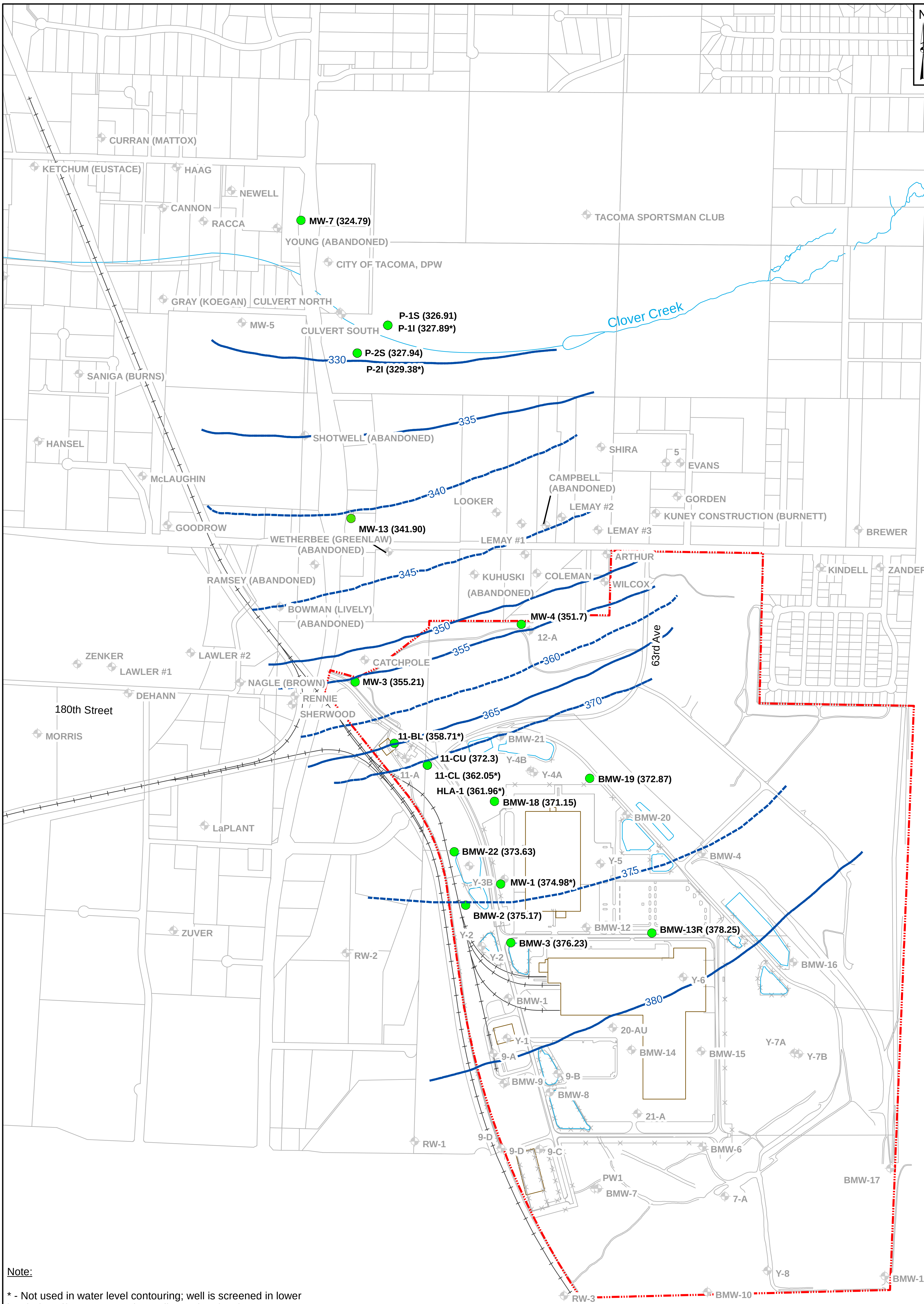
Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Kennesaw, GA | 28-Mar-2012

Figure **2-6b**

N:\Fredrickson\GIS\Figure 2-6b Olin CTC Conc Aquifer C.mxd; BAmos; 3/28/2012



Note:

* - Not used in water level contouring; well is screened in lower level of Aquifer A compared to wells used to develop contours.

Legend

- Water Level Contours (ft masl)
- Aquifer A Monitoring Well
- Private/Domestic Wells
- Property Boundary

1,000 500 0 1,000 Feet

Aquifer A Groundwater Levels
February 2011

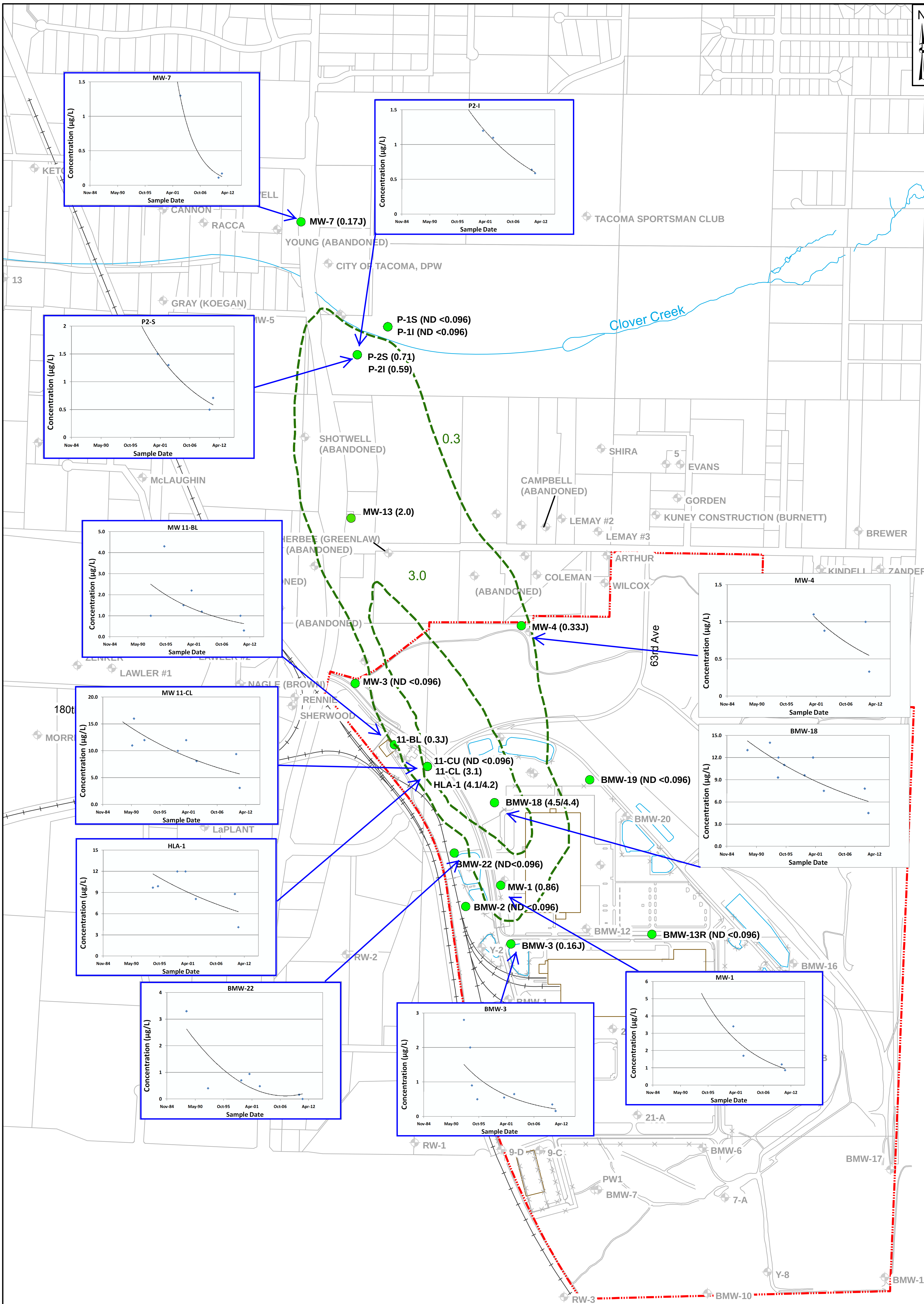
Fredericksonn Industrial Park
Frederickson, WA

Geosyntec consultants

Kennesaw, GA | 28-Mar-2012

Figure **2-7**

N:\Frederickson\GIS\Figure 2-7 Oln_GW_Elev_Feb_2011.mxd BAmos; 3/28/2012



Legend

- Aquifer A Monitoring Well (CTC Concentration (µg/L))
- Private/Domestic Wells
- February 2011 CTC Contours
- Property Boundary

(0.17 J) The results were above the Method Detection Limit (MDL), but below the Method Reporting Limit (MRL) and thus the values are estimated (i.e., j - flagged)

N:\Frederickson\GIS\Figure 2-8_Time_Trends_Feb_2011.mxd BAmos 3/28/2012

1,000 500 0 1,000 Feet

Concentration Trends for Carbon Tetrachloride
February 2011

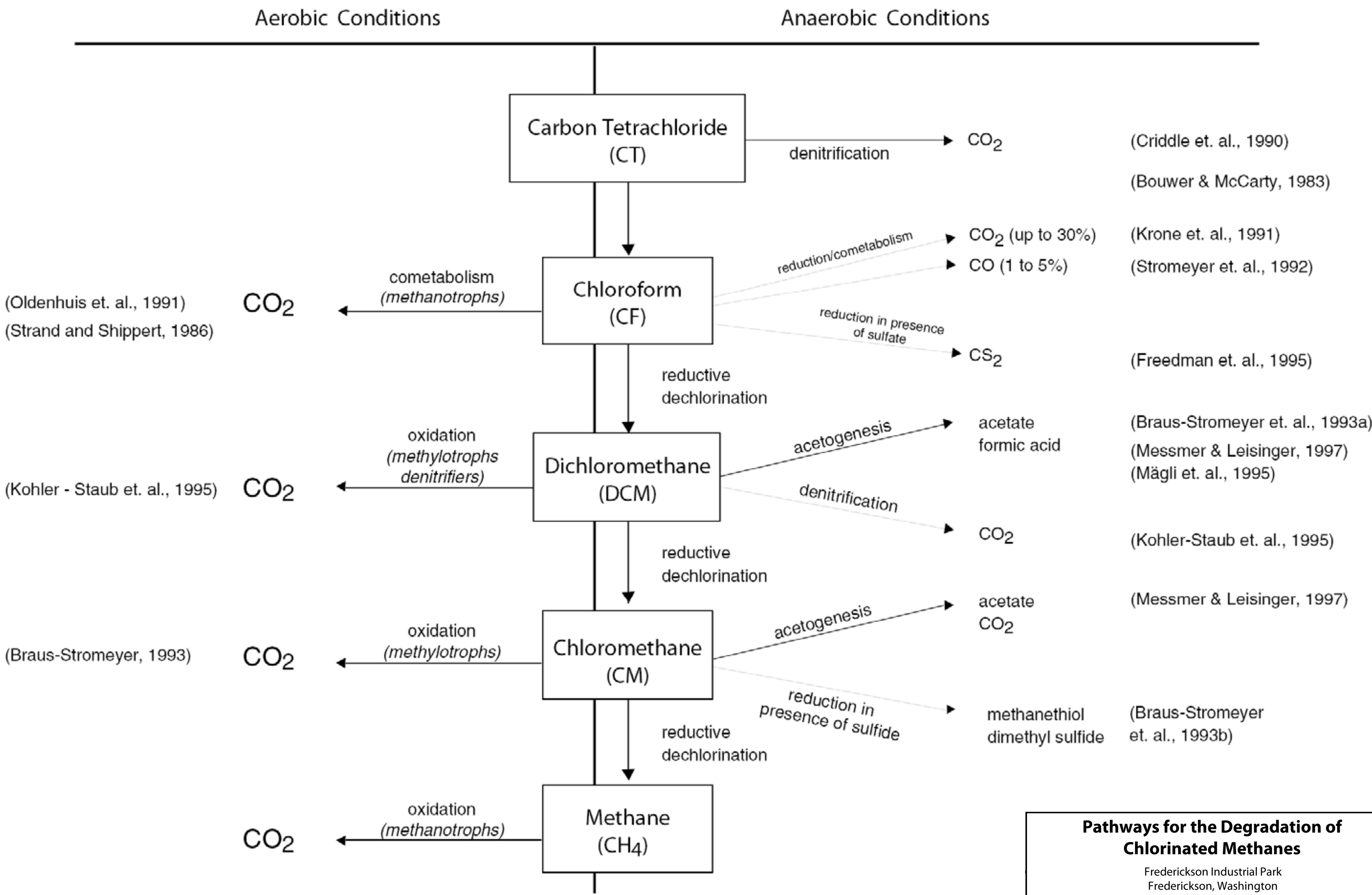
Frederickson Industrial Park
Frederickson, WA

Geosyntec consultants

Kennesaw, GA

28-Mar-2012

Figure **2-8**



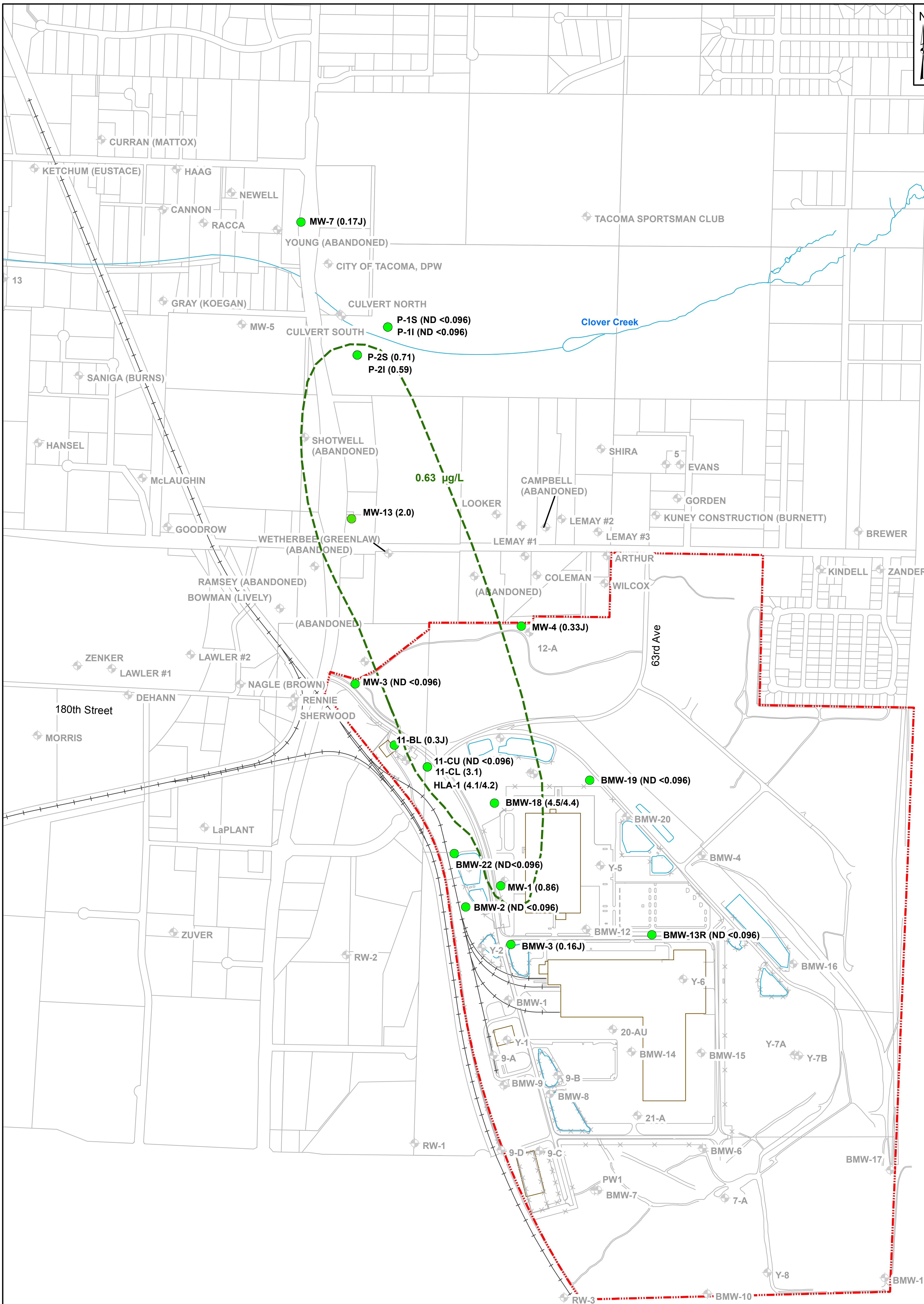
Pathways for the Degradation of Chlorinated Methanes

Frederickson Industrial Park
Frederickson, Washington

Geosyntec consultants

Kennesaw, Georgia | 28 March 2012

Figure 2-9



Legend

- Aquifer A Monitoring Well (CTC Concentration (µg/L))
- Private/Domestic Wells
- CTC Contour of 0.63 µg/L
- Property Boundary

(0.17 J) The results were above the Method Detection Limit (MDL), but below the Method Reporting Limit (MRL) and thus the values are estimated (i.e., j - flagged)

N:\Frederickson\GIS\Figure 3-1.mxd; BAmos; 3/28/2012

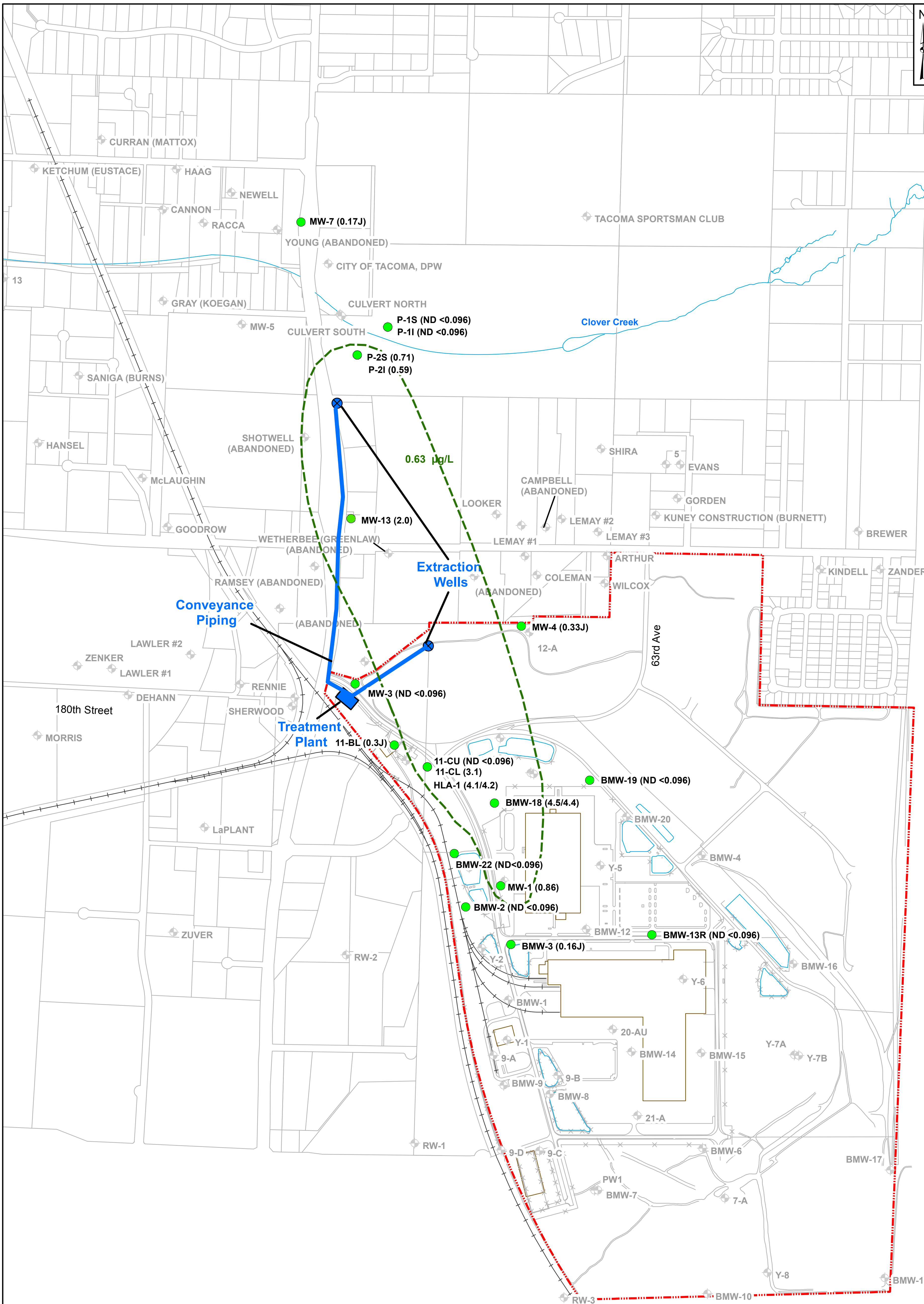
Groundwater Area Above Carbon Tetrachloride Cleanup Level

Fredrickson Industrial Park
Frederickson, WA

Geosyntec consultants

Figure 3-1

Kennesaw, GA | 28-Mar-2012



Legend

- Aquifer A Monitoring Well (CTC Concentration (µg/L))
- Private/Domestic Wells
- CTC Contour of 0.63 µg/L
- Property Boundary

(0.17 J) The results were above the Method Detection Limit (MDL), but below the Method Reporting Limit (MRL) and thus the values are estimated (i.e., j - flagged)

1,000 500 0 1,000 Feet

Conceptual Layout for Alternative 2

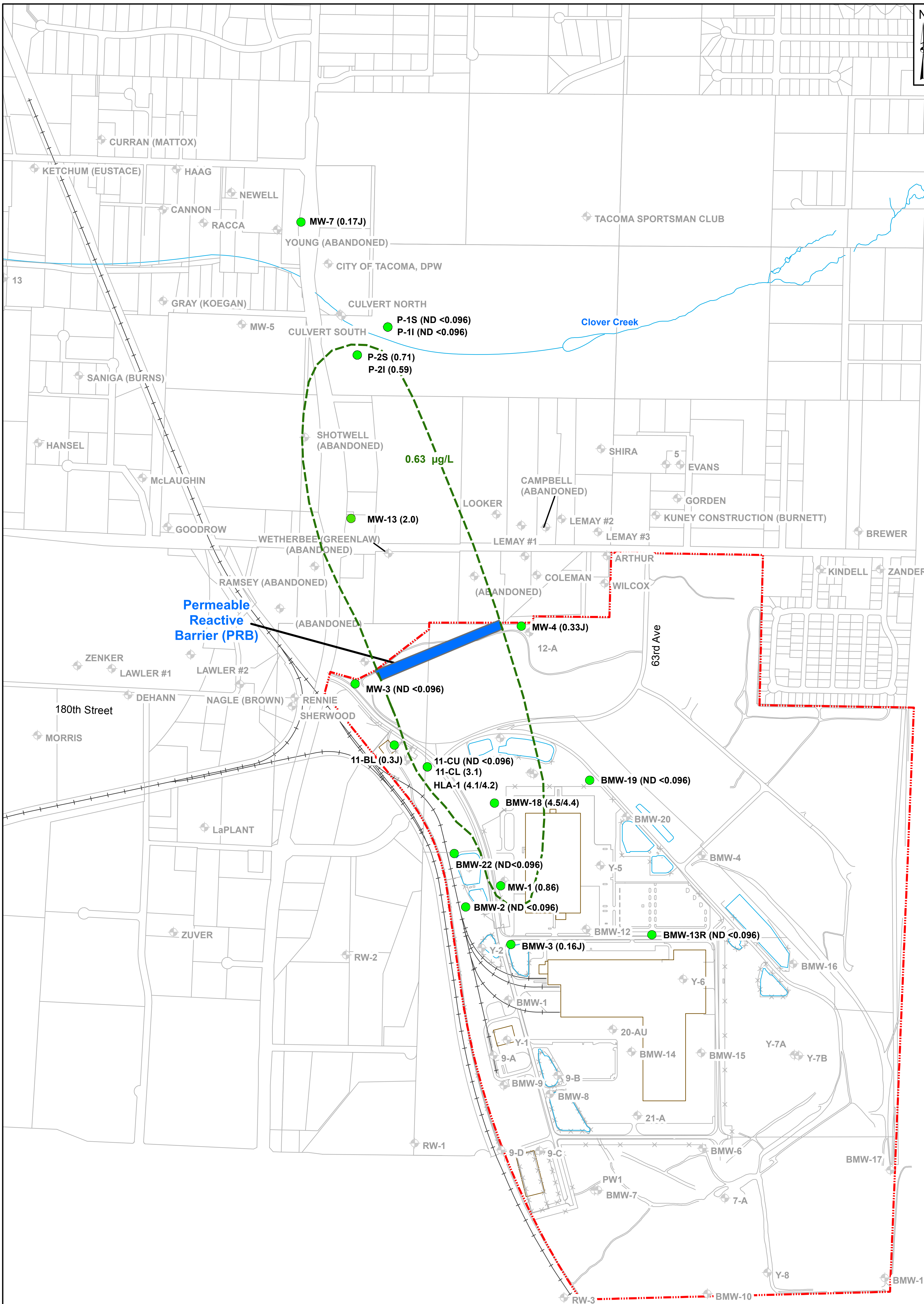
Fredericksson Industrial Park
Frederickson, WA

Geosyntec consultants

Figure 5-1

Kennesaw, GA | 28-Mar-2012

N:\Frederickson\GIS\Figure 5-1.mxd; BAmos; 3/28/2012



Legend

- Aquifer A Monitoring Well (CTC Concentration (µg/L))
- Private/Domestic Wells
- CTC Contour of 0.63 µg/L
- Property Boundary

(0.17 J) The results were above the Method Detection Limit (MDL), but below the Method Reporting Limit (MRL) and thus the values are estimated (i.e., j - flagged)

1,000 500 0 1,000 Feet

Conceptual Layout for Alternative 3

Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Kennesaw, GA

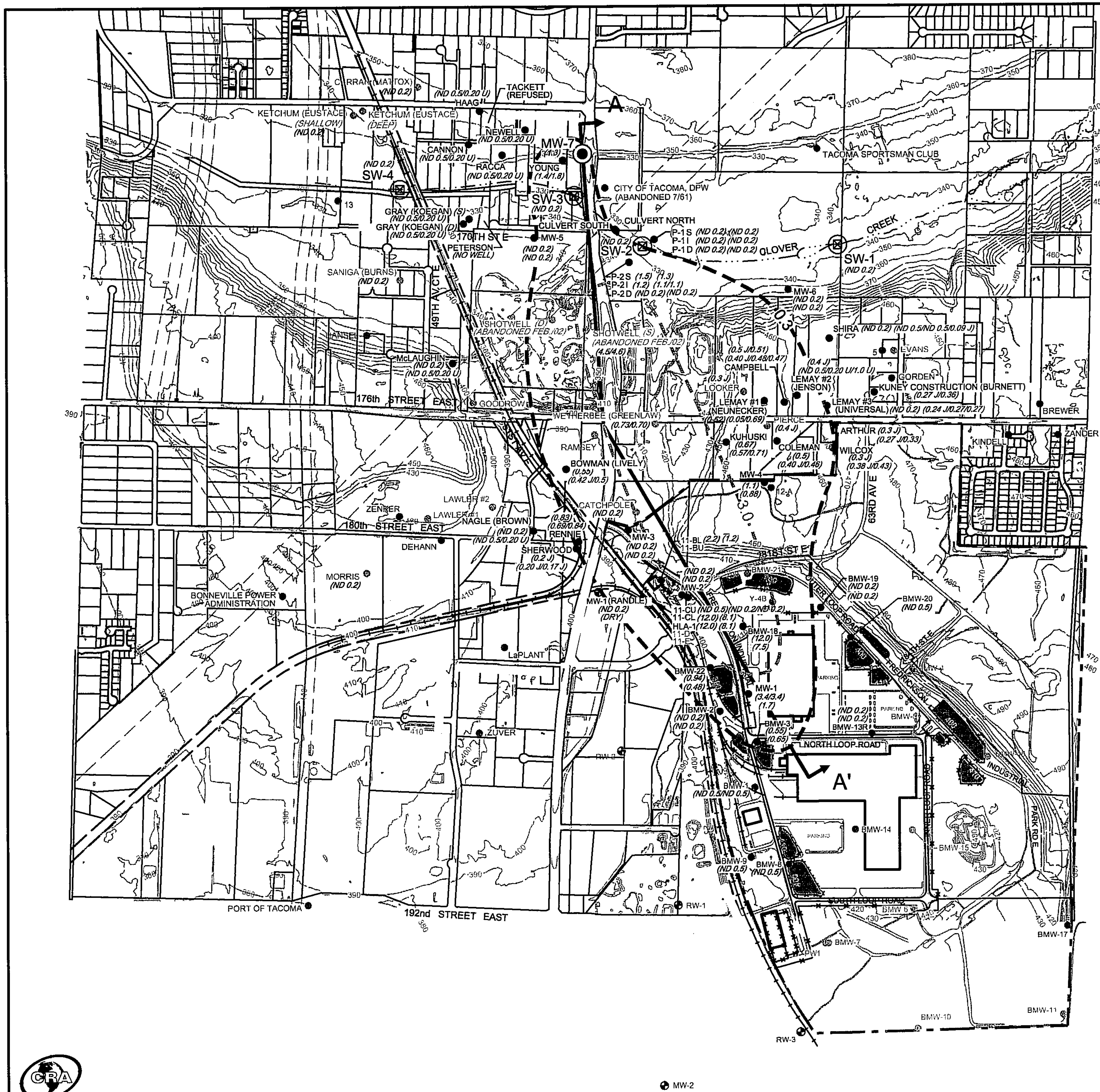
28-Mar-2012

Figure 5-2

N:\Fredrickson\GIS\Figure 5-2.mxd; BAmos; 3/28/2012

APPENDIX A

HISTORIC FIGURES & TABLES



0 600 1200ft

LEGEND

PROPERTY BOUNDARY

PRESETTLING OR INFILTRATION BASIN

BMW-17 — ON-SITE MONITORING WELL

BMW-7 — ON-SITE MONITORING WELL SECOND ROUND SAMPLING LOCATION

RW-1 — RANDLE WELL LOCATION

MW-1 (RANDLE) — RANDLE WELL LOCATION THIRD ROUND SAMPLING LOCATION

BROWN — WELL LOCATION AND RESIDENT

LEMAY #1 (NEUNECKER) — WELL LOCATION AND RESIDENT THIRD ROUND SAMPLING LOCATION

CURRENT RESIDENT OR OWNER

MW-7 — RECENTLY COMPLETED ADDITIONAL MONITORING WELL (OCTOBER 2002)

SW-1 — SURFACE WATER THIRD ROUND SAMPLING LOCATION

(ND 0.5) — APRIL 1999 CTC CONCENTRATION (ppb)

(ND 0.5) — NOVEMBER 2000 CTC CONCENTRATION (ppb) 2nd ROUND GROUNDWATER SAMPLING

(ND 0.5/0.20 U) — NOVEMBER 2002 CTC CONCENTRATION (ppb) 3rd ROUND GROUNDWATER SAMPLING (CRA / DOE) RESULTS

CATCHPOLE, LOOKER, LEMAY - AND WETHERBEE SUPPLIED WITH PUBLIC WATER PRIOR TO 3rd ROUND SAMPLING.

0.3 — CARBON TETRACHLORIDE CONCENTRATION CONTOUR (0.3 ppb) (NOV. 2002)

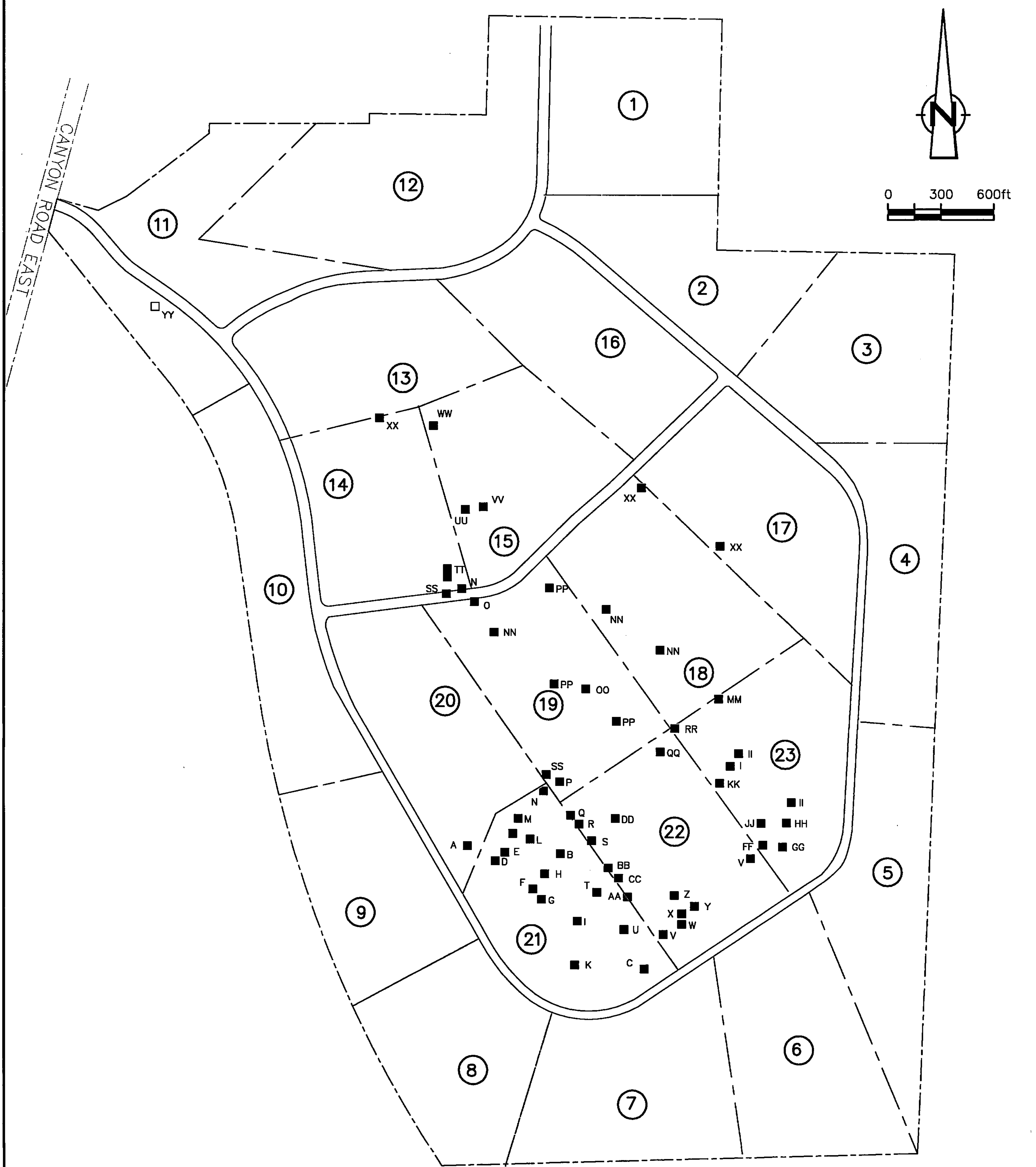
3.0 — CARBON TETRACHLORIDE CONCENTRATION CONTOUR (3.0 ppb) (NOV. 2002)

A — CROSS-SECTION LOCATION

figure 2

CTC ANALYTICAL DATA AND CROSS-SECTION LOCATION
RI/FS 3rd ROUND MONITORING PROGRAM
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

06578-00(WARR034)GN-WA005 MAR 27/2003



LEGEND

A	POWDER LOADING SPOT
B	WAREHOUSE
C	SKIDS
D	GLYCERINE STORAGE TANKS
E	GLYCERINE TREATING HOUSE
F	POWER HOUSE
G	BRINE HOUSE
H	STOREROOM
I	TESTING LABORATORY
J	CAP MAGAZINE
K	SHOOTING PEN
L	SULPHUR HOUSE
M	GARAGE
N	PARAFFIN STORAGE
O	WASTE HOUSE
P	SHELL HOUSE
Q	CHANGE HOUSE
R	LAUNDRY
S	BAG HOUSE
T	SODA HOUSE
U	AMMONIA WAREHOUSE
V	MIXED ACID STORAGE TANK
W	SULFURIC ACID STORAGE TANK
X	AMMONIA NEUT. HOUSE
Y	ACID TAMK & ACID RECOVERY
Z	AMMONIA CRYST. HOUSE
AA	SOLVENT STORAGE
BB	LABORATORY
CC	DOG KENNELS
DD	DOPE HOUSE
EE	40,000 GALLON WATER TANK
FF	MIXED ACID WEIGH SCALES
GG	GLYCERINE HEATER HOUSE
HH	WASTE ACID HOUSE
II	SLUM HOUSE
JJ	NITRATOR
KK	N.G. STORAGE
LL	N.G. BUGGY WALK
MM	GELATIN MIX HOUSE
NN	GELATIN MACHINE PACK HOUSE
OO	PARTS HOUSE
PP	DYNAMITE MACHINE PACK HOUSE
QQ	DYNAMITE MIX HOUSE
RR	COTTON DRY HOUSE
SS	PARAFFIN HEATER HOUSE
TT	BOX PACK HOUSE
UU	BOX STORAGE
VV	SAMPLE MAGAZINE
WW	FUSE MAGAZINE
XX	MAGAZINE
YY	OFFICE

■ COLUMBIA POWDER PLANT BUILDING/AREA

(4) CENTRUM DEVELOPMENT LOTS

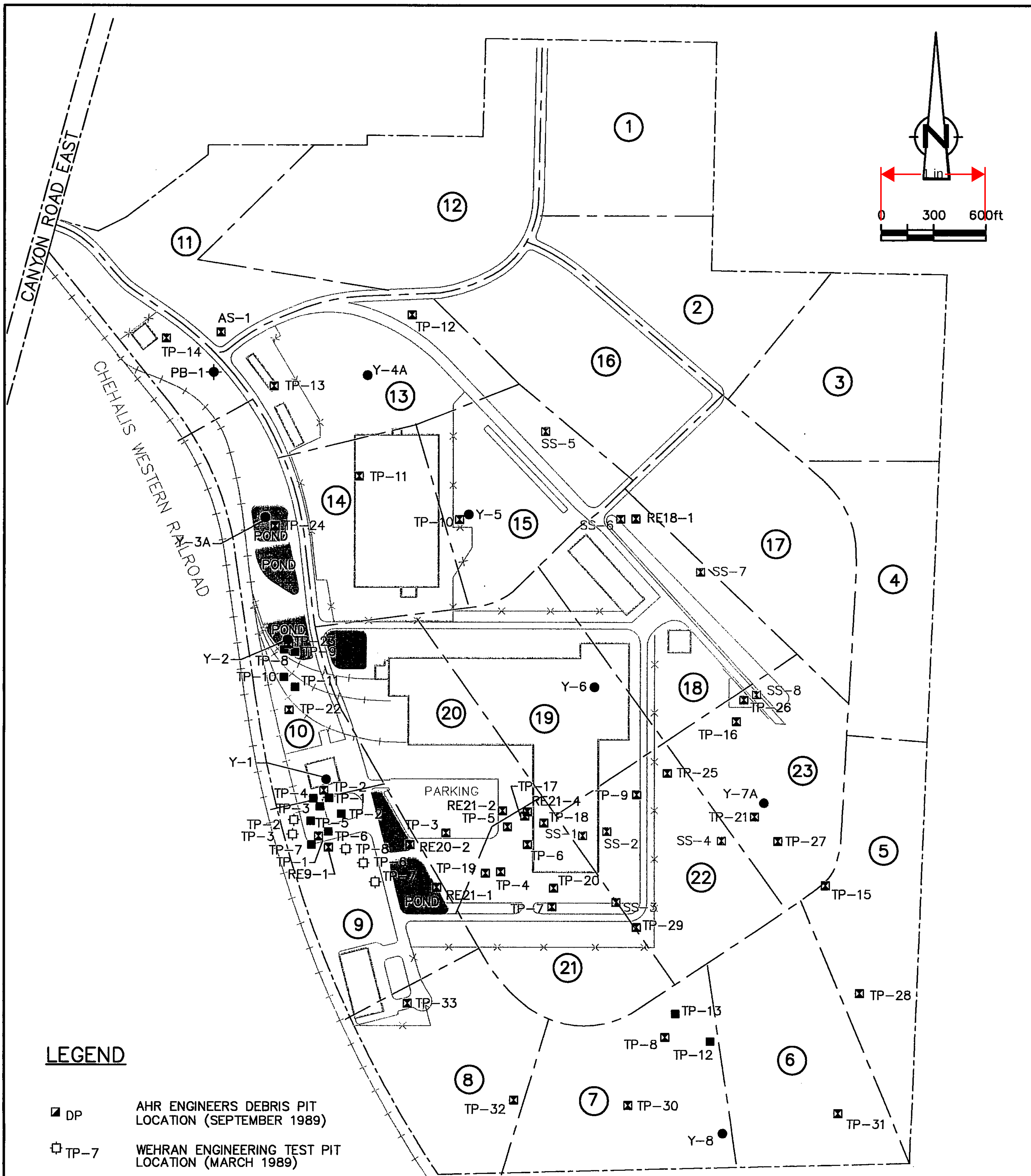
SOURCE: GEOENGINEERS 1990 AND CONVERSE 1992

figure 2.2

COLUMBIA POWDER PLANT LAYOUT/
CENTRUM DEVELOPMENT PLAN
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

6578 (2) JULY 10/97(W) REV.0 (P-42)



LEGEND

DP	AHR ENGINEERS DEBRIS PIT LOCATION (SEPTEMBER 1989)
TP−7	WEHRAN ENGINEERING TEST PIT LOCATION (MARCH 1989)
TP−3	AHR ENGINEERING TEST PIT LOCATION (SEPTEMBER 1989)
RE21−8 AS−1 SS−17	GEOENGINEERS TEST PIT AND SURFACE SOIL LOCATION (JANUARY 1991)
PB1	HARDING LAWSON ASSOCIATES BOREHOLE LOCATION (JULY 1994)
TP−10	GEOENGINEERS TEST PIT LOCATION (AUGUST 1990)
Y−7B	GEOENGINEERS SOIL BORING LOCATION (AUGUST 1990)
SS−3	GEOENGINEERS SURFACE SOIL LOCATION (AUGUST 1990)

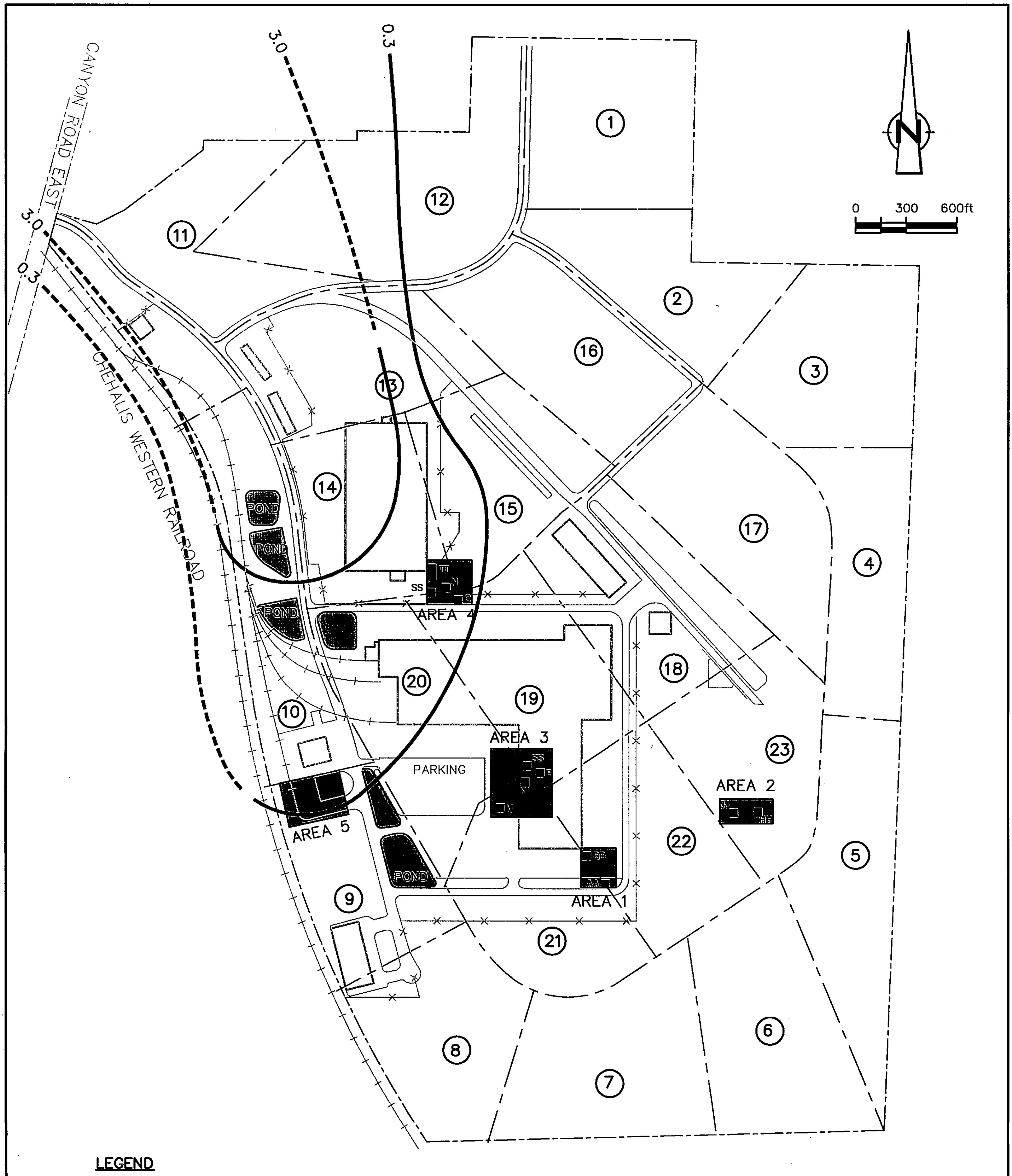
NOTE: ALL CTC SOIL CONCENTRATIONS ARE BELOW THE METHOD DETECTION LIMIT

figure 2.5

HISTORICAL CTC SOIL SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

6578 (2) JULY 10/97(W) REV.0 (P−19)



LEGEND

M GARAGE
N PARAFFIN STORAGE
O WASTE HOUSE
P SHELL HOUSE
AA SOLVENT STORAGE
BB LABORATORY
HH WASTE ACID HOUSE
JJ NITRATOR
SS PARAFFIN HEATER HOUSE
TT BOX PACK HOUSE

■ BUILDING/AREA LIKELY TO HAVE USED OR STORED CARBON TETRACHLORIDE

(7) CENTRUM DEVELOPMENT LOTS

POTENTIAL HISTORIC CTC SOURCE AREA TO BE INVESTIGATED

—3.0— CARBON TETRACHLORIDE CONCENTRATION CONTOUR (ppb)

figure 4.2

POTENTIAL HISTORIC CTC SOURCE AREAS
TO BE INVESTIGATED
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

6578 (2) JULY 10/97(W) REV.0 (P-43)

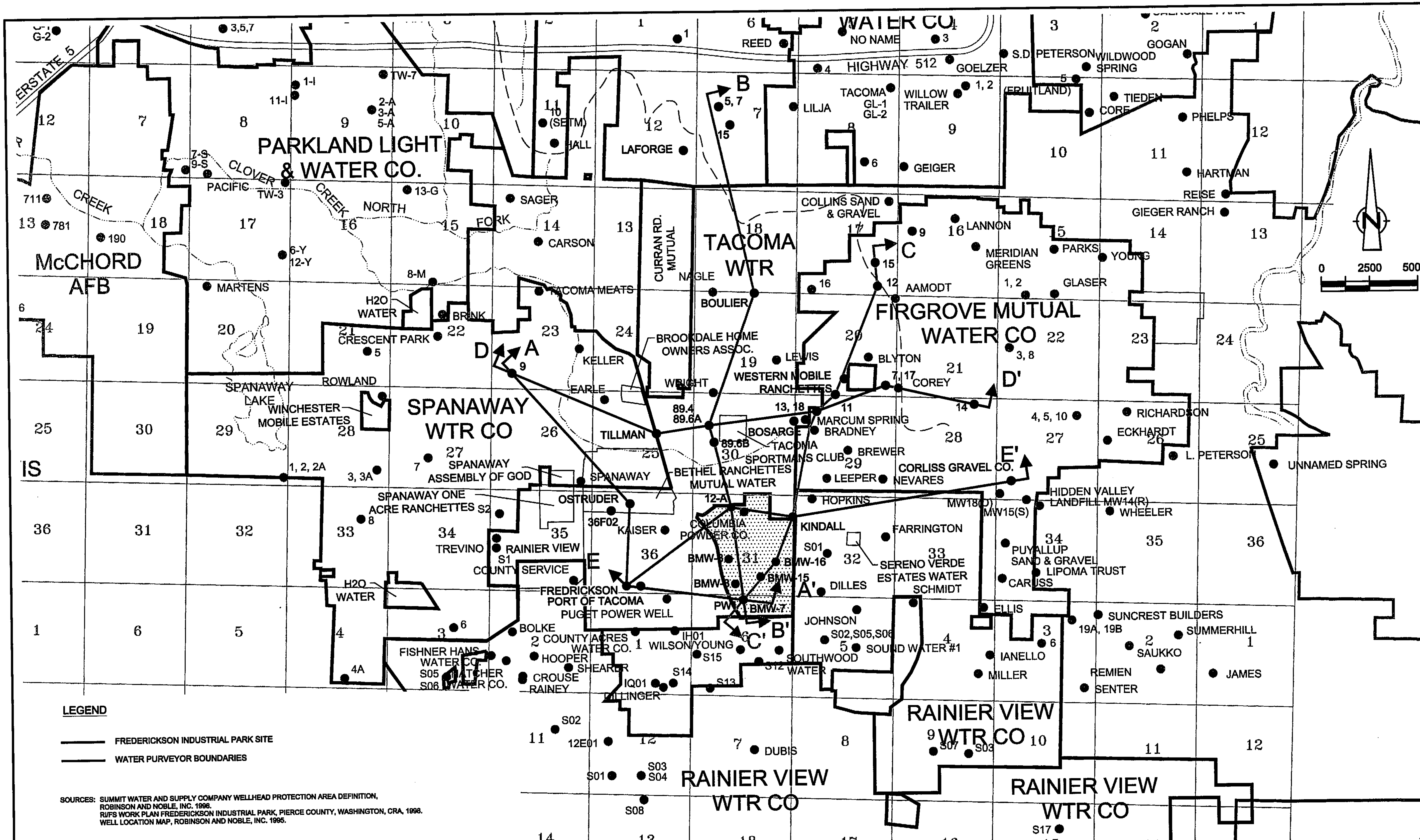
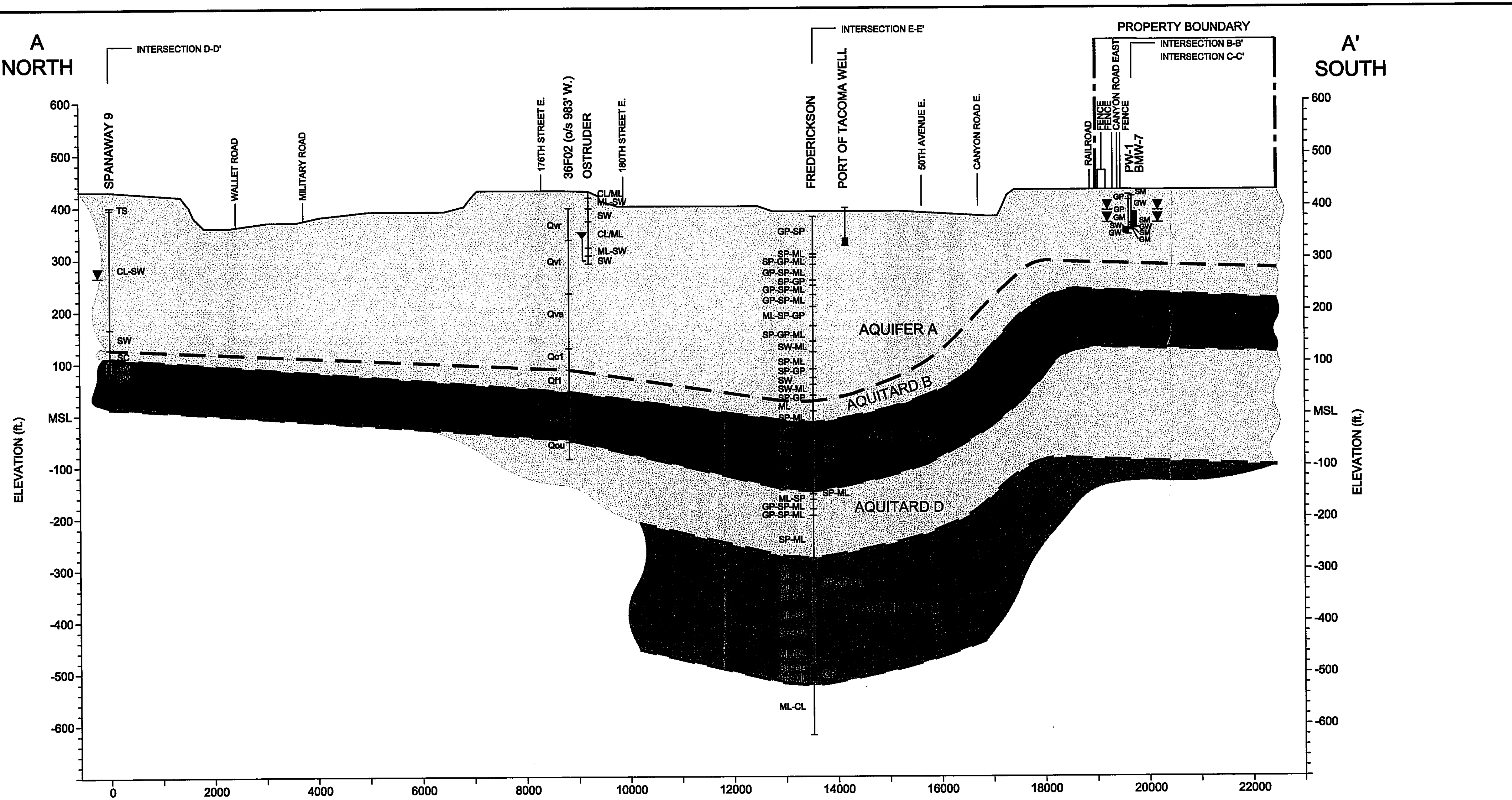


figure 3.1

CROSS-SECTION LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

06578-00(006)GN-WA017 FEB 18/2000



LEGEND

- MASELLA — WELL NAME
- 6,1 — LITHOLOGY IDENTIFIER
- SCREENED INTERVAL
- WATER TABLE ELEVATION
- POTENTIOMETRIC SURFACE ELEVATION
- INFERRED AQUIFER BOUNDARY

LITHOLOGY

GP	GRAVEL
SW	SAND AND GRAVEL
SP	SAND
ML/CL	CLAY, SILT, SAND AND GRAVEL MIX (AS TILL)
ML	SILT
CL	CLAY
SC	CLAY, SAND

NOTE: GEOLOGIC INTERPRETATION ON 36F02 PROVIDED BY TACOMA WATER DIVISION.

figure 3.2

CROSS-SECTION A-A'
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

06578-00(006)GN-WA003 FEB 18/2000

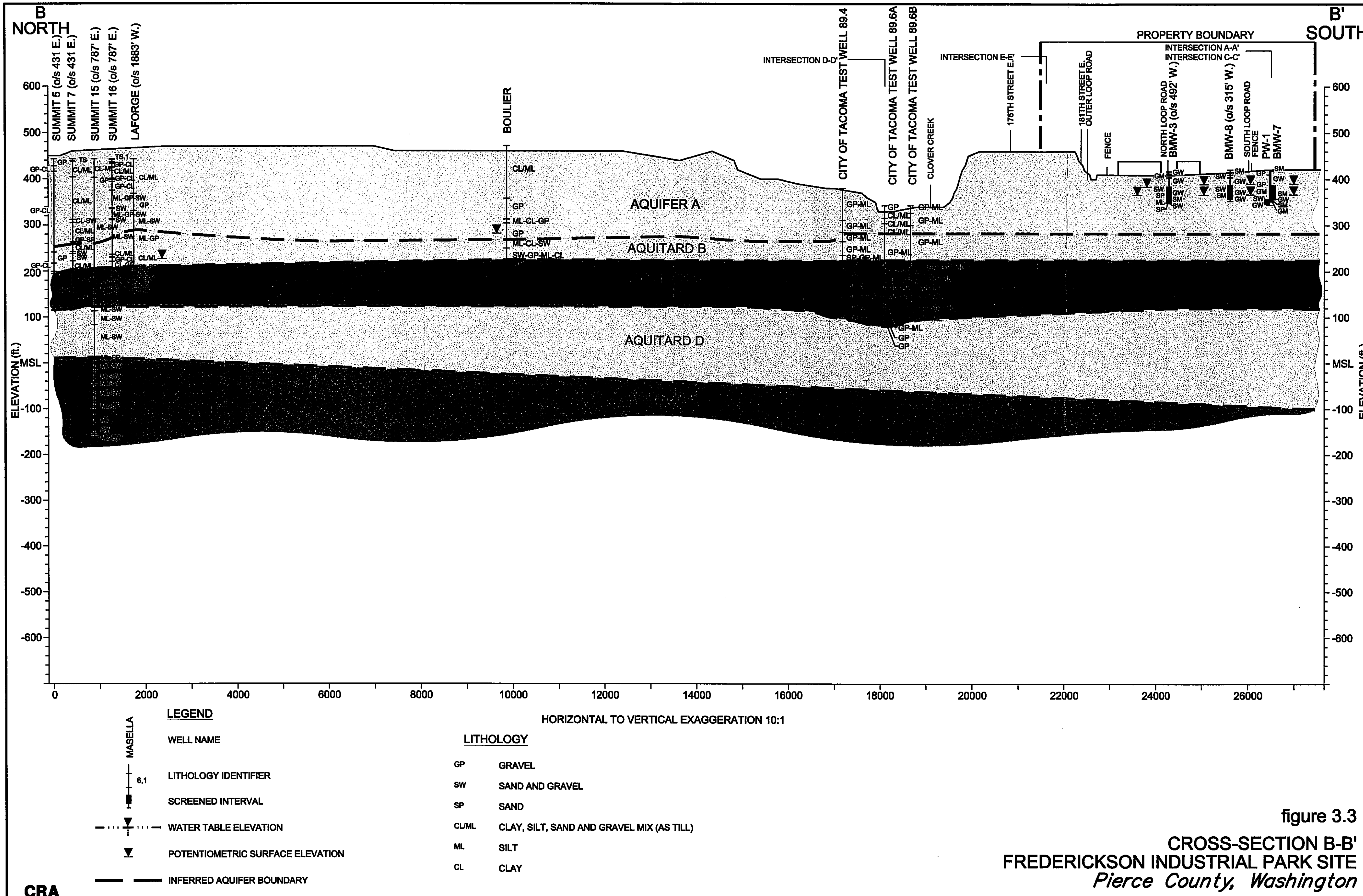


figure 3.3

CROSS-SECTION B-B'
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

06578-00(006)GN-WA004 FEB 18/2000

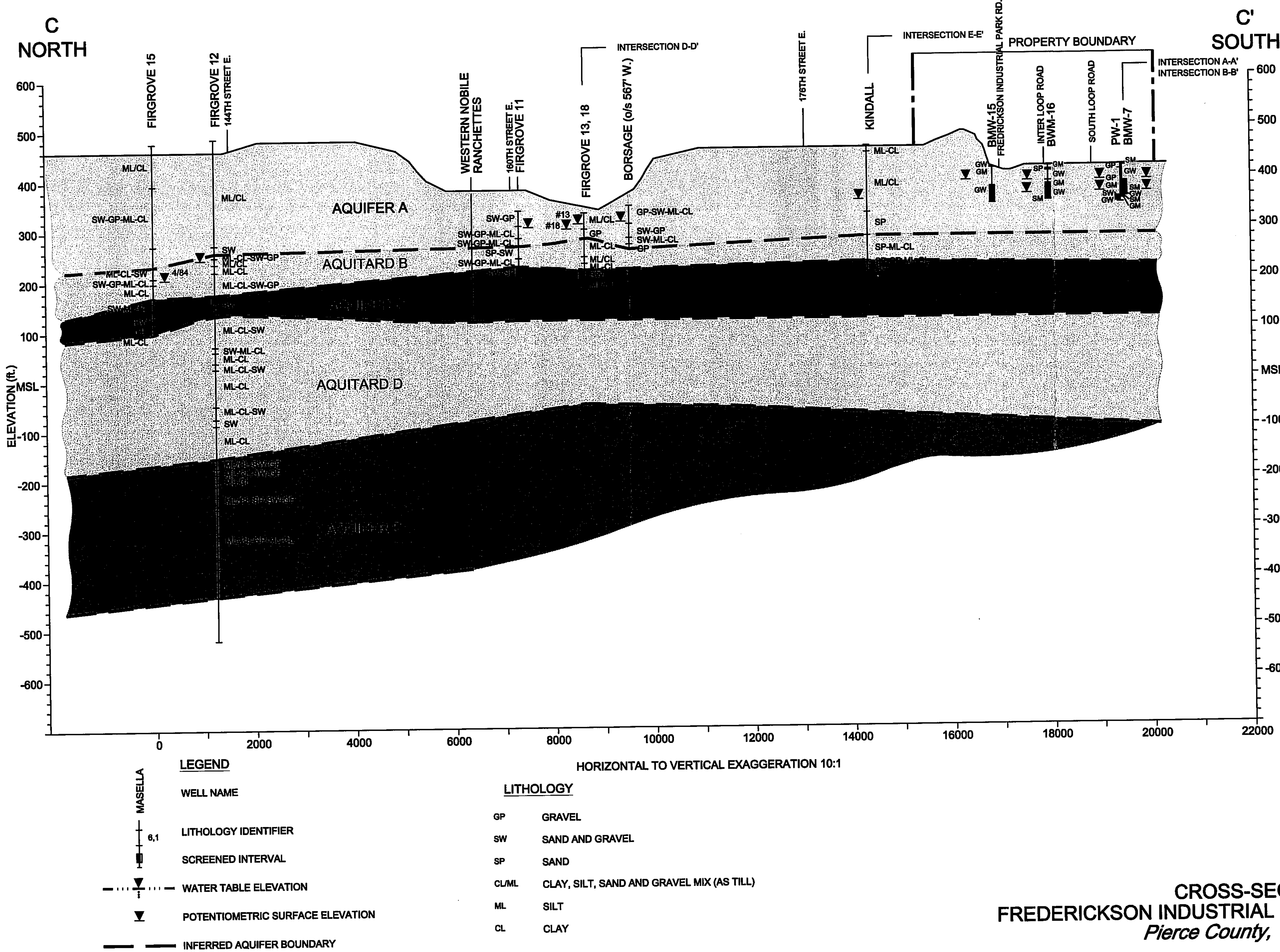
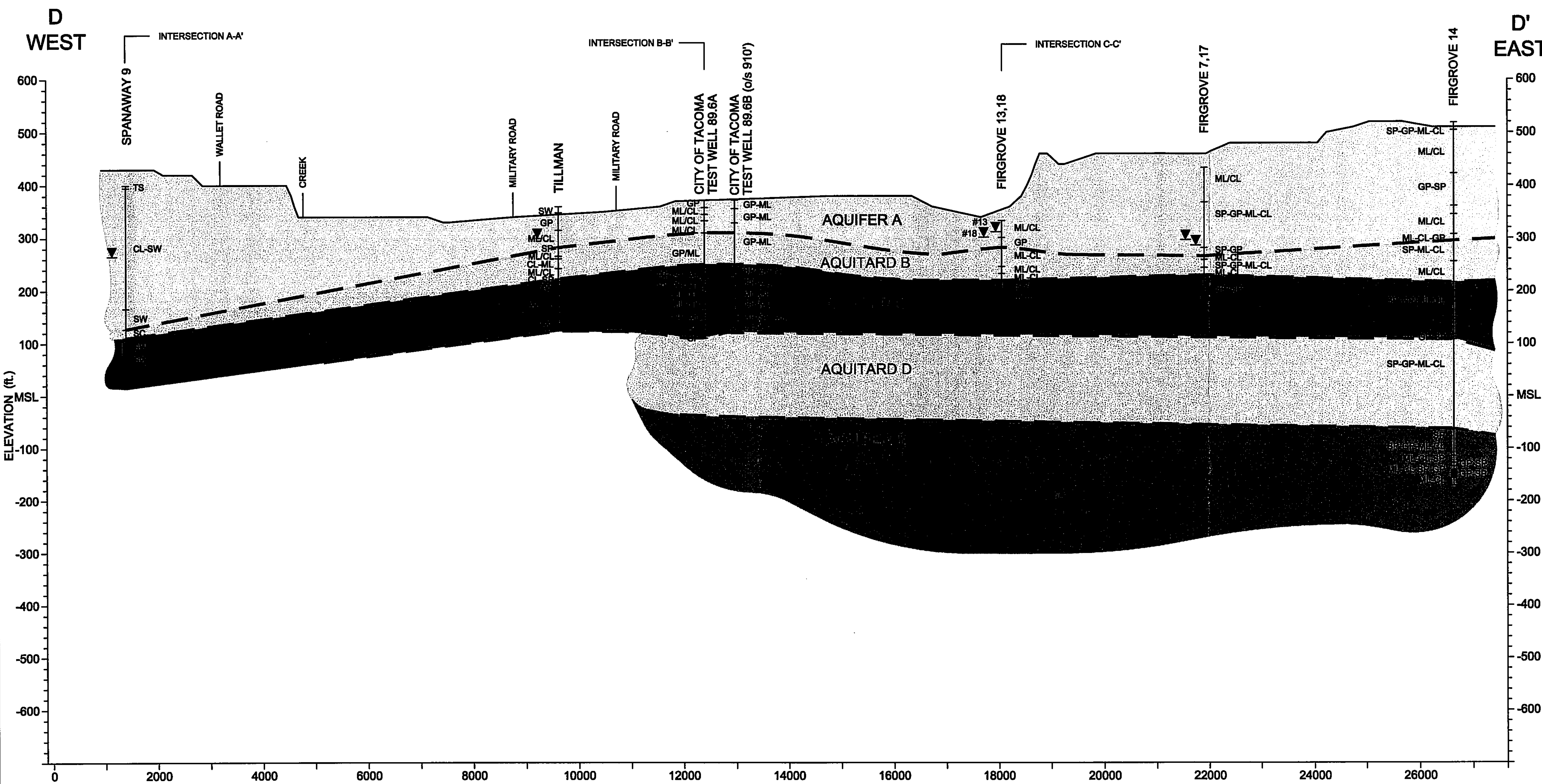


figure 3.4

CROSS-SECTION C-C'
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

06578-00(006)GN-WA005 FEB 18/2000



LEGEND

MASELLA — WELL NAME

6,1 — LITHOLOGY IDENTIFIER

SCREENED INTERVAL

WATER TABLE ELEVATION

POTENTIOMETRIC SURFACE ELEVATION

INFERRED AQUIFER BOUNDARY

LITHOLOGY

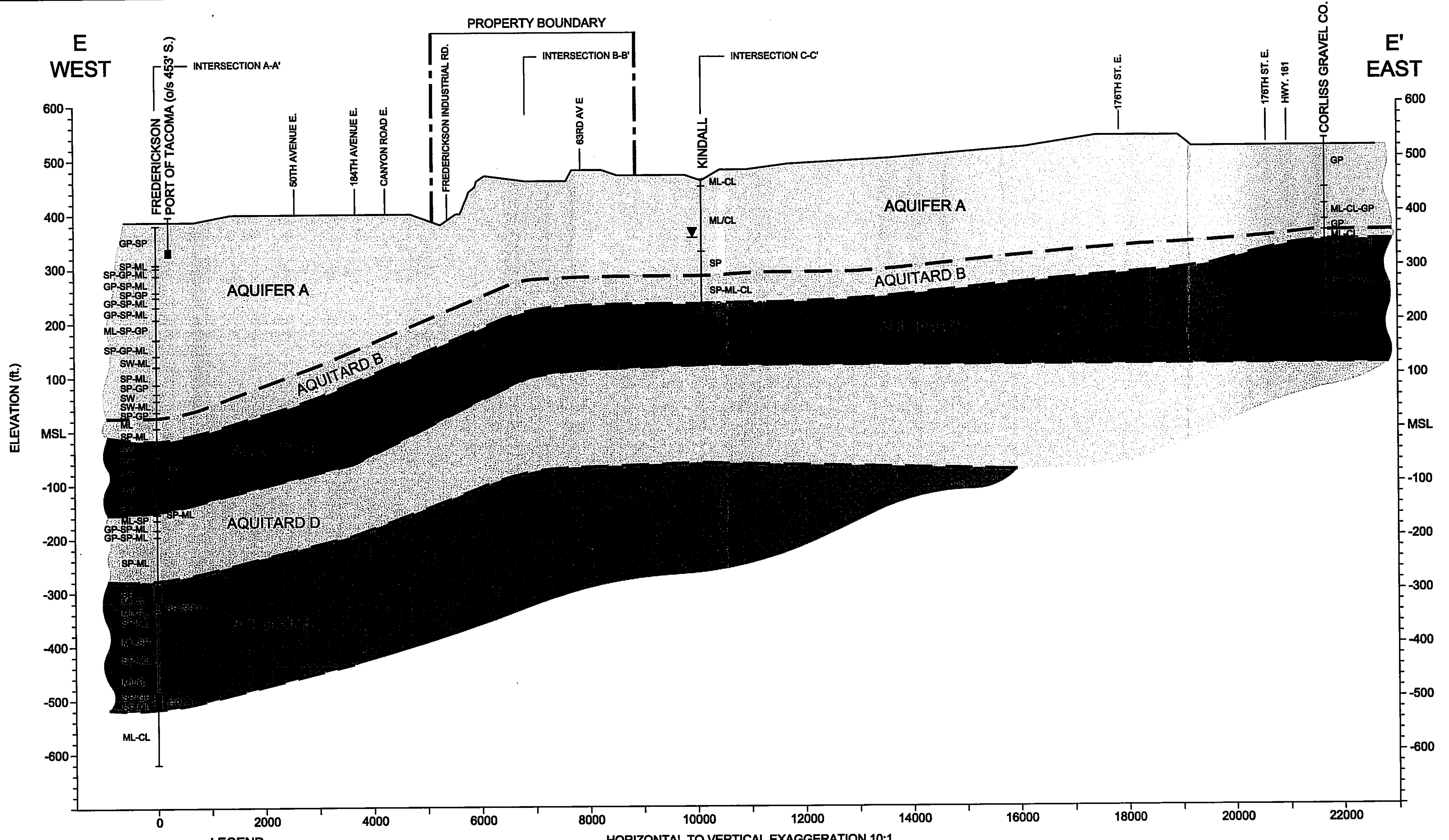
GP	GRAVEL
SW	SAND AND GRAVEL
SP	SAND
ML/CL	CLAY, SILT, SAND AND GRAVEL MIX (AS TILL)
ML	SILT
CL	CLAY
SC	CLAY, SAND

figure 3.5

CROSS-SECTION D-D'
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

06578-00(006)GN-WA007 FEB 18/2000



LEGEND

MASELLA	WELL NAME
6,1	LITHOLOGY IDENTIFIER
	SCREENED INTERVAL
	WATER TABLE ELEVATION
	POTENTIOMETRIC SURFACE ELEVATION
	INFERRED AQUIFER BOUNDARY

LITHOLOGY

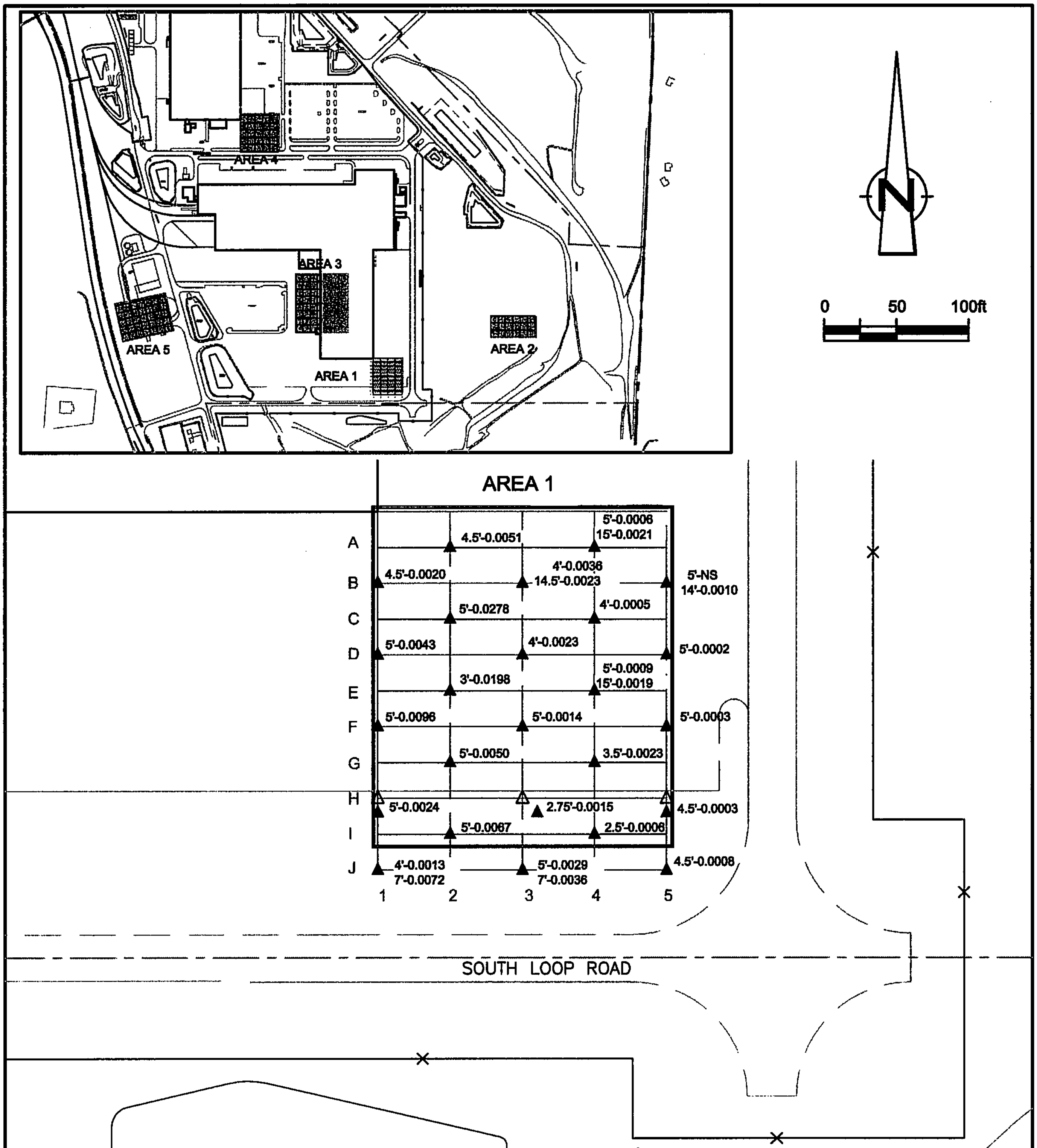
GP	GRAVEL
SW	SAND AND GRAVEL
SP	SAND
ML/CL	CLAY, SILT, SAND AND GRAVEL MIX (AS TILL)
ML	SILT
CL	CLAY

figure 3.6

CROSS-SECTION E-E'
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

06578-00(006)GN-WA008 FEB 18/2000



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

4'-0.0036 — FEET BELOW GROUND SURFACE — CTC SOIL GAS CONCENTRATION (ug/L)

△ INITIAL SOIL GAS SAMPLING ATTEMPT/LOCATION

▲ SOIL GAS SAMPLE LOCATION

ND NOT DETECTED (MDL=0.001 ug/L)

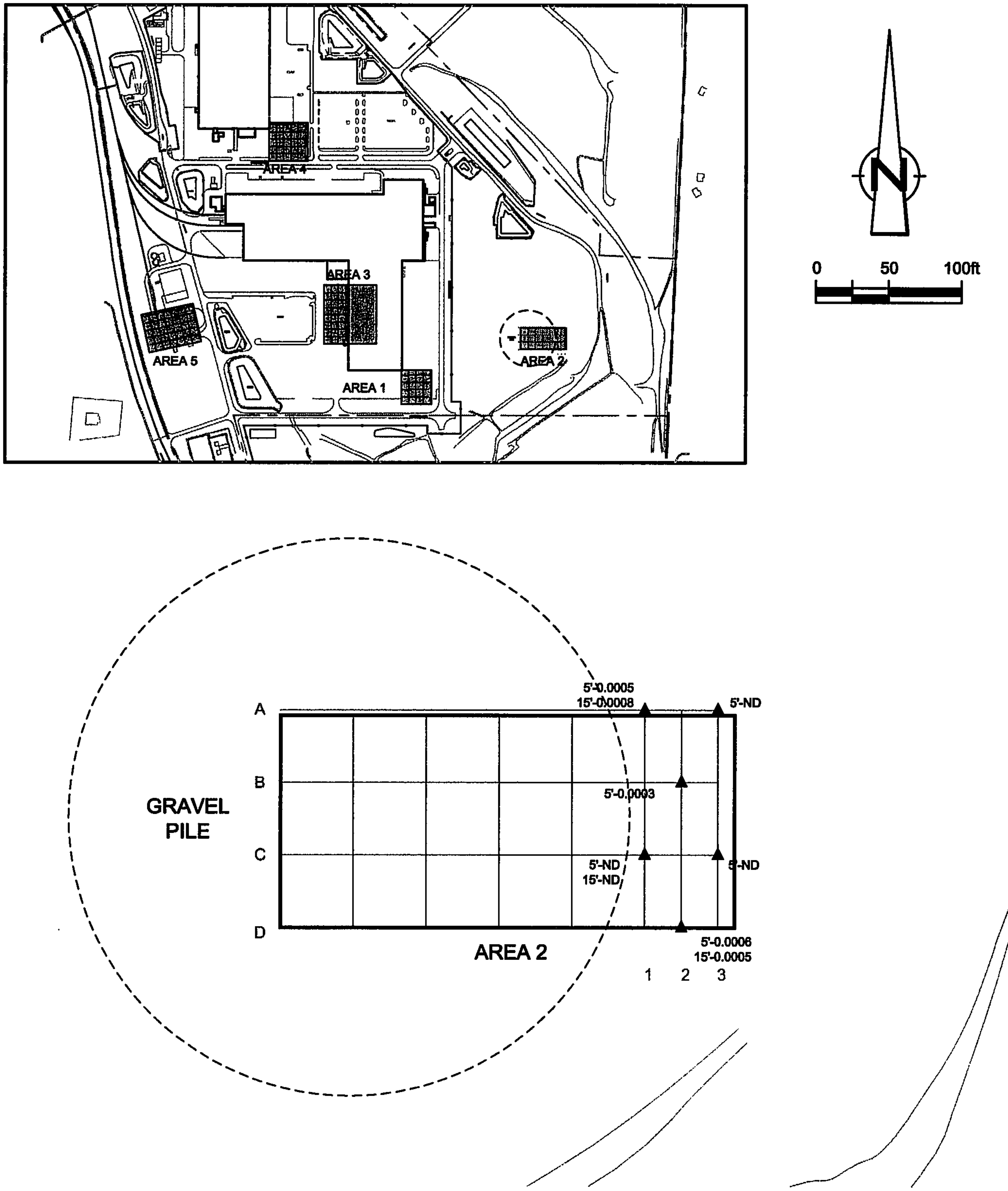
NS NOT SAMPLED

CRA

figure 5.1

AREA 1 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

06578-00(MEMO001)GN-WA003 MAY 28/1999



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

4'-0.0036 — FEET BELOW GROUND SURFACE
— CTC SOIL GAS CONCENTRATION (ug/L)

▲ SOIL GAS SAMPLE LOCATION

ND NOT DETECTED (MDL=0.0001 ug/L)

CRA

figure 5.2

AREA 2 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

06578-00(MEMO001)GN-WA004 MAY 28/1999

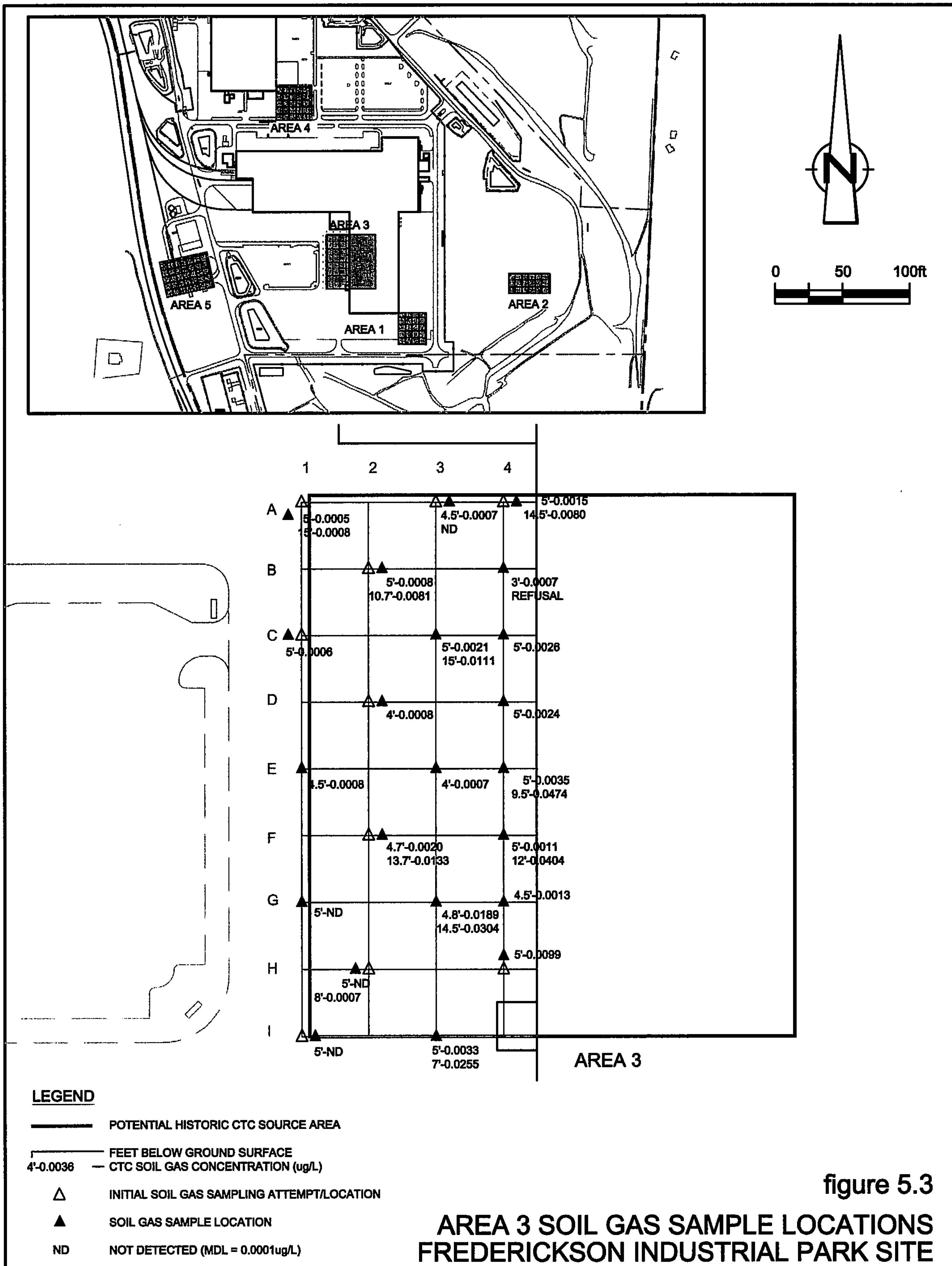
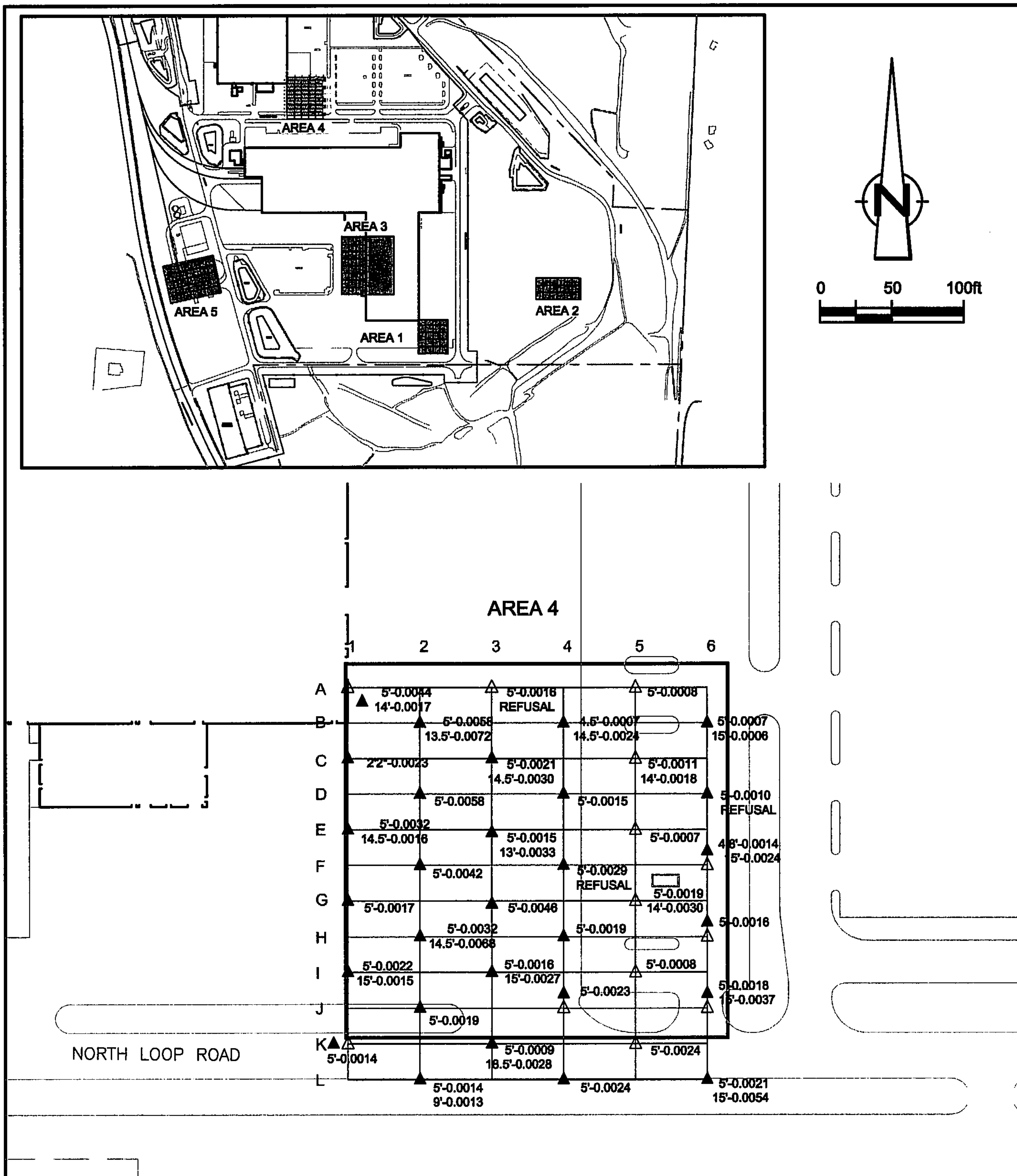


figure 5.3

AREA 3 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

06578-00(MEMO001)GN-WA005 MAY 31/1999



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

FEET BELOW GROUND SURFACE

4'-0.0036 — CTC SOIL GAS CONCENTRATION (ug/L)

△ INITIAL SOIL GAS SAMPLING ATTEMPT/LOCATION

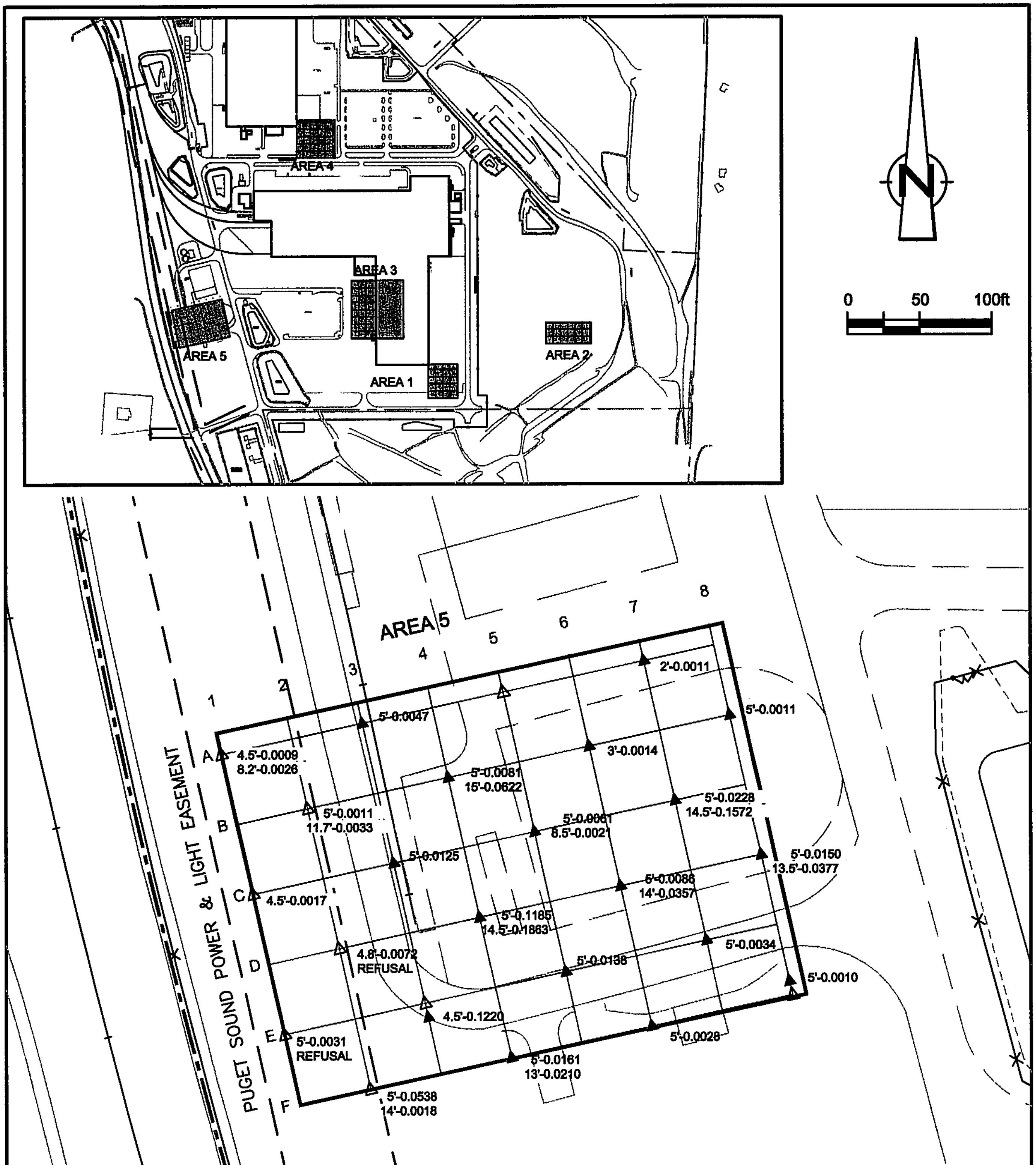
▲ SOIL GAS SAMPLE LOCATION

figure 5.4

AREA 4 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

06578-00(MEMO001)GN-WA007 MAY 31/1999



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

4'-0.0036 — FEET BELOW GROUND SURFACE / CTC SOIL GAS CONCENTRATION (ug/L)

△ INITIAL SOIL GAS SAMPLING ATTEMPT/LOCATION

▲ SOIL GAS SAMPLE LOCATION

APPROXIMATE LOCATION OF PUGET SOUND POWER AND LIGHT EASEMENT

CRA

figure 5.5

AREA 5 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

06578-00(MEMO001)GN-WA008 MAY 31/1999

TABLE 2.1

TEST PIT SOIL SAMPLING ANALYTICAL RESULTS
WEHRAN ENGINEERING - MARCH 1989
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Analytical Parameters (1)	*Test Pit Sampling Location and Collection Depth (feet)*				
	TP-2	*TP-3*	*TP-6*	*TP-7*	*TP-8*
	(1-2)	*(0-2)*	*(0-0.5)*	*(1-2)*	*(1-3)*
Volatile Organics (µg/kg)					
Benzene	190	<5.5	<1.1	<2.9	<6.3
Methylene Chloride	130	22	7.5	6.0	15B
Toluene	18	<4.4	<0.9	<2.3	<3.8
Semi-Volatile Organics (µg/kg)					
Anthracene	22M	<93	<74	84	<81
Benzoic Acid	6800	<930	<740	<690	<810
Benzo(a)anthracene	30M	<93	<74	310	<81
Benzo fluoranthenes*	<90	<93	<74	2000	<81
Benzo(a)pyrene	<90	<93	<74	460	<81
Benzo(g,h,i)perylene	<90	<93	<74	340	<81
Bis(2-ethyl-hexyl)phthalate	170	100	160	96	110
Chrysene	<90	<93	<74	1100	<81
Dibenzo(a,h)anthracene	<90	<93	<74	180M	<81
Dibenzofuran	58J	<93	<74	72	<81
Diethylphthalate	<90	110	<74	<69	<81
Di-n-Octyl Phthalate	150	96	130	<69	<81
Fluoranthene	93	<93	<74	940	<81
Indeno(1,2,3-c,d)pyrene	<90	<93	<74	550	<81
2-Methylphenol	30M	<93	<74	<69	<81
4-Methylphenol	79M	<93	<74	<69	<81
2-Methylnaphthalene	38M	<93	<74	96	<81
Naphthalene	120	<93	<74	160	<81
Pentachlorophenol	140J	<460	<370	<340	<400
Phenanthrene	200	<93	<74	340	<81
Phenol	220	<93	<74	<69	<81
Pyrene	240	<93	<74	960	<81

TABLE 2.1

TEST PIT SOIL SAMPLING ANALYTICAL RESULTS
WEHRAN ENGINEERING - MARCH 1989
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Analytical Parameters (1)	*Test Pit Sampling Location and Collection Depth (feet)*				
	TP-2	*TP-3*	*TP-6*	*TP-7*	*TP-8*
	(1-2)	*(0-2)*	*(0-0.5)*	*(1-2)*	*(1-3)*
PCBs/Pesticides (µg/kg)					
Aroclor-1260	<60	620	100	<60	210
Metals (mg/kg)					
Antimony	0.34	0.97	0.12	0.44/0.49	0.46
Arsenic	3.41	10.2	3.72	5.35/5.00	4.71
Beryllium	0.60	0.60	0.50	0.80/0.80	0.8
Cadmium	0.70	1.10	0.20	0.20/0.20	1.0
Chromium	21.4	39.1	19.7	22.6/18.8	24.1
Copper	42.3	501	22.2	43.1/66.7	51.5
Lead	59	687	9.0	21/20	131
Mercury	0.07	0.08	0.05	0.05/0.05	0.10
Nickel	22	54	20	23/21	26
Selenium	1.42	0.29	1.16	1.15/1.15	0.88
Silver	0.40	0.40	0.30	0.30/0.30	0.40
Thallium	0.14	0.14	0.12	0.12/0.12	0.13
Zinc	5250	680	42.9	40.6/37.6	795

Notes:

(1) Only those compounds detected are reported.
* The concentration of benzo fluoranthenes is the combined concentration of benzo(b)fluoranthene and benzo(k)fluoranthene, as these two compounds coelute and cannot be fully resolved.
B Indicates that the analyte was detected in sample and in laboratory method blank. Indicates possible/probable blank contamination.
J Indicates an estimated value of analyte found and confirmed by analyst but with low spectral match parameters.
M Indicates an estimated value when result is less than the method detection limit.
< Less than method detection limit. Concentrations are the method detection limits.

TABLE 2.2

TEST PIT SOIL SAMPLING ANALYTICAL RESULTS
AHR ENGINEERS - SEPTEMBER 1989
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

	Test Pit Sampling Location						
Analytical Parameters	*TP-1*	*TP-2*	*TP-3*	*TP-4*	*TP-5*	*TP-6*	*TP-7*
Purgeable Aromatics (mg/kg)							
Benzene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Toluene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chlorobenzene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ethyl benzene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
meta & para xylene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ortho xylene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,3-dichlorobenzene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,4-dichlorobenzene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,2-dichlorobenzene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Purgeable Halocarbons (mg/kg)							
Methylene Chloride	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,1-dichloroethylene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,2-dichloroethane	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,2-transdichloroethylene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chloroform	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,2-dichloroethane ** Freon	<0.1 (<0.1)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,1,1-trichloroethane	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bromodichloromethane ** Carbon Tetrachloride	<0.1 (<0.1)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,2-dichloropropane ** Trans-1,3-dichloropropene	<0.1 (<0.1)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Trichloroethylene	<0.05 (<0.05)	0.08	0.07	<0.05	<0.05	<0.05	<0.05
Cis-1,3-dichloropropene** 1,1,2-trichloroethane	<0.1 (<0.1)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chlorodibromomethane	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bromoform	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Tetrachloroethylene	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,1,2,2-tetrachloroethane	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chlorobenzene	0.27 (0.19)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PCB/Pesticides (mg/kg)							
1260	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

TABLE 2.2

TEST PIT SOIL SAMPLING ANALYTICAL RESULTS
AHR ENGINEERS - SEPTEMBER 1989
RI/FIS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Analytical Parameters	*Test Pit Sampling Location*						
	TP-1	*TP-2*	*TP-3*	*TP-4*	*TP-5*	*TP-6*	*TP-7*
Metals (mg/kg)							
Arsenic	<0.1	<0.1	0.1	<0.1	<0.1	0.4	<0.1
Barium	<0.1	0.3	0.2	0.2	0.2	0.3	0.4
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lead	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silver	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	<0.1	0.1	0.1	0.1	0.1	0.1	0.1
Zinc	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Notes:

* Sample 14 - Dirt on Lot 20 Asphalt Pad
** These halocarbons coelute

TABLE 2.2

TEST PIT SOIL SAMPLING ANALYTICAL RESULTS
AHR ENGINEERS - SEPTEMBER 1989
RI/FIS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

	Test Pit Sampling Location						
Analytical Parameters	*TP-8*	*TP-9*	*TP-10*	*TP-11*	*TP-12*	*TP-13*	*Sample 14**
Purgeable Aromatics (mg/kg)							
Benzene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
Toluene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
Chlorobenzene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
Ethyl benzene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
meta & para xylene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
ortho xylene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
1,3-dichlorobenzene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
1,4-dichlorobenzene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
1,2-dichlorobenzene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
Purgeable Halocarbons (mg/kg)							
Methylene Chloride	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
1,1-dichloroethylene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
1,2-dichloroethane	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
1,2-transdichloroethylene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
Chloroform	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
1,2-dichloroethane ** Freon	<0.1	<0.1	<0.1 (<0.1)	<0.1	<0.1	<0.1	<0.1
1,1,1-trichloroethane	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
Bromodichloromethane ** Carbon Tetrachloride	<0.1	<0.1	<0.1 (<0.1)	<0.1	<0.1	<0.1	<0.1
1,2-dichloropropane ** Trans-1,3-dichloropropene	<0.1	<0.1	<0.1 (<0.1)	<0.1	<0.1	<0.1	<0.1
Trichloroethylene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	0.9
Cis-1,3-dichloropropene** 1,1,2-trichloroethane	<0.1	<0.1	<0.1 (<0.1)	<0.1	<0.1	<0.1	<0.1
Chlorodibromomethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bromoform	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Tetrachloroethylene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08
1,1,2,2-tetrachloroethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chlorobenzene	<0.05	<0.05	<0.05 (<0.05)	<0.05	<0.05	<0.05	<0.05
PCB/Pesticides (mg/kg)							
1260	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.1

TABLE 2.2

TEST PIT SOIL SAMPLING ANALYTICAL RESULTS
AHR ENGINEERS - SEPTEMBER 1989
RI/FIS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

	Test Pit Sampling Location						
Analytical Parameters	*TP-8*	*TP-9*	*TP-10*	*TP-11*	*TP-12*	*TP-13*	*Sample 14**
Metals (mg/kg)							
Arsenic	<0.1	<0.1	<0.1	0.1	<0.1	0.1	0.5
Barium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.5
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lead	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silver	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.1
Zinc	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.1

Notes:

* Sample 14 - Dirt on Lot 20 Asphalt Pad
** These halocarbons coelute

TABLE 2.3

TEST PIT AND SOIL BORING ANALYTICAL RESULTS
GEOENGINEERS - AUGUST 1990
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

	Borings									*Test Pits*									
Analytical Parameters	***Y-1-3***	***Y-2-5***	***Y-3A-1***	***Y-4A-8***	***Y-5-1***	***Y-6-2***	***Y-6-5***	***Y-7A-7***	***Y-8-3***	***TP-1-2***	***TP-2-2***	***TP-3-1***	***TP-4-1(1)***	***TP-4-2(1)***	***TP-4-3***	***TP-5-2***	***TP-6-3***	***TP-7-2***	***TP-8-1***
Sample Depth (feet)	*34*	*42*	*5.5*	*45*	*10*	*18*	*33*	*40.5*	*15.5*	*2*	*5*	*0.5*	*0*	*0*	*0.5*	*5*	*10*	*5*	*0.5*
Volatile Organics (μg/kg)	ND					ND	ND												
Methylene Chloride		1.4(B)	0.4(B)	0.9(B)	1.2(B)			0.4(B)	0.5(B)	0.5(B)	0.3(B)	0.9(B)	0.5(B)	0.7(B)	0.9(B)	0.5(B)	0.3(B)	0.3(B)	0.7(B)
Acetone		1.5(B)			1.5(B)							1.1(B)	1.5	1.1	3.4				
Semivolatile Organics (μg/kg)		ND																	
Fluoranthene																			0.22(J)
Pyrene																			0.28(J)
Bis(2-Ethylhexyl)phthalate	0.09 (J)					0.41						0.26							
Chrysene																			0.39(J)
Benzo(b)Fluoranthene																			0.36(J)
Benzo(k)Fluoranthene																			0.16(J)
Benzo(a)pyrene																			0.16
Tentatively Identified Compounds																			
Unknown	1.25		1.8	1.3				1.3		1.2	1.4	1.0			1.6	0.79	0.51(B)	2.29	3.7
Hexanal	0.61						0.36(B)												
Tetrachloroethane				1.9(B)	0.95(B)	0.19(B)	0.81(B)				1.4(B)				1.3(B)	0.85(B)	1.1(B)		
Trichloroethane	0.90(B)					0.41(B)													
Branced Alcohol	0.87																		
Branched Hexanedioic Acid	5.7																		
Hexanedioic Acid, Dioctylester			0.38				6.9										6.8		
Hexanedioic Acid, Mono(2-ethylhexyl)ester				0.21															
Sum of Misc. Hydrocarbons			1.31	0.90	1.4	0.29	0.50(B)	0.96	0.36	1.71	1.46	2.15	66000	2670	2.73		0.53(B)	0.61	8.6
Total Petroleum Hydrocarbons	NA	NA	NA	NA	NA	NA	NA	NA	NA	320	7	630	750000	300000	1400	410	78	25	NA
Fuel Hydrocarbons (Modified 8015)													C8-C24	C8-C24					
Hydrocarbons Identified													8200	6700					
Pesticides/PCBs (8080)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrite (mg/kg)	NA	NA	NA	NA	NA	NA	NA	<3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate (mg/kg)	NA	NA	NA	NA	NA	NA	NA	4.8	NA	15	18	NA	NA	NA	NA	NA	NA	NA	NA
Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenolics	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pH	NA	NA	6.6	7.0	NA	NA	NA	6.4	NA	6.9	6.0	5.9	NA	NA	6.6	5.8	NA	NA	5.7

Notes:

All untis are mg/kg except for pH
ND - not detected, see analytical reports for detection limits
NA - not analyzed
Only organic compounds detected are listed
B - also found in blank
J - estimated value
(1) Samples TP-4-1 and TP-4-2 were solidified substances tentatively identified as paraffin.

TABLE 2.3

TEST PIT AND SOIL BORING ANALYTICAL RESULTS
GEOENGINEERS - AUGUST 1990
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Analytical Parameters	*TP-9-1*	*TP-10-2*	*TP-11-3*	*TP-12-3*	*TP-13-1*	*TP-13-4*	*TP-14-1*	*TP-14-4*	*TP-15-2*	*TP-16-3*	*TP-17-3*	*TP-17-5*	*TP-18-3*	*TP-19-1*	*TP-20-1*	*TP-21-2*	*TP-22-1*	*TP-23-5*
Sample Depth (feet)	*0.5*	*5.0*	*10.0*	*10.0*	*0.5*	*20*	*17.5*	*5.0*	*10.0*	*5.0*	*7.0*	*3.0*	*15.0*	*1.5*	*5.0*	*1.0*	*21*	*18*
Volatile Organics (μg/kg)													ND			ND	ND	
Ethylbenzene											12							
Xylenes											40							
Methylene Chloride	0.4(B)	0.4(B)	0.6(B)	0.6(B)	0.8(B)	0.4(B)	1.5(B)	1.1(B)	0.6(B)	0.6(B)		0.5(B)		0.9(B)	0.6(B)	1.2(B)		2.0(B)
Acetone							3.3(B)							1.2(B)				5.2(B)
Semivolatile Organics (μg/kg)						ND				ND								
Anline					1.0													
Naphthalene											4.3							
2-Methylnaphthalene											0.17(J)							
Di-n-butylphthalate													0.99(B)				1.4(B)	
Pyrene											0.76(J)			0.08(J)				
Butylbenzylphthalate	0.23																	
Bis(2-Ethylhexyl)phthalate											13			0.09(J)		7.5		
Chrysene											0.33(J)							
Benzo(b)Fluoranthene											0.40(J)							
Benzo(k)Fluoranthene											0.28(J)							
Benzo(a)pyrene														0.18(J)				
Tentatively Identified Compounds																		
Unknown	1.9	0.95	0.83		1.4				0.78			1.3			1.2	2.3		1.4
Tetrachloroethane		0.85(B)	0.83(B)	0.79(B)			1.1(B)	1.2(B)	0.86(B)			1.1(B)	0.47(B)		1.0(B)		0.48(B)	1.8(B)
Trichloroethane	1.5(B)												0.27(B)					
Hexanedioic Acid, Dioctylester					5.3			0.3				5.5			4.8			0.34
Hexanedioic Acid, Mono(2-ethylhexyl)ester							0.53									8.4		
Sum of Misc. Hydrocarbons	1.39	0.23	0.16	0.21	3.29		3.70	0.56			22.50	0.91	1.40		3.50	3.29	4.10	0.84
Total Petroleum Hydrocarbons	3,200	NA	NA	ND	NA	NA	NA	98	NA	NA	51,000	88	NA	510	42	NA	NA	NA
Fuel Hydrocarbons (Modified 8015)								ND			C6-C12							
Hydrocarbons Identified											800,000							
Pesticides/PCBs (8080)	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA	NA
Nitrite (mg/kg)	NA	<3.0	NA	NA	NA	NA	NA	NA	<3	<3	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate (mg/kg)	NA	<3.0	NA	NA	NA	NA	NA	NA	3.0	3.4	NA	NA	NA	NA	NA	NA	NA	NA
Cyanide	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA	NA
Phenolics	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	0.45	NA	NA	NA	NA	NA	NA	NA
pH	NA	6.5	5.5	NA	NA	NA	NA	NA	6.8	5.9	NA	5.6	7.1	NA	NA	NA	NA	NA

Notes:

All units are mg/kg except for pH
NA - Not Available
ND - Not Detected
Only organic compounds detected are listed
B - also found in blank
J - estimated value

TABLE 2.3

TEST PIT AND SOIL BORING ANALYTICAL RESULTS
GEOENGINEERS - AUGUST 1990
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

	Test Pits										*Shallow Soil Samples*								
Analytical Parameters	***TP-24-5***	***TP-25-1***	***TP-26-2***	***TP27-3***	***TP28-1***	***TP-29-1***	***TP-30-1***	***TP-31-2***	***TP-32-1***	***TP-33-1***	***SS-1-1***	***SS-1-2***	***SS-2-1***	***SS-3-2***	***SS-4-1***	***SS-5-1***	***SS-6-1***	***SS-7-1***	***SS-8-1***
Sample Depth (feet)	***5.0***	***0.5***	***10***	***0.5***	***0.5***	***0.5***	***5.0***	***5.0***	***0.5***	***0.5***	***0.0***	***0.0***	***0.0***	***3.0***	***1.5***	***1.5***	***0.1***	***1.0***	***0.5***
Volatile Organics (µg/kg)	ND		ND	ND		ND											ND	ND	
Methylene Chloride		0.9(B)			1.9(B)		1.5(B)	1.3(B)	1.2(B)	1.4(B)	1.0(B)	1.1(B)	0.9(B)	0.4(B)	0.6(B)	0.5(B)			1.5(B)
Acetone					1.2(B)						2.4(B)	2.2(B)	2.1(B)						
Semivolatile Organics (µg/kg)													NA						
Phenanthrene											0.23						0.30		
Anthracene											0.18								
2-Methylnaphthalene																	0.08(J)		
Bis(2-ethylexyl)phthalate															0.78	13			
Tentatively Identified Compounds																			
Unknown	1.2	1.2		1.2(B)	1.52	1.77(B)	3.1	1.18	3.5						0.99	0.58		0.58(B)	
Tetrachloroethane	0.49(B)	0.82(B)		1.5(B)	0.67(B)	1.6(B)	0.69(B)	0.70(B)							1.0(B)	0.59(B)		1.1(B)	
Tetramethyl Pentadelane												15							
Hexanedioic Acid, Dioctylester		0.37																	
Branched Hexanedioic Acid														4.5	5.6				
Sum of Misc. Hydrocarbons	0.49	0.90	268	0.63	1.20	0.70	1.33	0.86	2.04	315	108	47		4.60	0.18		17.20	5.40	32.70
Total Petroleum Hydrocarbons	NA	50	11,000	11	NA	23	NA	NA	NA	NA	22,000	NA	1,700	40	49	7.00	1,300	NA	7,400
Fuel Hydrocarbons (Modified 8015)																	C8-C24		
Hydrocarbon Range																	1,400		
Pesticides/PCBs (8080)	NA	NA	NA	NA	NA	NA	ND	NA	NA	ND	1.5	NA	NA	NA	NA	NA	NA	NA	NA
Nitrite	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA
Nitrate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.7	NA	NA	NA
Cyanide	NA	NA	NA	NA	NA	NA	ND	NA	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenolics	NA	NA	NA	NA	NA	NA	ND	NA	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
pH	NA	NA	NA	NA	NA	NA	6.1	NA	NA	6.1	6.4	NA	6.1	NA	NA	NA	6.9	7.1	NA

Notes:

All untis are mg/kg except for pH
ND - not detected, see analytical reports for detection limits
NA - not analyzed
Only organic compounds detected are listed
B - also found in blank
J - estimated value

TABLE 2.3

TEST PIT AND SOIL BORING ANALYTICAL RESULTS
GEOENGINEERS - AUGUST 1990
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

	Borings			Test Pits									
Metal	*Y-4A-8*	*Y-5-1*	*Y-7A-7*	*TP-1-2*	*TP-2-2*	*TP-3-1*	*TP-10-2*	*TP-14-4*	*TP-17-3(1)*	*TP-17-4*	*TP-18-3*	*TP-30-1*	*TP-33-1*
Sample Depth	**45**	**10**	**40.5**	**2**	**5**	**0.5**	**5**	**17.5**	**5**	**5**	**15**	**0.5**	**0.5**
Antimony	<0.5	<0.5	<0.5	1.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Arsenic	2.2	1.9	<0.5	<5.0 (3)	3.5	8.0	2.7	2.2	2.8	1.8	1.6	2.5	5.8
Beryllium	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium	<1	<1	<1	6	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	18	15	<2	130	60	30	9.8	31	30	11	13	12	15
Copper	13	21	3.2	9,400	22	58	19	12	140	21	19	18	21
Lead	<10	<10	<10	560	<10	97	<10	<10	150	<10	<10	<10	<10
Mercury	0.44	<0.15	<0.15	0.17	<0.15	<0.15	<0.15	0.53	<0.15	<0.15	<0.15	<0.15	<0.15
Nickel	26	21	<3	130	25 (1)	36	16	16	30	16	17	25	26
Selenium	<0.5	<0.5	<0.5	3.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	<2	<2	<2	5	<2	<2	<2	<2	28	<2	<2	<2	<2
Thallium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc	27	32	10	6,600	37	95	25	29	88	37	27	47	56

Notes:

All units mg/kg
(1) Sample of hydrocarbon-like material
(2) Source: Pevear, D., unpublished data as presented in Dexter, et. al., NOAA Technical Memorandum OMPA-13
(3) Higher detection limit due to matrix interference

TABLE 2.4

TEST PIT SOIL SAMPLING ANALYTICAL RESULTS
GEOENGINEERS - JANUARY 1991
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Analytical Parameters (1)	*Test Pit Sampling Location and Collection Depth (feet)*					
	RE9-1-6	*RE18-1-6*	*RE20-2-12*	*RE21-1-2*	*RE21-2-4*	*RE21-4-5*
	(6.0)	*(5.0)*	*(4.0)*	*(3.0)*	*(1.0)*	*(1.5)*
Volatile Organics (μg/kg)						
Acetone	3.5	ND	ND	7.2M	2.5BJ	2.2BJ
Benzene	ND	ND	ND	0.7J	ND	ND
Methylene Chloride	4.5B	1.3JB	1.5JB	12B	4.1B	5.7B
1,1-Dichloroethane	ND	ND	ND	1.0M	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	3.1	0.7J	1.1J
1,1,2-Trichloro-1,2,2-Trifluoroethane	ND	ND	ND	ND	3.5B	1.0BJ
Toluene	ND	ND	ND	4.2	ND	0.6J
Xylenes (total)	ND	ND	ND	4.6	ND	ND
Semivolatile Organics (μg/kg)						
Benzoic Acid	ND	ND	100J	ND	ND	ND
Pyrene	ND	ND	100	430	69J	ND
Bis(2-Ethylhexyl)Phthalate	ND	ND	130	ND	1300	140J
Naphthalene	ND	ND	ND	300	ND	ND
2-Methylnapthalene	ND	ND	ND	640	ND	ND
Dibenzofuran	ND	ND	ND	150	ND	ND
Phenanthrene	ND	ND	ND	540	ND	ND
Anthracene	ND	ND	ND	100M	ND	ND
Fluoranthene	ND	ND	ND	460	ND	ND
Benzo(a)Anthracene	ND	ND	ND	260	ND	ND
Crysene	ND	ND	ND	380	ND	ND
Benzo(b&k)Fluoranthene	ND	ND	ND	400	ND	ND
Benzo(a)Pyrene	ND	ND	ND	110	ND	ND
Indeno(1,2,3-cd)Pyrene	ND	ND	ND	83	ND	ND
Total Priority Pollutant Metals (mg/kg)						
Arsenic	ND	--	ND	13	--	5
Beryllium	0.4	--	0.4	0.6	--	0.5
Cadmium	0.4	--	0.4	0.9	--	0.6
Chromium (total)	26.5	--	27.1	12.6	--	32
Copper	44.1	--	43.5	43.7	--	1860
Lead	23	--	20	59	--	138
Mercury (inorganic)	0.05	--	0.05	0.11	--	0.07
Nickel	29	--	30	28	--	23
Zinc	150	--	70.5	153	--	349

Notes:

(1) Only those compounds detected were reported
NA - Not Available
ND - Not Detected
-- Signifies "not tested"
J - Indicates an estimated value when result is less than specified detection limit.
B - This flag is used when the analyte is found in the blank as well as a sample. Indicates possible/probable blank contaminat
M - Indicates an estimated value of analyte found and confirmed by analyst but with low spectral match parameters.

TABLE 2.4

TEST PIT SOIL SAMPLING ANALYTICAL RESULTS
GEOENGINEERS - JANUARY 1991
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Analytical Parameters	*Test Pit Sampling Location and Collection Depth (feet)*				
	RE21-4-6	*RE21-4-7*	*RE21-4-8*	*AS1-1*	*AS1-2*
	(2.0)	*(4.0)*	*(5.0)*	*(0.5)*	*(8.0)*
Volatile Organics (µg/kg)					
Acetone	--	--	--	ND	2.7JB
Benzene	--	--	--	ND	ND
Methylene Chloride	--	--	--	3.4B	3.6B
1,1-Dichloroethane	--	--	--	ND	ND
1,1,1-Trichloroethane	--	--	--	ND	ND
1,1,2-Trichloro-1,2,2-Trifluoroethane	--	--	--	ND	ND
Toluene	--	--	--	ND	ND
Xylenes (total	--	--	--	ND	ND
Semivolatile Organics (µg/kg)					
Benzoic Acid	--	--	--	ND	ND
Pyrene	--	--	--	ND	ND
Bis(2-Ethylhexyl)Phthalate	--	--	--	ND	ND
Naphthalene	--	--	--	ND	ND
2-Methylphenol	--	--	--	ND	ND
Dibenzofuran	--	--	--	ND	ND
Phenanthrene	--	--	--	ND	ND
Anthracene	--	--	--	ND	ND
Fluoranthene	--	--	--	ND	ND
Benzo(a)Anthracene	--	--	--	ND	ND
Crysene	--	--	--	ND	ND
Benzo(b)Fluoranthene	--	--	--	ND	ND
Benzo(a)Pyrene	--	--	--	ND	ND
Indeno(1,2,3-cd)Pyrene	--	--	--	ND	ND
Total Priority Pollutant Metals (mg/kg)					
Arsenic	--	--	--	--	--
Beryllium	--	--	--	--	--
Cadmium	--	--	--	--	--
Chromium (total)	--	--	--	--	--
Copper	21.6	26.0	23.2	--	--
Lead	--	--	--	--	--
Mercury (inorganic)	--	--	--	--	--
Nickel	--	--	--	--	--
Zinc	--	--	--	--	--

Notes:

NA - Not Available
ND - Not Detected
-- Signifies "not tested"
J - Indicates an estimated value when result is less than specified detection limit.
B - This flag is used when the analyte is found in the blank as well as a sample. Indicates possible/probable blank contamination.
M - Indicates an estimated value of analyte found and confirmed by analyst but with low spectral match parameters.

TABLE 2.5

PB-1 SOIL BORING ANALYTICAL RESULTS
HARDING LAWSON ASSOCIATES - JULY 1994
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Analytical Parameters	*PB-1 (1)*
Acetone	ND(1.1)
Benzene	ND(0.057)
Bromodichloromethane	ND(0.057)
Bromoform	ND(0.29)
Bromomethane	ND(0.57)
2-Butanone (MEK)	ND(0.57)
Carbon Disulfide	ND(0.057)
Carbon Tetrachloride	ND(0.057)
Chlorobenzene	ND(0.057)
Chloroethane	ND(0.057)
Chloroform	ND(0.057)
Chloromethane	ND(0.57)
Dibromochloromethane	ND(0.057)
1,1-Dichloroethane	ND(0.057)
1,2-Dichloroethane	ND(0.057)
1,1-Dichloroethene	ND(0.057)
1,2-Dichloroethene (total)	ND(0.057)
1,2-Dichloropropane	ND(0.057)
Cis-1,3-Dichloropropene	ND(0.057)
Trans-1,3-Dichloropropene	ND(0.057)
Ethylbenzene	ND(0.057)
2-Hexanone (MBK)	ND(0.57)
4-Methyl-2-Pentanone (MIBK)	ND(0.57)
Methylene Chloride	ND(0.29)
Styrene	ND(0.057)
1,1,2,2-Tetrachloroethane	ND(0.057)
Tetrachloroethene	ND(0.057)
Toluene	ND(0.057)
1,1,1-Trichloroethane	ND(0.057)
1,1,2-Trichloroethane	ND(0.057)
Trichloroethene	ND(0.057)
Vinyl Acetate	ND(0.57)
Vinyl Chloride	ND(0.057)
Total Xylenes	ND(0.057)

Notes:

(1) PB-1 was drilled adjacent to Well No. 11-CL in the northwest portion of the site at a depth of 98.2 ft. and completed as monitoring well HLA-1. Note the soil sample was collected at 97 feet bgs at PB-1 (HLA, March 24, 1995).

TABLE 2.8

CARBON TETRACHLORIDE GROUNDWATER CONCENTRATION SUMMARY
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Monitoring Well	*Concentration (µg/L)*								
	11/88 (1)	*02/89 (2)*	*07/89 (3)*	*08/89 (3)*	*09/89 (3)*	*01/90 AHR*	*02/90 AHR*	*03/90 AHR*	*04/90 AHR*
Existing Wells									
7-A	–	ND1.0	–	–	–	–	–	–	–
9-D	ND0.5	ND1.0	–	–	–	–	–	–	–
11-BU	–	–	ND1.0	ND1.0	–	–	–	–	–
11-BL	–	–	ND1.0	ND1.0	–	0.3	15.7	28.7	–
11-CU	–	–	ND1.0	ND1.0	–	–	–	–	–
11-CL	–	–	15.7	51.3	25.0	9.7	19.8	53.1	–
11-D	–	–	–	–	–	–	–	–	–
11-E	–	–	–	14.0	5.0	8.2	16.0	56.1	8.8
HLA-1	–	–	–	–	–	–	–	–	–
12-A	–	–	–	ND1.0	–	–	–	–	–
14-AU	–	–	–	ND1.0	–	–	–	–	–
14-AL	–	–	–	27.2	19	5.3	15.9	52.9	–
Y-4B	–	–	–	–	–	–	–	–	–
BMW-1	–	–	–	–	–	–	–	–	–
BMW-2	–	–	–	–	–	–	–	–	–
BMW-3	–	–	–	–	–	–	–	–	–
BMW-8	–	–	–	–	–	–	–	–	–
BMW-9	–	–	–	–	–	–	–	–	–
BMW-11	–	–	–	–	–	–	–	–	–
BMW-13R	–	–	–	–	–	–	–	–	–
BMW-14	–	–	–	–	–	–	–	–	–
BMW-15	–	–	–	–	–	–	–	–	–
BMW-18	–	–	–	–	–	–	–	–	–
BMW-19	–	–	–	–	–	–	–	–	–
BMW-20	–	–	–	–	–	–	–	–	–
BMW-21	–	–	–	–	–	–	–	–	–
BMW-22	–	–	–	–	–	–	–	–	–

TABLE 2.8

CARBON TETRACHLORIDE GROUNDWATER CONCENTRATION SUMMARY
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Monitoring Well	*Concentration (µg/L)*								
	11/88 (1)	*02/89 (2)*	*07/89 (3)*	*08/89 (3)*	*09/89 (3)*	*01/90 AHR*	*02/90 AHR*	*03/90 AHR*	*04/90 AHR*
Off-Site Wells									
Brown	–	–	–	–	–	–	–	–	–
Brewer	–	–	–	–	–	–	–	–	–
Burns	–	–	–	–	–	–	–	–	–
Campbell	–	–	–	–	–	–	–	–	–
Catchpole	–	–	–	–	–	–	–	–	–
Eustace	–	–	–	–	–	–	–	–	–
Greenlaw	–	–	–	–	–	–	–	–	–
Kuhuski	–	–	–	–	–	–	–	–	–
LaPlant	–	–	–	–	–	–	–	–	–
Lively	–	–	–	–	–	–	–	–	–
Looker	–	–	–	–	–	–	–	–	–
Mattox	–	–	–	–	–	–	–	–	–
McLaughlin	–	–	–	–	–	–	–	–	–
Morris	–	–	–	–	–	–	–	–	–
Neunecker	–	–	–	–	–	–	–	–	–
Pettit/Cope	–	–	–	–	–	–	–	–	–
Pierce	–	–	–	–	–	–	–	–	–
Ramsey	–	–	–	–	–	–	–	–	–
Shotwell (shallow)	–	–	–	–	–	–	–	–	–
Shotwell (deep)	–	–	–	–	–	–	–	–	–
Tacoma Sportsment Club	–	–	–	–	–	–	–	–	–
Abandoned Wells									
9-A	1.4	ND1.0	–	–	–	–	–	–	–
9-B	ND0.5	ND1.0	–	–	–	–	–	–	–
9-C	–	–	–	–	–	–	–	–	–
11-A	15.0	12.0	11.9	56.6	27.0	3.3	8.7	33.9	–
20-AU	–	–	–	ND1.0	–	–	–	–	–
20-AL	–	–	–	ND1.0	–	–	–	–	–
21-A	–	ND1.0	–	–	–	–	–	–	–
21-B	–	–	–	–	–	–	–	–	–
21-C	–	–	–	–	–	–	–	–	–
21-D	–	–	–	–	–	–	–	–	–

TABLE 2.8

CARBON TETRACHLORIDE GROUNDWATER CONCENTRATION SUMMARY
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Monitoring Well	*Concentration (µg/L)*								
	11/88 (1)	*02/89* (2)	*07/89* (3)	*08/89* (3)	*09/89* (3)	*01/90* *AHR*	*02/90* *AHR*	*03/90* *AHR*	*04/90* *AHR*
Abandoned Wells									
Y-1	–	–	–	–	–	–	–	–	–
Y-2	–	–	–	–	–	–	–	–	–
Y-3A	–	–	–	–	–	–	–	–	–
Y-3B	–	–	–	–	–	–	–	–	–
Y-4A	–	–	–	–	–	–	–	–	–
Y-5	–	–	–	–	–	–	–	–	–
Y-6	–	–	–	–	–	–	–	–	–
Y-7A	–	–	–	–	–	–	–	–	–
Y-7B	–	–	–	–	–	–	–	–	–
Y-8	–	–	–	–	–	–	–	–	–

Notes:

Ndxx - Not detected at detection limit xx.
- Exceeds carbon tetrachloride concentration MTCA Method B value of 0.337 µg/L.

(1) Data collected by Wehran.
(2) Data collected by Crosby & Overton.
(3) Summary of Environmental Investigation for Contaminated Wastes and Remedial Action, Vol. I, AHR Engineers, September 1989.
(4) Environmental Site Assessment, Vol. I, GeoEngineers, Inc., August 31, 1990.
(5) Report of Geoenvironmental Services Remedial Excavation of Soil, GeoEngineers, Inc., January 1991.
(6) Annual Report August 1992 to July 1993, Groundwater Monitoring Program, Applied Geotechnology, Inc., November 16, 1993.
(7) Technical Memorandum Phase I Remedial Investigation, Harding Lawson Associates, March 24, 1995.
(8) Analytical results from the Columbia Analytical Services, Inc. laboratory, October 25, 1995.
(9) Sampling Results from EMCON Report 10/4/95.
(OC) Olin Chemicals off-site monitoring well data (Report dated September 6, 1995).
Existing Monitoring Wells BMW-4, BMW-5, BMW-6, BMW-7, BMW-10, BMW-16, BMW-17, and PW-1 were not analyzed for carbon tetrachloride.
Monitoring well BMW-12 was not analyzed for carbon tetrachloride.

TABLE 2.8

CARBON TETRACHLORIDE GROUNDWATER CONCENTRATION SUMMARY
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Monitoring Well	*Concentration (µg/L)*									
	05/90 AHR	*07/90 AHR*	*07/90 (4)*	*8/90 (OC)*	*11/90 (5)*	*10/92 (6)*	*11/92 (6)*	*2/94 (OC)*	*5/94 (OC)*	*6/94 (7)*
Existing Wells										
7-A	–	–	–	–	–	–	–	–	–	–
9-D	–	–	–	–	–	–	–	–	–	–
11-BU	–	–	ND1.0	–	ND2.0	–	–	–	–	–
11-BL	1.7	0.5	ND1.0	–	1.1	–	1.0	–	–	–
11-CU	–	–	ND1.0	–	ND1.0	–	ND0.2	–	–	–
11-CL	6.9	10.4	11.0	–	16.0	–	12.0	–	–	–
11-D	–	–	8.0	–	11.0	–	–	–	–	–
11-E	6.6	8.7	12.0	–	–	–	–	–	–	–
HLA-1	–	–	–	–	–	–	–	–	–	–
12-A	–	–	–	–	–	–	–	–	–	–
14-AU	–	–	ND1.0	–	ND1.0	–	ND0.2	–	–	–
14-AL	3.1	ND0.1	ND1.0	–	10.0	–	9.7	–	–	–
Y-4B	–	–	ND1.0	–	0.9	–	0.3	–	–	–
BMW-1	–	–	–	–	–	–	–	–	–	1.3
BMW-2	–	–	–	–	–	–	–	–	ND0.2	–
BMW-3	–	–	–	–	–	–	2.8	2.0	–	0.9 /ND1.0
BMW-8	–	–	–	–	–	–	–	–	ND0.2	–
BMW-9	–	–	–	–	–	–	–	–	–	ND0.2
BMW-11	–	–	–	–	–	–	–	–	ND0.2	–
BMW-13R	–	–	–	–	–	–	ND0.2	–	–	–
BMW-14	–	–	–	–	–	–	–	–	ND0.2	–
BMW-15	–	–	–	–	–	–	–	–	ND0.2	–
BMW-18	–	–	–	–	–	13.0	14.0	–	9.3	7.9/12
BMW-19	–	–	–	–	–	ND1.0	ND0.2	–	–	–
BMW-20	–	–	–	–	–	–	–	–	ND0.2	–
BMW-21	–	–	–	–	–	–	–	–	ND0.2	–
BMW-22	–	–	–	–	–	3.3	0.4	–	–	–

TABLE 2.8

CARBON TETRACHLORIDE GROUNDWATER CONCENTRATION SUMMARY
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Monitoring Well	*Concentration (μg/L)*									
	05/90 AHR	*07/90 AHR*	*07/90 (4)*	*8/90 (OC)*	*11/90 (5)*	*10/92 (6)*	*11/92 (6)*	*2/94 (OC)*	*5/94 (OC)*	*6/94 (7)*
Off-Site Wells										
Brown	–	–	–	–	–	–	–	–	–	–
Brewer	–	–	–	–	–	–	–	–	–	–
Burns	–	–	–	–	–	–	–	–	–	–
Campbell	–	–	–	–	–	–	–	–	–	–
Catchpole	–	–	–	–	–	–	–	–	–	–
Eustace	–	–	–	–	–	–	–	–	–	–
Greenlaw	–	–	–	ND0.2	–	–	–	–	–	–
Kuhuski	–	–	–	ND0.2	–	–	–	–	–	–
LaPlant	–	–	–	–	–	–	–	–	–	–
Lively	–	–	–	ND0.2	–	–	–	–	–	–
Looker	–	–	–	–	–	–	–	–	–	–
Mattox	–	–	–	–	–	–	–	–	–	–
McLaughlin	–	–	–	ND0.2	–	–	–	–	–	–
Morris	–	–	–	–	–	–	–	–	–	–
Neunecker	–	–	–	–	–	–	–	–	–	–
Pettit/Cope	–	–	–	ND0.2	–	–	–	ND0.2	ND0.2	ND0.2
Pierce	–	–	–	–	–	–	–	–	–	–
Ramsey	–	–	–	–	–	–	–	–	–	–
Shotwell (shallow)	–	–	–	–	–	–	–	3.8	3.8	3.8
Shotwell (deep)	–	–	–	4	–	–	–	ND0.2	ND0.2	ND0.2
Tacoma Sportsment Club	–	–	–	–	–	–	–	–	–	–
Abandoned Wells										
9-A	1.0	–	ND1.0	–	2.6	–	–	–	–	–
9-B	–	–	ND1.0	–	ND2.0	–	–	–	–	–
9-C	–	–	ND1.0	–	–	–	–	–	–	–
11-A	–	5.3	7.0	–	12.0	–	–	–	–	–
20-AU	–	–	ND1.0	–	ND1.0	–	–	–	–	–
20-AL	–	–	–	–	ND1.0	–	–	–	–	–
21-A	–	–	–	–	–	–	–	–	–	–
21-B	–	–	ND1.0	–	ND1.0	–	–	–	–	–
21-C	–	–	ND1.0	–	ND1.0	–	–	–	–	–
21-D	–	–	ND1.0	–	–	–	–	–	–	–

TABLE 2.8

CARBON TETRACHLORIDE GROUNDWATER CONCENTRATION SUMMARY
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Monitoring Well	*Concentration (µg/L)*									
	05/90 AHR	*07/90 AHR*	*07/90 (4)*	*8/90 (OC)*	*11/90 (5)*	*10/92 (6)*	*11/92 (6)*	*2/94 (OC)*	*5/94 (OC)*	*6/94 (7)*
Abandoned Wells										
Y-1	--	--	ND1.0	--	2.7	--	--	--	--	--
Y-2	--	--	ND1.0	--	2.8	--	--	--	--	--
Y-3A	--	--	ND1.0	--	4.7	--	--	--	--	--
Y-3B	--	--	ND1.0	--	3.6	--	--	--	--	--
Y-4A	--	--	ND1.0	--	3.9	--	--	--	--	--
Y-5	--	--	ND1.0	--	0.7	--	--	--	--	--
Y-6	--	--	ND1.0	--	--	--	--	--	--	--
Y-7A	--	--	ND1.0	--	ND1.0	--	--	--	--	--
Y-7B	--	--	ND1.0	--	ND1.0	--	--	--	--	--
Y-8	--	--	ND1.0	--	ND2.0	--	--	--	--	--

Notes:

Ndxx - Not detected at detection limit xx.
- Exceeds carbon tetrachloride concentration MTCA Method B value of 0.337 µg/L.

(1) Data collected by Wehran.
(2) Data collected by Crosby & Overton.
(3) Summary of Environmental Investigation for Contaminated Wastes and Remedial Action, Vol. I, AHR Engineers, September 1989.
(4) Environmental Site Assessment, Vol. I, GeoEngineers, Inc., August 31, 1990.
(5) Report of Geoenvironmental Services Remedial Excavation of Soil, GeoEngineers, Inc., January 1991.
(6) Annual Report August 1992 to July 1993, Groundwater Monitoring Program, Applied Geotechnology, Inc., November 16, 1993.
(7) Technical Memorandum Phase I Remedial Investigation, Harding Lawson Associates, March 24, 1995.
(8) Analytical results from the Columbia Analytical Services, Inc. laboratory, October 25, 1995.
(9) Sampling Results from EMCON Report 10/4/95.
(OC) Olin Chemicals off-site monitoring well data (Report dated September 6, 1995).
Existing Monitoring Wells BMW-4, BMW-5, BMW-6, BMW-7, BMW-10, BMW-16, BMW-17, and PW-1 were not analyzed for carbon tetrachloride.
Monitoring well BMW-12 was not analyzed for carbon tetrachloride.

TABLE 2.8

CARBON TETRACHLORIDE GROUNDWATER CONCENTRATION SUMMARY
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Monitoring Well	*7/94 (7)*	*8/94 (7)*	*9/94 HLA*	*12/94 (OC)*	*4/95 (OC)*	*7/95 (8)*	*8/95 (9)*
<u>*Existing Wells*</u>							
7-A	–	–	–	–	–	–	–
9-D	–	–	–	–	–	–	–
11-BU	–	–	–	–	–	ND0.2	–
11-BL	–	–	–	–	–	4.3	–
11-CU	–	–	–	–	–	–	–
11-CL	–	–	–	–	–	–	–
11-D	–	–	–	–	–	–	–
11-E	–	–	–	–	–	–	–
HLA-1	9.7/9.0	–	–	–	–	9.9	–
12-A	–	–	–	–	–	–	–
14-AU	–	–	–	–	–	–	–
14-AL	–	–	–	–	–	–	–
Y-4B	–	0.5	–	–	–	0.5	–
BMW-1	–	–	–	–	–	0.5/0.5	–
BMW-2	–	ND0.2	–	–	–	0.3	–
BMW-3	–	–	–	–	–	0.5	–
BMW-8	–	ND0.2	–	–	–	ND0.2	–
BMW-9	–	–	–	–	–	ND0.2/0.4	–
BMW-11	–	–	–	–	–	ND0.2	–
BMW-13R	–	–	–	–	–	–	–
BMW-14	–	ND0.2	–	–	–	ND0.2	–
BMW-15	–	ND0.2	–	–	–	ND0.2	–
BMW-18	–	–	–	–	–	11	–
BMW-19	–	–	–	–	–	–	–
BMW-20	–	ND0.2	–	–	–	ND0.2	–
BMW-21		ND0.2/ND0.2	–	–	–	0.4	–
BMW-22	–	–	–	–	–	–	–

TABLE 2.8

CARBON TETRACHLORIDE GROUNDWATER CONCENTRATION SUMMARY
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Monitoring Well	*7/94 (7)*	*8/94 (7)*	*9/94 HLA*	*12/94 (OC)*	*4/95 (OC)*	*7/95 (8)*	*8/95 (9)*
Off-Site Wells							
Brown	–	–	ND0.2	–	–	ND0.2	–
Brewer	–	–	–	–	–	–	–
Burns	–	–	–	–	–	ND0.2	–
Campbell	–	–	–	–	ND0.2	–	0.3
Catchpole	–	–	–	ND	–	–	–
Eustace	–	–	ND0.2	–	–	–	–
Greenlaw	–	–	–	–	ND0.2	2.0	–
Kuhuski	–	–	0.7	0.86	–	1.4	–
LaPlant	–	–	–	–	–	–	–
Lively	–	–	–	0.21	–	0.8	–
Looker	–	–	0.4	–	–	0.7	–
Mattox	–	–	ND0.2	–	–	ND0.2	–
McLaughlin	–	–	–	–	ND0.2	–	ND0.2
Morris	–	–	ND0.2	–	–	ND0.2	–
Neunecker	–	–	–	–	–	–	0.6
Pettit/Cope	–	–	–	–	–	ND0.2	–
Pierce	–	–	–	–	0.48	–	0.3
Ramsey	–	–	–	0.9	–	1.7	–
Shotwell (shallow)	–	–	–	–	–	4.2	–
Shotwell (deep)	–	–	–	–	–	–	–
Tacoma Sportsment Club	–	–	–	–	–	–	–
Abandoned Wells							
9-A	–	–	–	–	–	–	–
9-B	–	–	–	–	–	–	–
9-C	–	–	–	–	–	–	–
11-A	–	–	–	–	–	–	–
20-AU	–	–	–	–	–	–	–
20-AL	–	–	–	–	–	–	–
21-A	–	–	–	–	–	–	–
21-B	–	–	–	–	–	–	–
21-C	–	–	–	–	–	–	–
21-D	–	–	–	–	–	–	–

TABLE 2.8

CARBON TETRACHLORIDE GROUNDWATER CONCENTRATION SUMMARY
RI/FS WORK PLAN
FREDERICKSON INDUSTRIAL PARK SITE
PIERCE COUNTY, WASHINGTON

Monitoring Well	7/94 (7)	8/94 (7)	9/94 HLA	12/94 (OC)	4/95 (OC)	7/95 (8)	8/95 (9)
Abandoned Wells							
Y-1	–	–	–	–	–	–	–
Y-2	–	–	–	–	–	–	–
Y-3A	–	–	–	–	–	–	–
Y-3B	–	–	–	–	–	–	–
Y-4A	–	–	–	–	–	–	–
Y-5	–	–	–	–	–	–	–
Y-6	–	–	–	–	–	–	–
Y-7A	–	–	–	–	–	–	–
Y-7B	–	–	–	–	–	–	–
Y-8	–	–	–	–	–	–	–

Notes:

Ndxx - Not detected at detection limit xx.
- Exceeds carbon tetrachloride concentration MTCA Method B value of 0.337 µg/L.
(1) Data collected by Wehran.
(2) Data collected by Crosby & Overton.
(3) Summary of Environmental Investigation for Contaminated Wastes and Remedial Action, Vol. I, AHR Engineers, September 1989.
(4) Environmental Site Assessment, Vol. I, GeoEngineers, Inc., August 31, 1990.
(5) Report of Geoenvironmental Services Remedial Excavation of Soil, GeoEngineers, Inc., January 1991.
(6) Annual Report August 1992 to July 1993, Groundwater Monitoring Program, Applied Geotechnology, Inc., November 16, 1993.
(7) Technical Memorandum Phase I Remedial Investigation, Harding Lawson Associates, March 24, 1995.
(8) Analytical results from the Columbia Analytical Services, Inc. laboratory, October 25, 1995.
(9) Sampling Results from EMCON Report 10/4/95.
(OC) Olin Chemicals off-site monitoring well data (Report dated September 6, 1995).
Existing Monitoring Wells BMW-4, BMW-5, BMW-6, BMW-7, BMW-10, BMW-16, BMW-17, and PW-1 were not analyzed for carbon tetrachloride.
Monitoring well BMW-12 was not analyzed for carbon tetrachloride.

APPENDIX B

VAPOR INTRUSION EVALUATION

APPENDIX B

VAPOR INTRUSION EVALUATION
FREDERICKSON INDUSTRIAL PARK, FREDERICKSON, WASHINGTON

This Appendix presents the results of an evaluation of the potential for subsurface carbon tetrachloride (CTC) vapors related to the Frederickson Industrial Park (the Site) to migrate into the indoor air of occupied buildings (i.e., vapor intrusion; VI) at or near the Site. The Department of Ecology Draft Guidance for Evaluating Vapor Intrusion[1] (Draft Guidance) was utilized in this analysis. The Draft Guidance recommends a tiered evaluation approach, beginning with a preliminary assessment and progressing through Tier 1, 2, and 3 assessments depending on results of each analysis. This Appendix describes the pertinent Site characteristics and results of the preliminary and Tier 1 assessments, and outlines options for further actions to complete the assessment.

SITE CHARACTERISTICS

The Property is a 527 acre active industrial facility in Pierce County, Washington, that is surrounded by several properties representing a mix of land uses. Two active industrial buildings are located on-Property. Previous investigations identified historic disposal areas approximately 350 feet west of the on-Property buildings near the western property boundary, as shown on Figure B1. CTC was detected in the Site groundwater, but groundwater sampling during the Remedial Investigation[2] did not identify any other significant detections of volatile organic compounds (VOCs)[3]. Excavation and removal of the disposal areas was conducted in 1989 through 1991. Subsequently in 1999, Conestoga Rovers & Associates (CRA) conducted a soil gas survey of the areas where CTC may have been handled at the Property and concluded that a CTC source area was not identifiable[3].

The subsurface is comprised of over 400 feet of unconsolidated interlayered fine and coarse grained materials, the majority of which are glacial deposits. The uppermost unit, referred to as Aquifer A, is more than 100 feet thick. The shallow portion (and vadose zone) of Aquifer A is

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[1] Department of Ecology; Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action; Washington State Department of Ecology, Toxics Cleanup Program, Publication no. 09-09-047, Review Draft, October 2009. http://www.ecy.wa.gov/programs/tcp/policies/VaporIntrusion/vig.html.

[2] Conestoga-Rovers and Associates, 1999; Task 5: Technical Memorandum No. 1; Frederickson Industrial Park Site, Pierce County, Washington. Prepared by Conestoga-Rovers & Associates, August 1999.

[3] Conestoga-Rovers and Associates, 1999; Task 5: Technical Memorandum No. 1; Frederickson Industrial Park Site, Pierce County, Washington. Prepared by Conestoga-Rovers & Associates, August 1999.

comprised of the Vachon Glacial Outwash, which is a mix of coarse sand and gravel. Aquifer A is unconfined with groundwater flow to the north and northwest. Monitoring wells screened across the water table show it to be located at a depth of about 15 to over 100 feet, with the variation in depth related to variations in topographic elevation. Based on the 2010 water level measurements (Table 2-2 of this RI/FS Report), the depth to the water table is approximately:

- 38 feet beneath the Property;
- 50 to >100 feet just north of the Property;
- 50 feet at 176th Street East; and
- 15 feet at monitoring well P2 near Clover Creek.

Figures 2-4a and 2-6a of this RI/FS Report are maps of the Aquifer A groundwater CTC data based on June 2010 and February 2011 groundwater sampling, respectively. CTC in groundwater extends from the Property approximately 3,000 feet to the north and northwest, with the highest concentrations corresponding to on-Property monitoring wells. The results of groundwater samples collected every 10 feet during the installation of monitoring well MW-13 show that the CTC is present in this area in the deeper portions of Aquifer A; samples collected from the top 20 feet of Aquifer A did not have detectable concentrations of CTC (Table 2-3 of this RI/FS Report). This layer of clean groundwater represents a barrier to volatilization of CTC from groundwater to soil gas.

CTC concentrations in Aquifer A are generally declining over time or are stable, as discussed in Section 2.3.6 of this RI/FS Report. For example, CTC concentrations for samples from well BMW-18 (screened in the upper portion of the aquifer) have decreased from 14 µg/L in 1992 to 7.8 µg/L in June 2010, and further to 4.5 µg/L in February 2011.

PRELIMINARY ASSESSMENT

The preliminary assessment involves evaluating whether: (1) volatile and toxic constituents are present in the subsurface; and (2) existing buildings are within 100 feet (or buildings could be constructed within 100 feet) of the constituents. The preliminary assessment concludes that:

- CTC is considered volatile and toxic; it is included in Table B-1 of the Draft Guidance.

- Geosyntec identified buildings within 100 feet of the zone of CTC in groundwater based on inspection of imagery available online from Google Earth® and later confirmed via a site visit. All buildings located were assumed to be occupied. Figure B2 shows the building locations.

Geosyntec is not aware of any Site conditions that would trigger the need for immediate action per the Draft Guidance (i.e., spill within a structure, odors, reported health effects, light non-aqueous phase liquid (LNAPL) free product adjacent to or beneath a building, fire or explosive risk). Therefore a Tier 1 screening is the next step.

VAPOR INTRUSION TIER 1 SCREENING

The Tier 1 Screening process includes identification of the vapor source (vadose zone soil contamination and/or VOCs in shallow groundwater), comparison of measured groundwater and/or soil gas concentrations to generic Tier 1 screening levels, and predictive modeling.

Identification of Vapor Sources

The Draft Guidance requires that soil and groundwater be considered as potential vapor sources. The Tier 1 evaluation considers both soil and groundwater as potential vapor sources, and thus soil gas and groundwater data are compared to the generic Tier 1 screening levels.

Comparison of Soil Gas Data to Tier 1 Screening Levels

The 1999 soil gas survey was conducted at sampling grids established over five areas where CTC was previously handled. Soil gas samples from depths of 5 and 15 feet below ground surface (ft bgs) were collected at the locations shown in Attachment A and analyzed by portable gas chromatograph with analytical detection limits of 0.1 $\mu g/m^3$ (0.0001 µg/L). The highest CTC concentration identified was 186.3 $\mu g/m^3$ collected from a depth of 14.5 ft bgs in Area 5 (Attachment A). This result is slightly greater than the Tier 1 screening level of 170 $\mu g/m^3$ for 15 ft bgs samples at industrial buildings, but the location is over 300 feet from the nearest industrial building and the CTC soil gas distribution in Area 5 shows declining concentrations with increasing distance from this sample point. A soil gas sample from a depth of 5 ft bgs in Area 1 near the southeast corner of the southern building had a CTC concentration of 27.8 ug/m^3, which is slightly greater than the generic industrial soil gas screening levels of 17 ug/m^3 for 5 ft samples, but samples collected closer to the building had CTC concentrations that did not exceed the screening level. No other CTC soil gas concentrations exceeded the Tier 1 screening levels for industrial buildings. Based on these results, vadose zone soil in areas where CTC was previously handled is not evaluated further as a potential source of CTC vapors for indoor air.

Comparison of Groundwater Data to Tier 1 Screening Levels

Figure B2 shows the locations of occupied buildings that overlie, or are near, the zone of CTC in groundwater. The building uses include residential, commercial and industrial. The Draft Guidance also requires consideration of areas where buildings could be constructed. There are undeveloped lands along Clover Creek and just north of the Property that are zoned commercial. For the purposes of this evaluation, we assumed that commercial buildings could be constructed on these lands in the future.

The Draft Guidance identifies five conditions in which the generic Tier 1 screening levels are not applicable:

1. Fractured rock or karst vadose zone – the vadose zone is comprised of granular materials, not fractured rock or karst;

2. Utility corridor as preferential pathway – A natural gas pipeline traverses the area in a northeast-southwest direction on the northern boundary of the Frederickson Industrial Park Property (see Figure B2); however, no buildings overlie it;

3. Preferential pathways such as open utility penetrations, earthen floors or sumps – All buildings appear to be constructed with slab on grade foundations or crawl spaces. No information is available regarding open utility penetrations or other potential preferential pathways; however, dewatering sumps are unlikely given that the water table is deep enough that it would not be encountered by such structures;

4. Water table less than 15 ft bgs – the water table is deeper than 15 ft bgs; and

5. LNAPL free product – LNAPL free product has not been identified at the Site, and is not expected based on CTC (a compound that is denser than water) as the constituent of concern.

None of the five precluding conditions are knowingly present; therefore, for the purposes of this assessment, the generic Tier 1 screening levels are applicable.

Groundwater was evaluated by comparing measured groundwater concentrations to the Tier 1 screening levels for industrial and residential/commercial buildings. Table B-1 of the Draft Guidance shows values of 2.2 and 0.22 µg/L, respectively, for industrial and residential/commercial buildings. However, the Department of Ecology posted updates to their Method B values on April 13, 2011[4] that changes the screening values to 5.4 and 0.54 µg/L, respectively. Measured groundwater concentrations in Aquifer A in June 2010 ranged from non-detect to 9.4 µg/L (Figure 2-4a of this RI/FS Report) and in February 2011 ranged from non-detect to 4.5 µg/L (Figure 2-6a of this RI/FS Report). Given that CTC concentrations at several locations are greater than the screening levels, the next step in the Tier 1 process, predictive modeling, was conducted for groundwater.

Vapor Intrusion Modeling for Groundwater

When measured groundwater concentrations are above the Tier 1 screening levels, the Draft Guidance for Tier I specifies further evaluation. One of the options for further evaluation involves use of the Johnson and Ettinger model (JEM) to predict indoor air concentrations.

Geosyntec used the United States Environmental Protection Agency (US EPA) spreadsheet implementations of the JEM model (GW-ADV Version 3.1 02/04[5]). Conservative default values

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[4] The updates are described at the following Ecology website: https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx. The updated CTC values can be found at the following Ecology website: https://fortress.wa.gov/ecy/clarc/FocusSheets/updatesTable.htm.

[5] www.epa.gov/oswer/ riskassessment/airmodel/johnson_ettinger.htm

were used for input parameters, except where Site-specific information was available. Site-specific values of depth to water table, soil type, soil/groundwater soil temperature, and groundwater CTC concentrations were used. Table B1 lists the model input parameter values used and source of each value, as well as generic default values where applicable.

Land use and zoning is industrial for the Property. Pierce County zoning maps indicate commercial zoning for all areas north of the Property, although there are some residential areas in this area that appear to pre-date the county zoning. Aside from the two industrial buildings on the Property, the only presently occupied buildings within 100 feet of CTC in groundwater are relatively new commercial buildings on the southeast corner of Canyon Road East and 176th Street East. In addition, there are two residential buildings adjacent to the Property. All industrial and commercial buildings are understood to be slab on grade without significant open sub-floor structures such as sumps or trenches that could represent a preferential pathway for subsurface vapor migration. The residences are assumed to be slab on grade, but could have suspended floors with crawlspaces. No basements are present based on tax parcel data describing the residences as single story with zero basement square footage. Slab on grade foundations were assumed in this evaluation to be conservative.

To be conservative, a seasonal high water table is usually considered as site condition for the JEM (high water table results in a less thick vadose zone and less VOC attenuation). Comparison of the June 2010 and February 2011 water levels show that they were very similar, despite the different seasons in which they were measured. Comparison of these water levels with measurements over the period of 1989 to 1999 (data in the Remedial Investigation Report[3]) shows that the June 2010 and February 2011 water levels are near the highest of the range measured previously, but water level temporal variations during 1989 to 1999 are typically greater than 30 feet. For the purposes of this VI analysis, Geosyntec used the more conservative June 2010 water level data (Table 2-2), corresponding with the higher CTC concentration detections (compared to February 2011), to define the depth to the water table for modeling purposes.

Six scenarios, shown on Figure B3, were identified for predictive modeling based on the combination of building use, type, and locations; land use zoning; groundwater CTC data for monitoring wells (Table 2-1) and historic water supply wells (Table B2) collected over the last decade; and depth to the water table data (Table 2-2). This approach is conservative because, as shown in Table 2-1 of this RI/FS Report, groundwater CTC concentrations have been declining at many monitoring locations over the last decade.

- Scenario 1: Current industrial slab-on-grade buildings where the water table is 38 ft bgs and the CTC groundwater concentration ranges from 0.35 μg/L (BMW-3) to 14 μg/L (BMW-18) based data for BMW-3, MW-1 and BMW-18.

- Scenario 2: Current commercial slab-on-grade buildings where the water table is about 30 ft bgs and the CTC groundwater concentration ranges from non-detect (<0.096 μg/L) to

0.71 µg/L based on samples from the Wetherbee, Kuhuski and Bowman water supply wells and the shallow nested on-Property well 11-CU.

- Scenario 3: Current residential slab-on-grade buildings where the water table is about 35 ft bgs and the CTC groundwater concentration ranges between non-detect (<0.096 µg/L) and 0.1 µg/L based on samples from MW-3 and the Catchpole well.

- Scenario 4: Current residential slab-on-grade buildings where the water table is about 100 ft bgs and the CTC groundwater concentration is non-detect (<0.096 µg/L) to 1.1 µg/L based on samples from MW-4 and the Kuhuski and Pierce wells.

- Scenario 5: Current residential slab-on-grade buildings where the water table is about 120 ft bgs and the CTC groundwater concentration ranges from non-detect (<0.096 µg/L) to 1.1 µg/L based on samples from the Lemay #1, #2, and #3, Arthur, Wilcox, Coleman and Pierce wells and MW-4.

- Scenario 6: Future potential slab-on-grade commercial buildings where the water table is 15 ft bgs and the CTC groundwater concentration ranges from non-detect (<0.096 µg/L) to 1.5 µg/L based on samples from P-2S and the shallow samples collected at MW-13 during installation.

The JEM spreadsheet was used iteratively for each scenario by varying the groundwater concentration until the predicted indoor air CTC concentration (obtained from the INTERCALCS page of the JEM spreadsheet) matched the Indoor Air Cleanup Level specified in the Draft Guidance. The Draft Guidance shows values of 0.17 µg/m^3 and 1.7 µg/m^3, respectively, for residential / commercial and industrial buildings. However, the Department of Ecology posted updates to the values on April 13, 2011 that changes the Indoor Air Cleanup Level to 0.42 µg/m^3 and 4.2 µg/m^3, respectively. The corresponding groundwater concentration was then established as the site-specific groundwater screening level. The JEM spreadsheet input parameters and INTERCALCS pages for each scenario are provided in Attachment B. The table below compares the range of measured CTC concentrations to the site-specific groundwater screening level.

Scenario (Building type, depth to water table)	Range of Measured Groundwater CTC Concentration (ug/L)	Site-Specific Groundwater CTC Screening Level (µg/L)
Scenario 1 - Current industrial, 38 ft	0.35 to 14	54
Scenario 2 - Current commercial, 30 ft	<0.096 to 0.71	4.6
Scenario 3 - Current residential, 35 ft	<0.096 to 0.1	1.3
Scenario 4 - Current residential, 100 ft	<0.096 to 1.1	2.8
Scenario 5 - Current residential, 120 ft	<0.096 to 1.0	3.3
Scenario 6 - Future commercial, 15 ft	<0.096 to 1.5	3.2

None of the six scenarios modeled (Scenario 6) have measured groundwater concentrations that exceed the site-specific groundwater screening level. This evaluation uses conservative input parameters and conservative assumptions regarding groundwater concentrations that likely over-estimate current shallow groundwater concentrations. Data from water supply wells that were sampled between 2000 and 2002, and have since been abandoned, were included even though monitoring well data collected since 2002 show declining concentrations. Furthermore, many of the water supply wells also showed declining trends prior to abandonment. Additionally, on-Property well nest 11 and the vertical aquifer sampling conducted during installation of MW-13 show a vertical profile of clean shallow groundwater underlain by CTC-impacted groundwater. In circumstances where concentrations increase with depth, using CTC data for wells that are screened deeper in Aquifer A (such as MW-3 or MW-4 or some of the former water supply wells), rather than wells screened directly across the water table, may also over-estimate actual current shallow CTC groundwater concentrations. Despite the potential over-estimation, none of the groundwater CTC concentrations indicate the potential for vapor intrusion to be adversely impacting the existing buildings.

SUMMARY

This vapor intrusion assessment considered CTC in both vadose zone soil and groundwater as potential sources of CTC vapors to indoor air. Conservative assumptions regarding groundwater CTC concentrations and residential building construction were used in the assessment. Preliminary and Tier 1 assessments were conducted using draft state guidance. No unacceptable indoor air exposures were identified.

TABLES

Table B1
Input Parameters for the Johnson and Ettinger Model (1991)
Frederickson Industrial Park
Frederickson, Washington

Input Parameter	Symbol	Site-Specific Inputs	Units	Justification
Groundwater Concentration	C_W		µg/L	Varies for each scenario - See description in text
Depth Below Grade to Water Table	L_{WT}		cm	Varies for each scenario - See description in text
Soil Stratum Directly Above Water Table	-	A	unitless	Site-specific
Soil Type Directly Above Water Table	-	S	unitless	Site-specific
Average Soil/Groundwater Temperature	T_S	11	^oC	Figure 8 of USEPA User's Guide for Eval Subsurface VI into Buildings (June 19, 2003)
Depth Below Grade to Bottom of Enclosed Space Floor	L_F	15	cm	US EPA JEM default for slab on grade
Thickness of Soil Stratum A	h_A		cm	Set equal to depth to water table
Stratum A Soil Type	-	S	unitless	Site-specific
Stratum A Soil Dry Bulk Density	ρ_b^A	1.66	g/cm^3	US EPA JEM default value for Sand
Stratum A Soil Total Porosity	n^A	0.375	unitless	US EPA JEM default value for Sand
Stratum A Soil Water-Filled Porosity	θ_w^A	0.054	cm^3/cm^3	US EPA JEM default value for Sand
Enclosed Space Floor Thickness	L_{crack}	15	cm	US EPA JEM default for slab on grade
Soil-Building Pressure Differential	ΔP	40	$g/cm\text{-}s^2$	US EPA JEM default value
Enclosed Space Floor Length	L_B	1000	cm	US EPA JEM default value
Enclosed Space Floor Width	W_B	1000	cm	US EPA JEM default value
Enclosed Space Height	H_B	244	cm	US EPA JEM default value
Floor-Wall Seam Crack Width	w	0.1	cm	US EPA JEM default value
Indoor Air Exchange Rate	ER	0.25/1	1/h	US EPA JEM default value for basement residential scenario and CA DTSC (Dec 15/04) default value of 1.0 for industrial and commercial buildings
Average Vapor Flow Rate into Building	Q_{soil}	5	L/min	US EPA JEM default value
Averaging Time for Carcinogens	AT_C		yrs	Value not used in calculation of indoor air concentration
Averaging Time of Non-Carcinogens	AT_{NC}		yrs	Value not used in calculation of indoor air concentration
Exposure Duration	ED		yrs	Value not used in calculation of indoor air concentration
Exposure Frequency	EF		days/yr	Value not used in calculation of indoor air concentration
Target Risk for Carcinogens	TR		unitless	Value not used in calculation of indoor air concentration
Target Hazard Quotient for Non-Carcinogens	THQ		unitless	Value not used in calculation of indoor air concentration

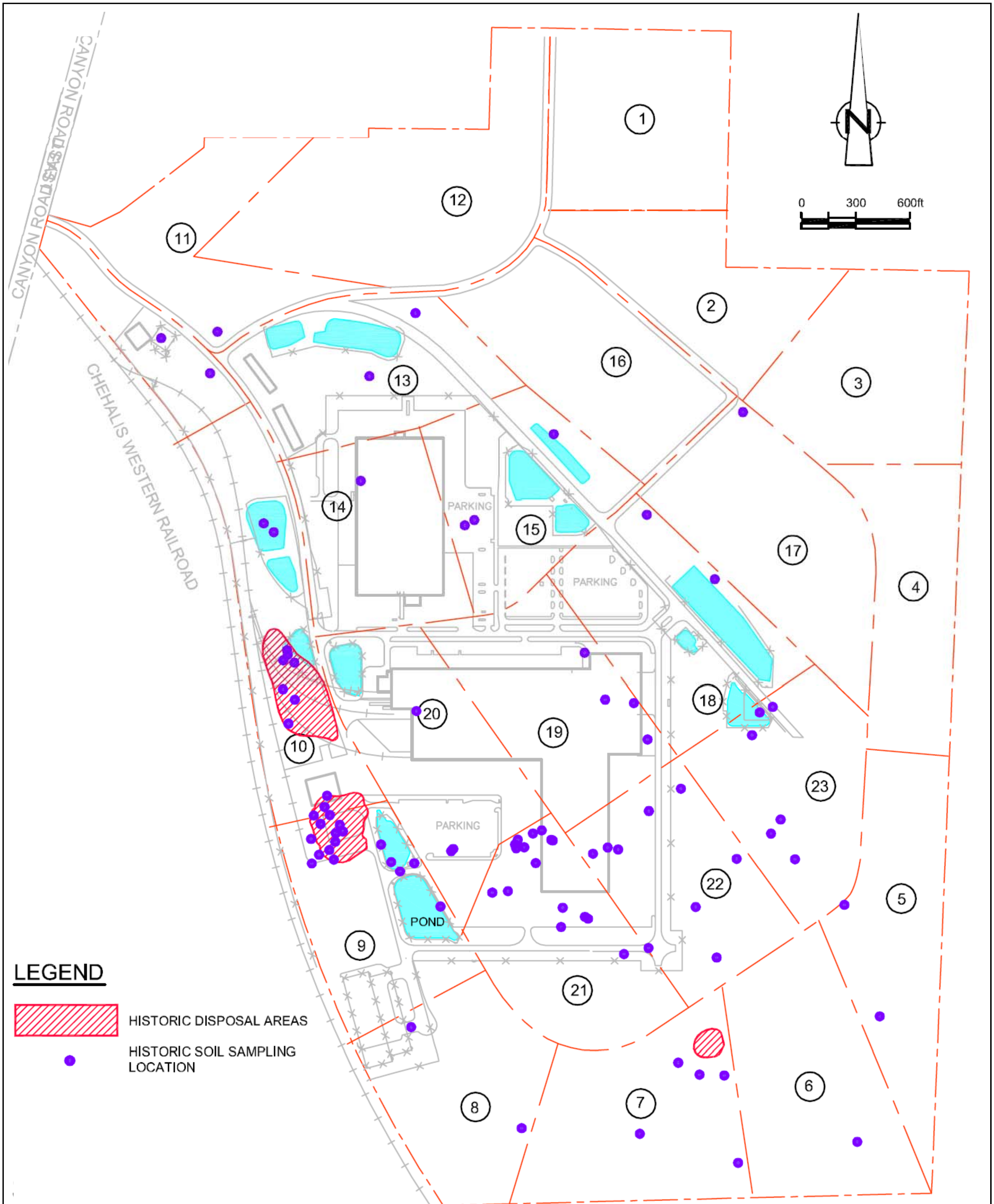
Notes:
µg - microgram
g - gram
^oC - degrees Celsius
cm - centimeter
L - liter
s - second
min - minute
h - hour
yr - year

Table B2
Historic Data for Water Supply Wells
Frederickson Industrial Park
Frederickson, Washington

Wells	Nov-88	Feb-89	Jul-89	Aug-89	Sep-89	Jan-90	Feb-90	Mar-90	Apr-90	May-90	Jul-90	Jul-90	Aug-90	Nov-90	Sep-88	Nov-92	Feb-94	May-94	Jun-94	Jul-94	Aug-94	Aug-90	Dec-94	Apr-95	Jul-95	Aug-95	Apr-99	Nov-00	Nov-02	Nov-02
7-A	--	0.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9-D	0.25	0.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11-BU	--	--	0.5	0.5	--	--	--	--	--	--	--	0.5	--	1.0	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	--
11-BL	--	--	0.5	0.5	--	**0.3**	**15.7**	**28.7**	--	**1.7**	**0.5**	0.5	--	**1.1**	--	**1.0**	--	--	--	--	--	--	--	--	**4.3**	--	**1.5**	**2.2**	**1.2**	--
11-CU	--	--	0.5	0.5	--	--	--	--	--	--	--	0.5	--	0.5	--	0.1	--	--	--	--	--	--	--	--	--	--	0.25	0.1	0.1	--
11-CL	--	--	**15.7**	**51.3**	**25.0**	**9.7**	**19.8**	**53.1**	--	**6.9**	**10.4**	**11.0**	--	**16.0**	--	**12.0**	--	--	--	--	--	--	--	--	--	--	**10.0**	**12.0**	**8.1**	--
11-D	--	--	--	--	--	--	--	--	--	--	--	**8.0**	--	**11.0**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11-E	--	--	--	**14.0**	**5.0**	**8.2**	**16.0**	**56.1**	**8.8**	**6.6**	**8.7**	**12.0**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HLA-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**9.7**	--	--	--	--	**9.9**	--	**12.0**	**12.0**	**8.1**	--
12-A	--	--	--	0.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14-AU	--	--	--	0.5	--	--	--	--	--	--	--	0.5	--	0.5	--	0.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14-AL	--	--	--	**27.2**	**19.0**	**5.3**	**15.9**	**52.9**	--	**3.1**	0.5	0.5	--	**10.0**	--	**9.7**	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Y-4B	--	--	--	--	--	--	--	--	--	--	--	0.5	--	**0.9**	--	**0.3**	--	--	--	--	**0.5**	--	--	--	**0.5**	--	--	--	--	--
BMW-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**1.3**	--	--	--	--	--	**0.5**	--	0.25	--	--	--
BMW-2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	0.1	--	--	--	**0.3**	--	0.25	0.1	0.1	--
BMW-3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**2.8**	**2.0**	--	**0.9**	--	--	--	--	--	**0.5**	--	--	**0.55**	**0.65**	--
BMW-8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	0.1	--	--	--	0.1	--	0.25	--	--	--
BMW-9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	--	0.4	--	0.25	--	--	--
BMW-11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	--	--	0.1	--	--	--	--	--
BMW-13R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	--	--	--	--	--	--	0.25	0.1	0.1	--
BMW-14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	0.1	--	--	--	0.1	--	0.25	--	--	--
BMW-15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	0.1	--	--	--	0.1	--	--	--	--	--
BMW-18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**13.0**	**14.0**	--	**9.3**	**12.0**	--	--	--	--	--	**11.0**	--	**9.6**	**12.0**	**7.5**	--
BMW-19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.5	0.1	--	--	--	--	--	--	--	--	--	--	0.25	0.1	0.1	--
BMW-20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	0.1	--	--	--	0.1	--	0.25	--	--	--
BMW-21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	0.1	--	--	--	**0.4**	--	--	--	--	--
BMW-22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**3.3**	**0.4**	--	--	--	--	--	--	--	--	--	--	**0.7**	**0.94**	**0.48**	--
MW1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**3.4**	**1.7**	--
MW2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	--
MW3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	--
MW4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**1.1**	**0.88**	--
MW5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	--
MW6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	--
MW7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**1.3**	--
P1S	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	--
P1I	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	--
P1D	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	--
P2S	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**1.5**	**1.3**	--
P2I	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**1.2**	**1.1**	--
P2D	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	--
MW1 (Randle)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	DRY	--
SW1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--
SW2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--
SW3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--
SW4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--
Arthur	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	***0.3***	***0.27***	**0.33**
Bowman (Lively)	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	--	--	--	--	--	**0.21**	--	**0.8**	--	***0.4***	**0.55**	***0.42***	**0.5**
Brewer	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Burns	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	0.1	--	--	--
Campbell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	**0.3**	**0.6**	**0.51**	***0.40***	**0.48**
Cannon	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.25	0.1
Catchpole	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	--	--
Coleman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	***0.5***	***0.5***	***0.4***	**0.46**
Eustace	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	0.1	--	--	--
Gray (Koegan) Deep	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.25	0.1
Gray (Koegan) Shallow	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.25	0.1
Haag	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.25	0.1
Kuhuski	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	--	--	--	--	**0.7**	**0.86**	--	**1.4**	--	**0.6**	**0.67**	**0.57**	**0.71**
Kuney Construction (Burne	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	***0.27***	**0.36**
LaPlant	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lemay #1 (Neunecker)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**0.6**	**0.7**	**0.5**	0.25	**0.69**
Lemay #2 (Jenson)	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	0.1	0.1	0.1	--	--	--	--	--	0.1	--	***0.4***	***0.4***	0.25	***0.5***
Lemay #3 (Universal Allied	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	***0.24***	**0.27**
Looker	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**0.4**	--	--	**0.7**	--	0.1	***0.3***	--	--
Mattox	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	0.1	--	0.1	--	--	--
McLaughlin	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	--	--	--	--	--	--	0.1	--	0.1	0.1	--	0.25	0.1
Morris	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	0.1	--	0.1	--	--	--
Nagle (Brown)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	0.1	--	0.1	--	0.25	0.1
Newell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.25	0.1
Pierce	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**0.48**	--	**0.3**	**0.6**	***0.4***	--	--
Racca	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.25	0.1
Ramsey	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**0.9**	--	**1.7**	--	--	--	--	--
Rennie	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**0.83**	**0.69**	**0.84**
Sherwood	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	***0.2***	***0.2***	***0.17***
Shira	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.25	***0.09***
Shotwell (deep)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.1	0.1	--	--	--	--	--	--	--	--	--	--	--
Shotwell (shallow)	--	--	--	--	--	--	--	--	--	--	--	--	4*	--	--	--	**3.8**	**3.8**	**3.8**	--	--	--	--	--	**4.2**	--	**4.6**	--	--	--
Tacoma Sportsmen Club	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wetherbee (Greenlaw)	--	--	--	--	--	--	--	--	--	--	--	--	0.1	--	--	--	--	--	--	--	--	--	--	0.1	**2.0**	--	**0.8**	**0.73**	--	--
Wilcox	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	***0.3***	***0.38***	**0.43**
Young	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**1.4**	**1.8**

Note:
1. Detected concentrations are **bolded**.
2. Estimated concentrations are **bolded** and ***italicized*** .

FIGURES



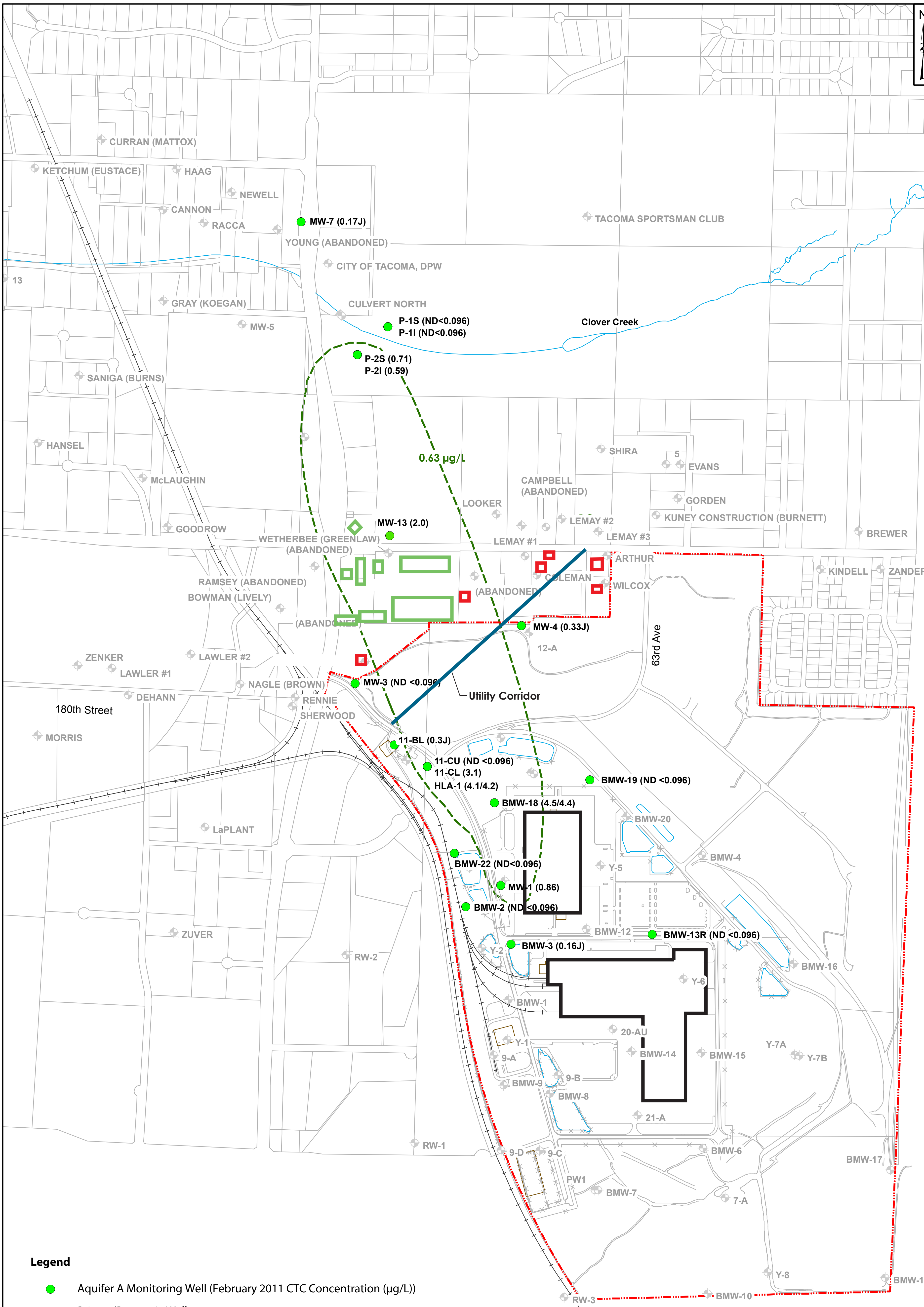
Historical Disposal Areas and Soil Sample Locations

Fredrickson (Brazier) Site Proposal
Fredrickson, WA

Geosyntec consultants
Kennesaw, Georgia

Figure B1

Figure Source is 24 February 2010 Presentation to Ecology



Legend

- Aquifer A Monitoring Well (February 2011 CTC Concentration (µg/L))
- Private/Domestic Wells
- CTC Contour of 0.63 µg/L
- Property Boundary
- Industrial Buildings
- Residential Buildings
- Commercial Buildings

(0.17 J) The results were above the Method Detection Limit (MDL), but below the Method Reporting Limit (MRL) and thus the values are estimated (i.e., j - flagged)

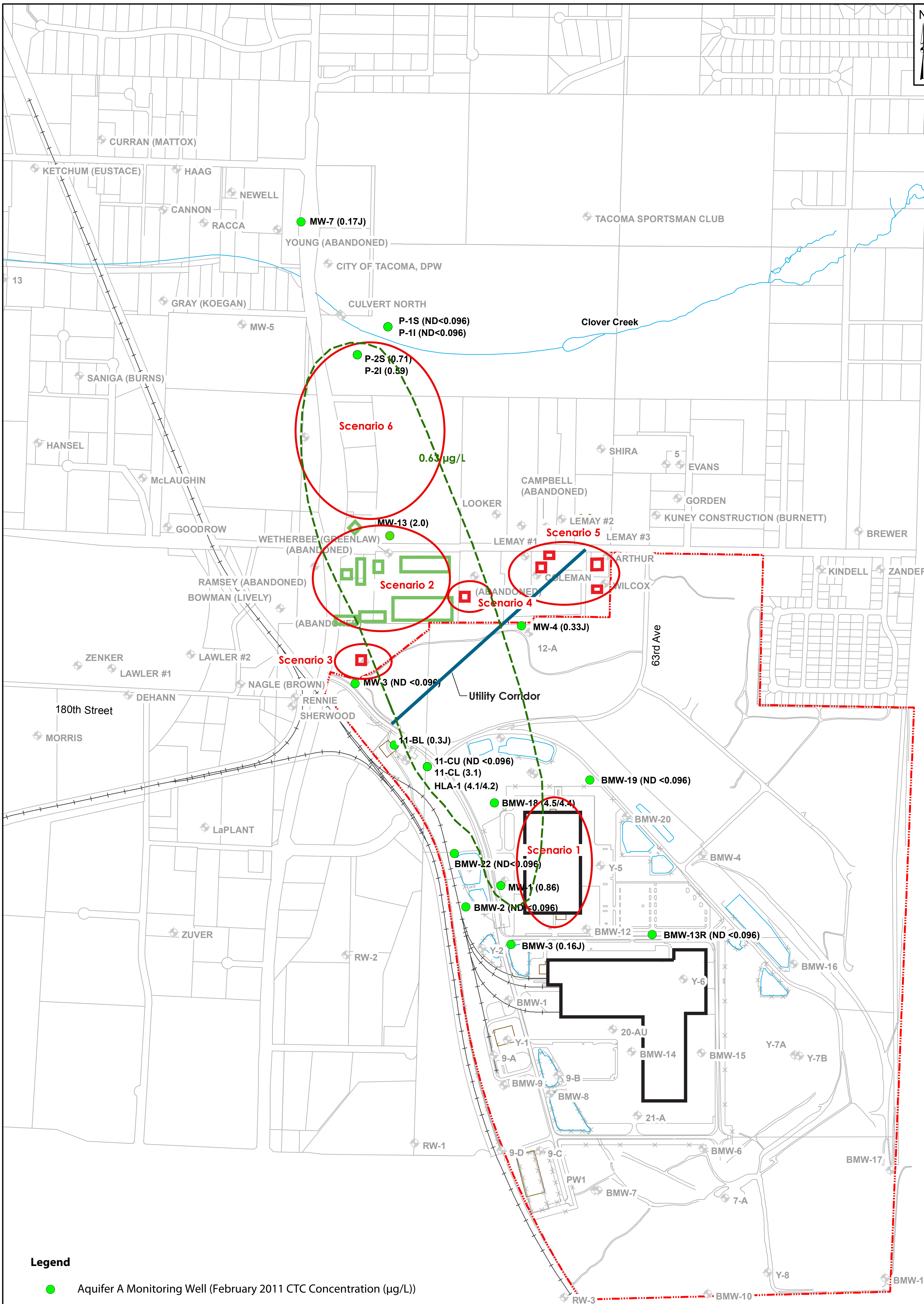
Building Locations Relative to CTC in Groundwater
Frederickson Industrial Park
Frederickson, WA

Geosyntec
consultants

Figure
B2

Kennesaw, GA | 1-August-2011

B-2 Building Locations_CTC in GW.ai



Legend

- Aquifer A Monitoring Well (February 2011 CTC Concentration (µg/L))
- Private/Domestic Wells
- CTC Contour of 0.63 µg/L
- Property Boundary
- Industrial Buildings
- Residential Buildings
- Commercial Buildings

(0.17 J) The results were above the Method Detection Limit (MDL), but below the Method Reporting Limit (MRL) and thus the values are estimated (i.e., j - flagged)

1,000 500 0 1,000 Feet

Scenarios for Predictive Modeling
Frederickson Industrial Park
Frederickson, WA

Geosyntec consultants

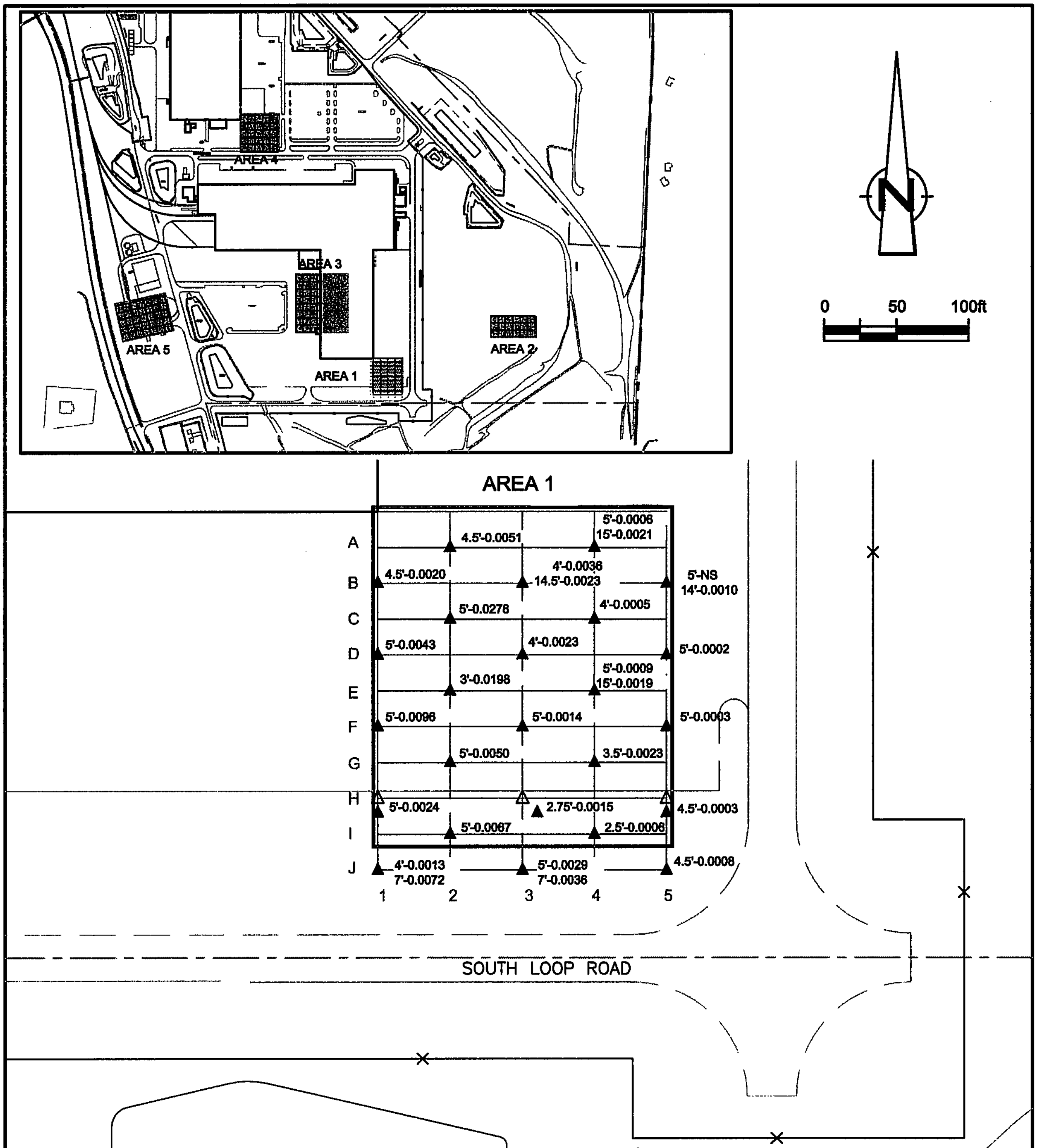
Kennesaw, GA | 1-August-2011

Figure
B3

B-2 Building Locations_CTC in GW.ai

ATTACHMENT A

SOIL GAS DATA



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

4'-0.0036 — FEET BELOW GROUND SURFACE — CTC SOIL GAS CONCENTRATION (ug/L)

△ INITIAL SOIL GAS SAMPLING ATTEMPT/LOCATION

▲ SOIL GAS SAMPLE LOCATION

ND NOT DETECTED (MDL=0.001 ug/L)

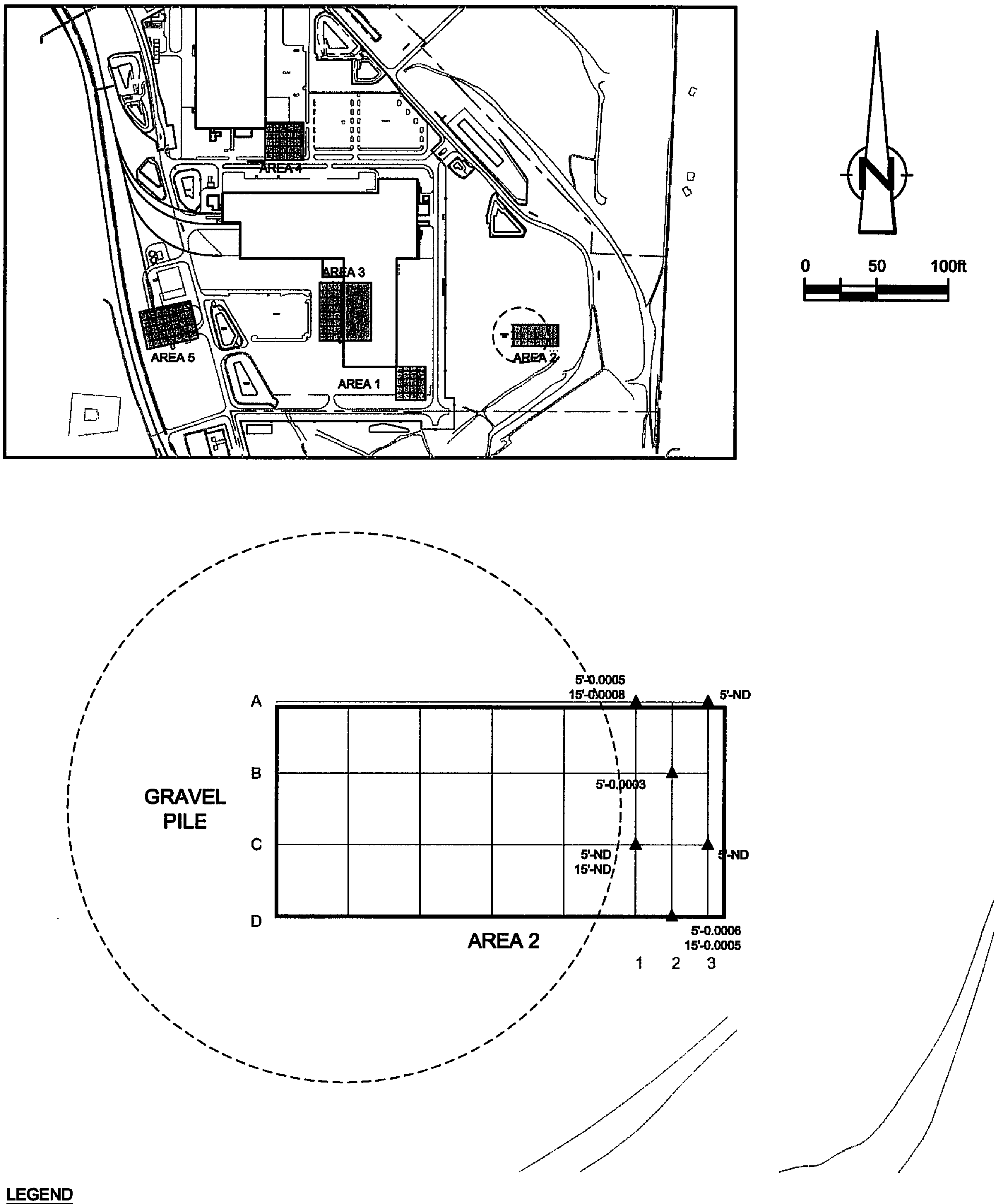
NS NOT SAMPLED

CRA

figure 5.1

AREA 1 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

06578-00(MEMO001)GN-WA003 MAY 28/1999



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

4'-0.0036 — FEET BELOW GROUND SURFACE — CTC SOIL GAS CONCENTRATION (ug/L)

▲ SOIL GAS SAMPLE LOCATION

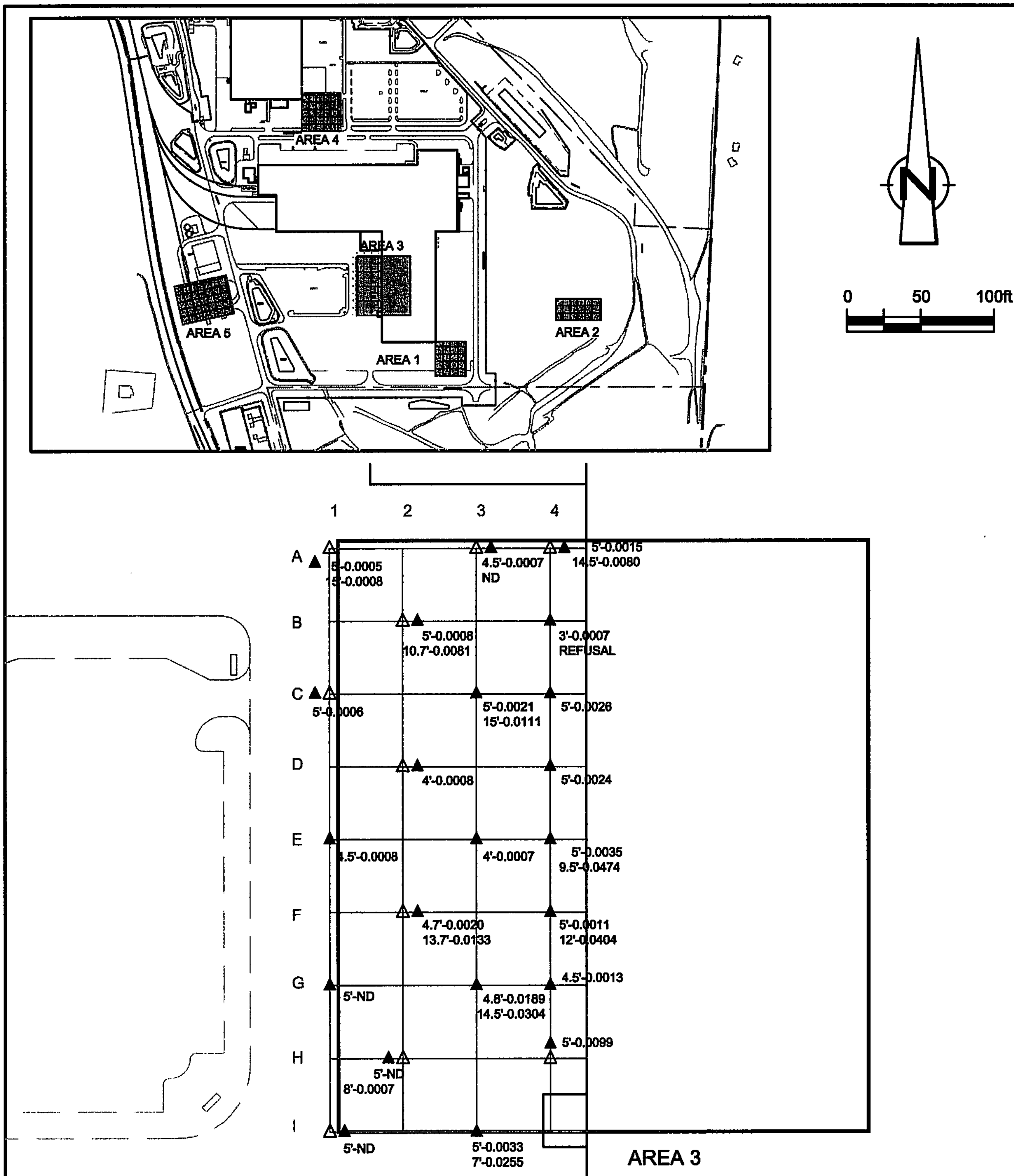
ND NOT DETECTED (MDL=0.0001 ug/L)

CRA

figure 5.2

AREA 2 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

06578-00(MEMO001)GN-WA004 MAY 28/1999



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

FEET BELOW GROUND SURFACE

4'-0.0036 — CTC SOIL GAS CONCENTRATION (ug/L)

△ INITIAL SOIL GAS SAMPLING ATTEMPT/LOCATION

▲ SOIL GAS SAMPLE LOCATION

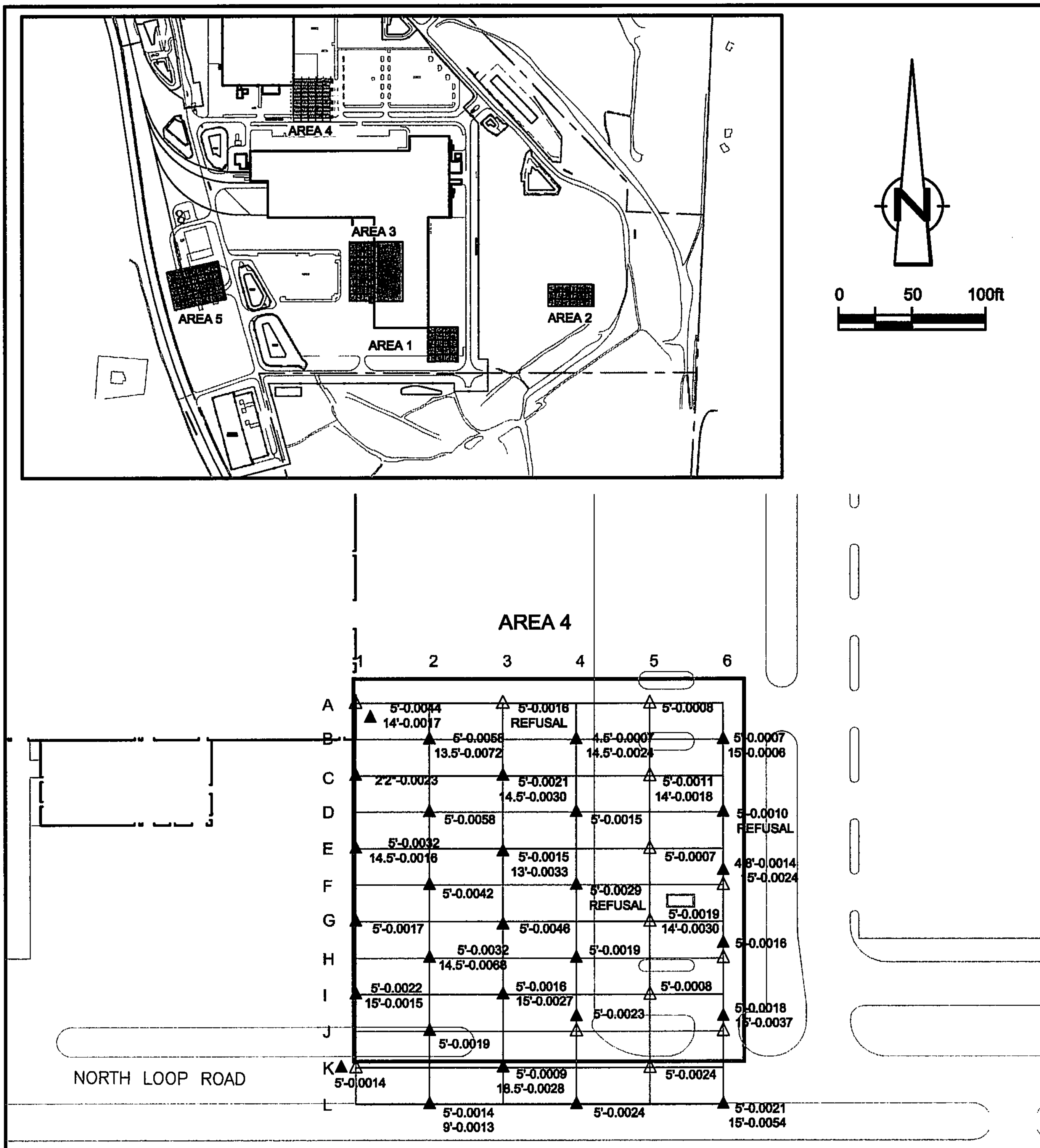
ND NOT DETECTED (MDL = 0.0001ug/L)

figure 5.3

AREA 3 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

06578-00(MEMO001)GN-WA005 MAY 31/1999



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

4'-0.0036 — FEET BELOW GROUND SURFACE — CTC SOIL GAS CONCENTRATION (ug/L)

△ INITIAL SOIL GAS SAMPLING ATTEMPT/LOCATION

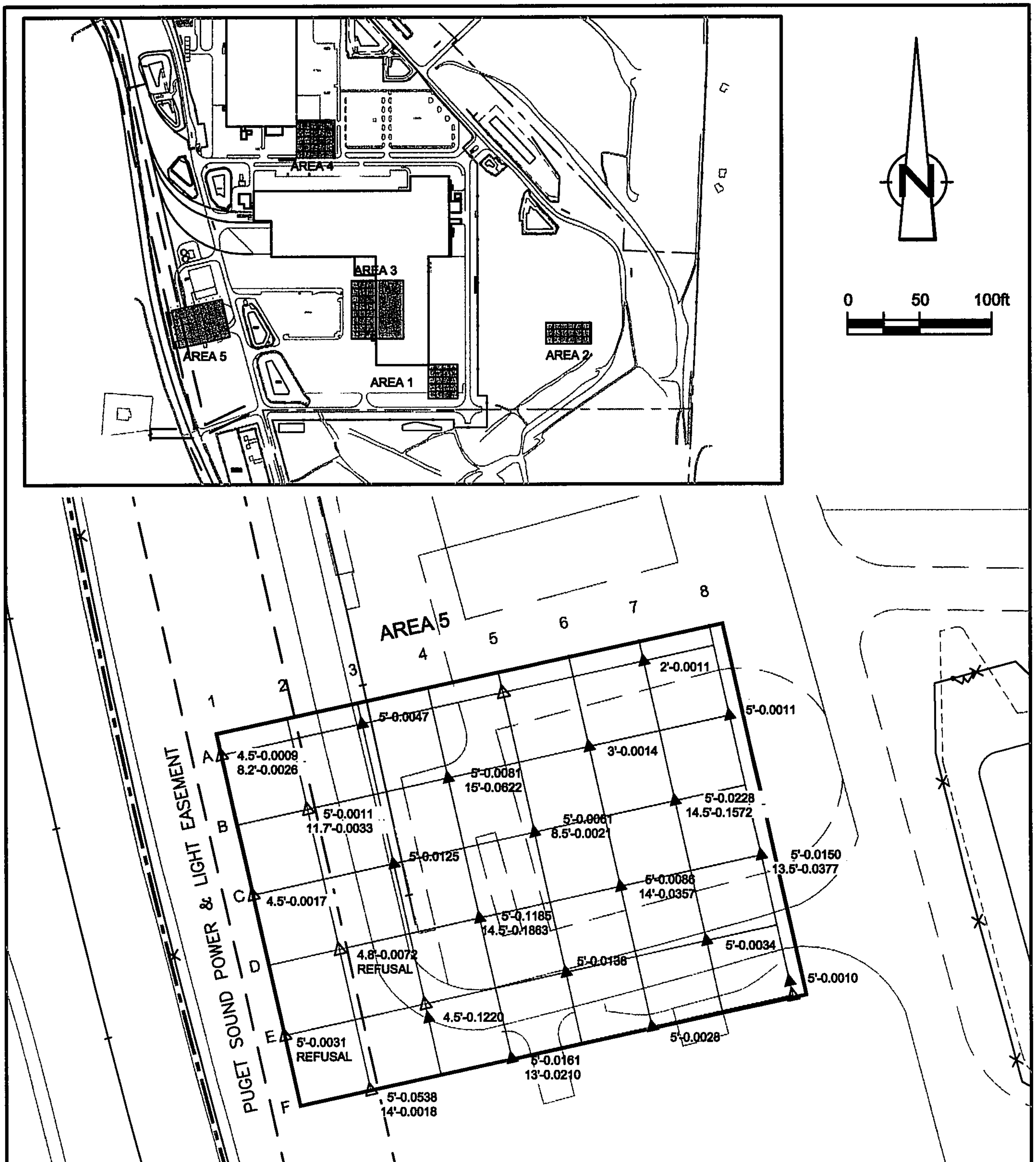
▲ SOIL GAS SAMPLE LOCATION

CRA

figure 5.4

AREA 4 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

06578-00(MEMO001)GN-WA007 MAY 31/1999



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

4'-0.0036 — FEET BELOW GROUND SURFACE — CTC SOIL GAS CONCENTRATION (ug/L)

△ INITIAL SOIL GAS SAMPLING ATTEMPT/LOCATION

▲ SOIL GAS SAMPLE LOCATION

APPROXIMATE LOCATION OF PUGET SOUND POWER AND LIGHT EASEMENT

figure 5.5

AREA 5 SOIL GAS SAMPLE LOCATIONS
FREDERICKSON INDUSTRIAL PARK SITE
Pierce County, Washington

CRA

06578-00(MEMO001)GN-WA008 MAY 31/1999

ATTACHMENT B

JOHNSON & ETTINGER MODELING

SCENARIO 1

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
56235	5.40E+01	Carbon tetrachloride

MORE ↓

ENTER Average soil/ groundwater temperature, T_S (^{o}C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
11	15	1158	1158	0	0	A	S	S		1.00E-08

Note: Thickness columns (ENTER): Totals must add up to value of L_{WT} (cell G28)

MORE ↓

ENTER Stratum A SCS soil type (Lookup Soil Parameters)	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type (Lookup Soil Parameters)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type (Lookup Soil Parameters)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054		1.5	0.43	0.215		1.5	0.43	0.215

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	244	0.1	1	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based groundwater concentration.

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	1143	0.321	0.215	0.215	0.003	9.94E-08	0.998	ERROR	17.05	0.375	0.122	0.253	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, $D^{eff}{}_A$ (cm^2/s)	Stratum B effective diffusion coefficient, $D^{eff}{}_B$ (cm^2/s)	Stratum C effective diffusion coefficient, $D^{eff}{}_C$ (cm^2/s)	Capillary zone effective diffusion coefficient, $D^{eff}{}_{cz}$ (cm^2/s)	Total overall effective diffusion coefficient, $D^{eff}{}_T$ (cm^2/s)	Diffusion path length, L_d (cm)
6.78E+04	1.06E+06	3.77E-04	15	7,849	1.58E-02	6.77E-01	1.76E-04	1.26E-02	0.00E+00	0.00E+00	5.00E-04	9.27E-03	1143

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	3.66E+04	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	1.15E-04	4.20E+00	1.5E-05	NA

END

SCENARIO 2

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	442	0.321	0.215	0.215	0.003	9.94E-08	0.998	ERROR	17.05	0.375	0.122	0.253	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
6.78E+04	1.06E+06	3.77E-04	15	7,849	1.58E-02	6.77E-01	1.76E-04	1.26E-02	0.00E+00	0.00E+00	5.00E-04	6.52E-03	442

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	2.17E+03	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	1.94E-04	4.21E-01	1.5E-05	NA

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
56235	3.20E+00	Carbon tetrachloride

MORE ↓

ENTER Average soil/ groundwater temperature, T_S (^oC)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
11	15	457	457	0	0	A	S	S		1.00E-08

MORE ↓

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054		1.5	0.43	0.215		1.5	0.43	0.215

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm-s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	244	0.1	1	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based groundwater concentration.

END

SCENARIO 3

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	3643	0.321	0.215	0.215	0.003	9.94E-08	0.998	ERROR	17.05	0.375	0.122	0.253	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
1.69E+04	1.06E+06	3.77E-04	15	7,849	1.58E-02	6.77E-01	1.76E-04	1.26E-02	0.00E+00	0.00E+00	5.00E-04	1.13E-02	3643

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	2.23E+03	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	1.87E-04	4.18E-01	1.5E-05	NA

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
56235	3.30E+00	Carbon tetrachloride

MORE ↓

ENTER Average soil/ groundwater temperature, T_S (^oC)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
11	15	3658	3658	0	0	A	S	S		1.00E-08

Totals must add up to value of L_{WT} (cell G28)

MORE ↓

ENTER Stratum A SCS soil type (Lookup Soil Parameters)	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type (Lookup Soil Parameters)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type (Lookup Soil Parameters)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054		1.5	0.43	0.215		1.5	0.43	0.215

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	244	0.1	0.25	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based groundwater concentration.

END

SCENARIO 4

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	3033	0.321	0.215	0.215	0.003	9.94E-08	0.998	ERROR	17.05	0.375	0.122	0.253	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
1.69E+04	1.06E+06	3.77E-04	15	7,849	1.58E-02	6.77E-01	1.76E-04	1.26E-02	0.00E+00	0.00E+00	5.00E-04	1.11E-02	3033

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	1.90E+03	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	2.19E-04	4.15E-01	1.5E-05	NA

END

GW-ADV
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
56235	2.80E+00	Carbon tetrachloride

MORE ↓

Totals must add up to value of L_{WT} (cell G28)

ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
11	15	3048	3048	0	0	A	S	S		1.00E-08

MORE ↓

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054		1.5	0.43	0.215		1.5	0.43	0.215

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	244	0.1	0.25	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based groundwater concentration.

END

SCENARIO 5

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	1052	0.321	0.215	0.215	0.003	9.94E-08	0.998	ERROR	17.05	0.375	0.122	0.253	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
1.69E+04	1.06E+06	3.77E-04	15	7,849	1.58E-02	6.77E-01	1.76E-04	1.26E-02	0.00E+00	0.00E+00	5.00E-04	9.06E-03	1052

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	8.67E+02	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	4.85E-04	4.21E-01	1.5E-05	NA

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
56235	1.28E+00	Carbon tetrachloride

MORE ↓

ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
11	15	1067	1067	0	0	A	S	S		1.00E-08

MORE ↓

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054		1.5	0.43	0.215		1.5	0.43	0.215

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	244	0.1	0.25	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based groundwater concentration.

END

SCENARIO 6

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	899	0.321	0.215	0.215	0.003	9.94E-08	0.998	ERROR	17.05	0.375	0.122	0.253	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
6.78E+04	1.06E+06	3.77E-04	15	7,849	1.58E-02	6.77E-01	1.76E-04	1.26E-02	0.00E+00	0.00E+00	5.00E-04	8.64E-03	899

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)
15	3.11E+03	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	1.34E-04	4.17E-01	1.5E-05	NA

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
56235	4.60E+00	Carbon tetrachloride

MORE ↓

ENTER Average soil/ groundwater temperature, T_S (^oC)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
11	15	914	914	0	0	A	S	S		1.00E-08

MORE ↓

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054		1.5	0.43	0.215		1.5	0.43	0.215

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm-s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	244	0.1	1	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based groundwater concentration.

END

APPENDIX C

SITE-SPECIFIC CARBON TETRACHLORIDE ATTENUATION RATE ESTIMATION

APPENDIX C

SITE-SPECIFIC CARBON TETRACHLORIDE ATTENUATION RATE ESTIMATION FREDERICKSON INDUSTRIAL PARK, PIERCE COUNTY, WASHINGTON

INTRODUCTION

Natural attenuation is the process by which natural processes clean up or attenuate contaminants in groundwater. Natural attenuation processes include a variety of physical, chemical, and/or biological processes that, under favorable conditions, reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. First-order attenuation rate constants can be used to characterize natural attenuation processes and evaluate the rate at which contaminant concentrations change temporally (EPA, 2002).

This Appendix summarizes the estimation of a site-specific carbon tetrachloride (CTC) attenuation rate for the Frederickson Industrial Park in Pierce County, Washington (the Site). The site-specific attenuation rate was used to aid in evaluation of monitored natural attenuation (MNA) as a remedial alternative for Site groundwater. The conceptual design for MNA is presented in Section 5 of the Remedial Investigation/Feasibility Study (RI/FS) Report.

METHODS

Attenuation rates were estimated using the method outlined in *Calculation and Use of First-order Rate Constants for Monitored Natural Attenuation Studies* (EPA, 2002). Rates were estimated for the twelve on-Property wells with a sufficient number of CTC detections to perform the analysis. The data for each well is summarized in Table C-1.

Attenuation rates for each well were estimated by graphing CTC detections versus time in Microsoft Office Excel®. An exponential trend line was added to each graph, representing best-fit regression of the data. The equation of the exponential trend follows the format shown in Equation (1):

$$C_t = C_0 \times e^{-k \times t} \qquad (1)$$

where t is time in years, C_t is the CTC concentration at time t in µg/L, C_o is the regression-estimated initial CTC concentration in µg/L, and k is the attenuation rate in inverse years. An example calculation is provided for BMW-18 in Figure C-1.

RESULTS

The attenuation rates for individual on-Property wells estimated using the methodology outlined above are summarized in Table C-2 and ranged from 0.037 to 0.28 year^{-1}. Regression statistics (i.e., standard error, R^2) are also provided in Table C-2. The site-specific attenuation rate constant was estimated to be 0.097 $year^{-1}$ based on the average of the individual well rate constants. If the data from the most recent sampling event (February 2011; which are the lowest concentrations to date) are excluded from the regression, the site-specific attenuation rate constant is 0.088 $year^{-1}$.

REFERENCES

Environmental Protection Agency (EPA), *Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies*. November, 2002.

TABLES

Table C-1
Historical Carbon Tetrachloride Groundwater Data
Frederickson Industrial Park
Frederickson, Washington

Date	Well											
	11-BL	11-CL	HLA-1	BMW-3	BMW-18	BMW-22	MW1	MW4	MW7	P2S	P2I	Pierce
Jul-89	ND(1.0)	15.7										
Aug-89	ND(1.0)	51.3										
Sep-89		25.0										
Jan-90	0.3	9.7										
Feb-90	15.7	19.8										
Mar-90	28.7	53.1										
May-90	1.7	6.9										
Jul-90	0.5	10.4										
Jul-90	ND(1.0)	11.0										
Nov-90	1.1	16.0										
Oct-92					13.0	3.3						
Nov-92	1.0	12.0		2.8	14.0	0.4						
Feb-94				2.0								
May-94					9.3							
Jun-94				0.9	12.0							
Jul-94			9.7									
Apr-95												0.48
Jul-95	4.3		9.9	0.5	11.0							
Aug-95												0.3
Apr-99	1.5	10.0	12.0		9.6	0.7						0.6
Nov-00	2.2	12.0	12.0	0.55	12.0	0.94	3.4	1.1		1.5	1.2	0.4
Nov-02	1.2	8.1	8.1	0.65	7.5	0.48	1.7	0.88	1.3	1.3	1.1	
Jun-10	1.0	9.4	9.3	***0.35***	7.8	***0.16***	1.2	1.0	***0.11***	0.5	0.64	0.1
Feb-11	***0.3***	3.1	4.1	***0.16***	4.5	ND(0.1)	0.86	***0.3***	***0.17***	0.71	0.59	

NOTES

Concentrations are in µg/L

0.5 = Estimated Value (i.e., concentration greater than method detection limit but less than method reporting limit)

ND(XX) = Non-Detected(Method Detection Limit)

Table C-2
Site-Specific Carbon Tetrachloride Attenuation Rates
Frederickson Industrial Park
Frederickson, Washington

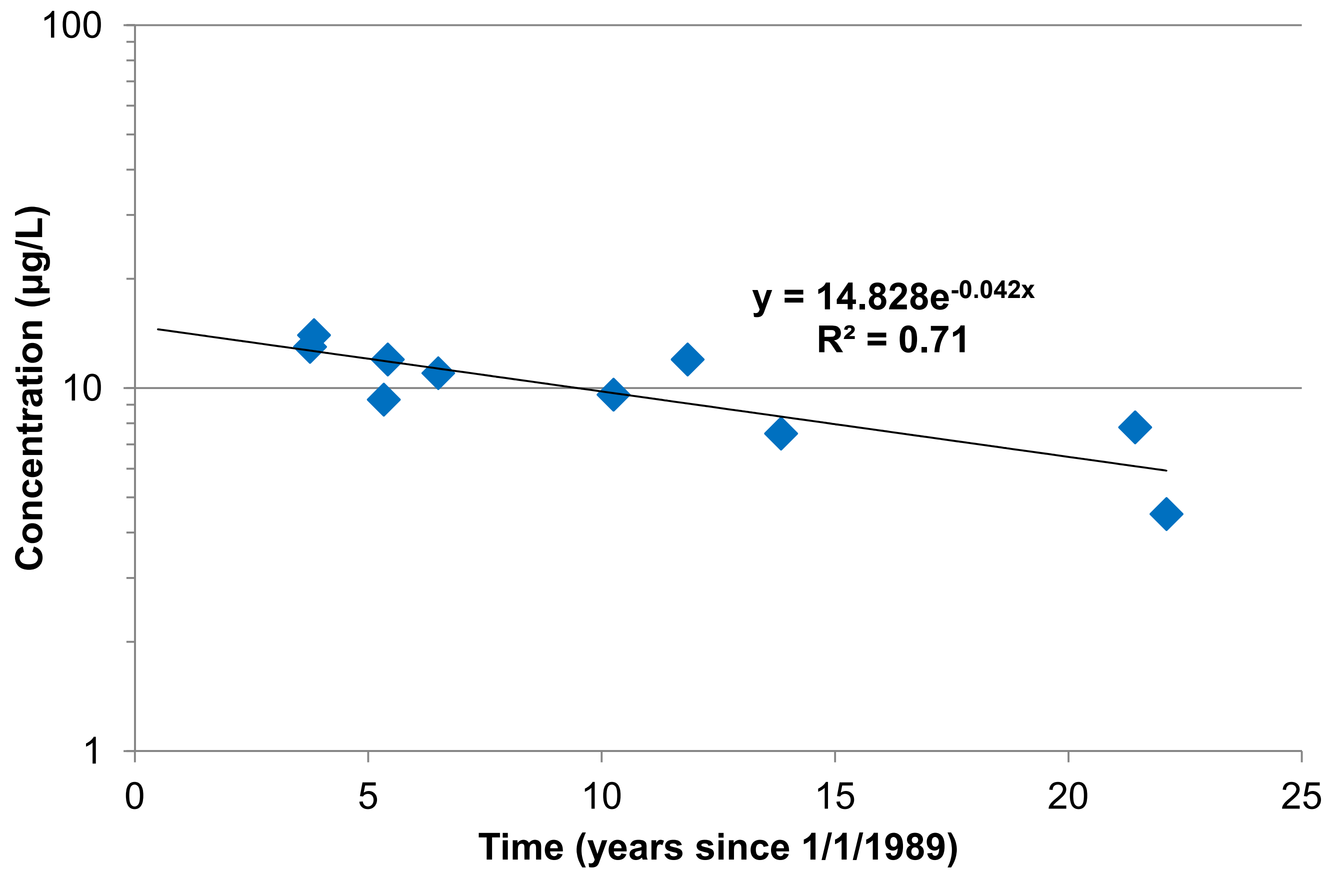
Well	Attenuation Rate (year^{-1})	Standard Error (year^{-1})	Regression Fit (R^2)	Half-Life (year)	CTC Concentration (µg/L)	MNA Duration (years)
11-BL	6.2E-02	5.0E-02	0.12	11.3	0.30	NA
11-CL	5.7E-02	2.0E-02	0.37	12.2	3.10	28
HLA-1	3.7E-02	1.8E-02	0.45	18.7	4.10	50
BMW-3	1.1E-01	2.7E-02	0.72	6.5	0.16	NA
BMW-18	4.2E-02	9.4E-03	0.71	16.7	4.50	47
BMW-22	1.1E-01	5.4E-02	0.49	6.5	ND	NA
MW1	1.0E-01	3.1E-02	0.85	6.7	0.86	3
MW4	6.6E-02	5.9E-02	0.38	10.5	0.30	NA
MW7	2.8E-01	6.8E-02	0.94	2.5	0.17	NA
P2S	9.3E-02	2.3E-02	0.89	7.4	0.71	1
P2I	7.0E-02	3.5E-03	0.995	10.0	0.59	NA
Pierce	1.4E-01	4.8E-02	0.74	5.0	0.10	NA
Average	**9.7E-02**	**-**	**-**	**7.2**	**-**	**26**

NOTES
1. Half-life = 0.693/[attenuation rate].
2. CTC concentration represents the most recent data for each well.
3. ND = Non-Detect.
4. NA = Not applicable; well concentration below cleanup concentration goal for CTC of 0.63 µg/L.
5. MNA duration estimated using the method outlined in *Calculation and Use of First-order Rate Constants for Monitored Natural Attenuation Studies* (EPA, 2002), using the following equation:

$$t = \frac{\ln\left(\frac{C_{goal}}{C_{start}}\right)}{-k}$$

where t is time in years, C_{goal} is the CTC cleanup concentration goal in µg/L, C_{start} is the most current concentration in µg/L, and k is the attenuation rate in inverse years.

FIGURE



Note:
Attenuation rate for BMW-18 was estimated by graphing CTC detections versus time in Microsoft Office Excel®. An exponential trend line was added to each graph, representing best-fit regression of the data. The equation of the exponential trend line followed the format shown below:

$$C_t = C_o \times e^{-k \times t}$$

where t is time in years, C_t is the CTC concentration at time t in µg/L, C_o is the regression-estimated initial CTC concentration in µg/L, and k is the attenuation rate in inverse years.

Using the above methodology, the attenuation rate for BMW-18 is estimated to be 0.042 year^{-1}.

Estimation of Carbon Tetrachloride (CTC) Attenuation Rate for BMW-18

Frederickson Industrial Park
Frederickson, Washington

Geosyntec consultants

Kennesaw, Georgia | 29-Sept-2011

Figure

C-1

N:\Frederickson\RIFS Report\Appendix C_MNA Rates

APPENDIX D

SUSTAINABILITY EVALUATION OF CLEANUP ACTION ALTERNATIVES

APPENDIX C

SITE-SPECIFIC CARBON TETRACHLORIDE ATTENUATION RATE ESTIMATION FREDERICKSON INDUSTRIAL PARK, PIERCE COUNTY, WASHINGTON

INTRODUCTION

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Attenuation rates for each well were estimated by graphing CTC detections versus time in Microsoft Office Excel®. An exponential trend line was added to each graph, representing best-fit regression of the data. The equation of the exponential trend follows the format shown in Equation (1):

$$C_t = C_0 \times e^{-k \times t} \qquad (1)$$

where t is time in years, C_t is the CTC concentration at time t in µg/L, C_o is the regression-estimated initial CTC concentration in µg/L, and k is the attenuation rate in inverse years. An example calculation is provided for BMW-18 in Figure C-1.

RESULTS

The attenuation rates for individual on-Property wells estimated using the methodology outlined above are summarized in Table C-2 and ranged from 0.037 to 0.28 year^{-1}. Regression statistics (i.e., standard error, R^2) are also provided in Table C-2. The site-specific attenuation rate constant was estimated to be 0.097 $year^{-1}$ based on the average of the individual well rate constants. If the data from the most recent sampling event (February 2011; which are the lowest concentrations to date) are excluded from the regression, the site-specific attenuation rate constant is 0.088 $year^{-1}$.

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Aug-89	ND(1.0)	51.3										
Sep-89		25.0										
Jan-90	0.3	9.7										
Feb-90	15.7	19.8										
Mar-90	28.7	53.1										
May-90	1.7	6.9										
Jul-90	0.5	10.4										
Jul-90	ND(1.0)	11.0										
Nov-90	1.1	16.0										
Oct-92					13.0	3.3						
Nov-92	1.0	12.0		2.8	14.0	0.4						
Feb-94				2.0								
May-94					9.3							
Jun-94				0.9	12.0							
Jul-94			9.7									
Apr-95												0.48
Jul-95	4.3		9.9	0.5	11.0							
Aug-95												0.3
Apr-99	1.5	10.0	12.0		9.6	0.7						0.6
Nov-00	2.2	12.0	12.0	0.55	12.0	0.94	3.4	1.1		1.5	1.2	0.4
Nov-02	1.2	8.1	8.1	0.65	7.5	0.48	1.7	0.88	1.3	1.3	1.1	
Jun-10	1.0	9.4	9.3	***0.35***	7.8	***0.16***	1.2	1.0	***0.11***	0.5	0.64	0.1
Feb-11	***0.3***	3.1	4.1	***0.16***	4.5	ND(0.1)	0.86	***0.3***	***0.17***	0.71	0.59	

NOTES
Concentrations are in µg/L
0.5 = Estimated Value (i.e., concentration greater than method detection limit but less than method reporting limit)
ND(XX) = Non-Detected(Method Detection Limit)

Table C-2
Site-Specific Carbon Tetrachloride Attenuation Rates
Frederickson Industrial Park
Frederickson, Washington

Well	Attenuation Rate ($year^{-1}$)	Standard Error ($year^{-1}$)	Regression Fit (R^2)	Half-Life (year)	CTC Concentration (µg/L)	MNA Duration (years)
11-BL	6.2E-02	5.0E-02	0.12	11.3	0.30	NA
11-CL	5.7E-02	2.0E-02	0.37	12.2	3.10	28
HLA-1	3.7E-02	1.8E-02	0.45	18.7	4.10	50
BMW-3	1.1E-01	2.7E-02	0.72	6.5	0.16	NA
BMW-18	4.2E-02	9.4E-03	0.71	16.7	4.50	47
BMW-22	1.1E-01	5.4E-02	0.49	6.5	ND	NA
MW1	1.0E-01	3.1E-02	0.85	6.7	0.86	3
MW4	6.6E-02	5.9E-02	0.38	10.5	0.30	NA
MW7	2.8E-01	6.8E-02	0.94	2.5	0.17	NA
P2S	9.3E-02	2.3E-02	0.89	7.4	0.71	1
P2I	7.0E-02	3.5E-03	0.995	10.0	0.59	NA
Pierce	1.4E-01	4.8E-02	0.74	5.0	0.10	NA
Average	**9.7E-02**	**-**	**-**	**7.2**	**-**	**26**

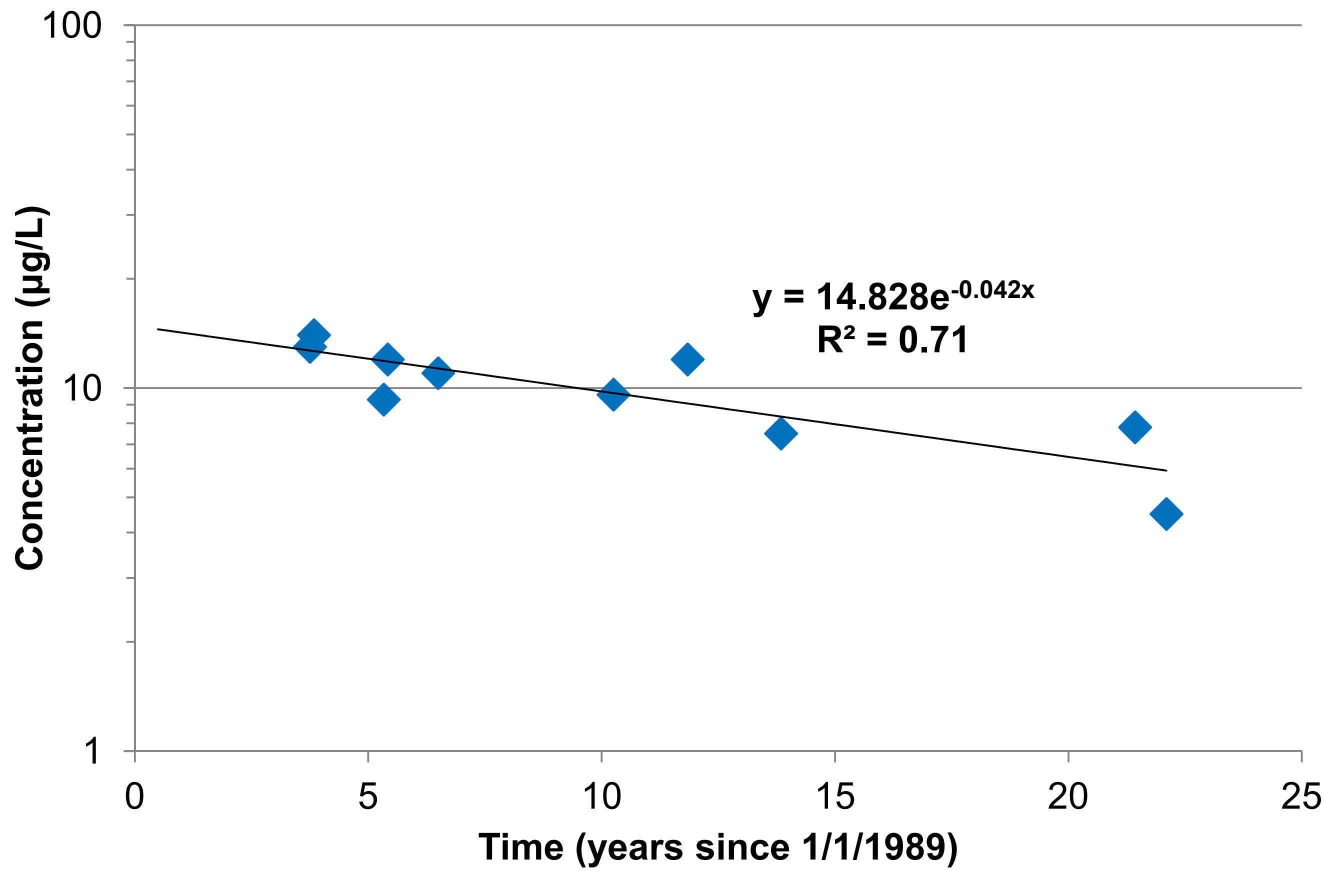
NOTES

1. Half-life = 0.693/[attenuation rate].
2. CTC concentration represents the most recent data for each well.
3. ND = Non-Detect.
4. NA = Not applicable; well concentration below cleanup concentration goal for CTC of 0.63 µg/L.
5. MNA duration estimated using the method outlined in *Calculation and Use of First-order Rate Constants for Monitored Natural Attenuation Studies* (EPA, 2002), using the following equation:

$$t = \frac{\ln\left(\frac{C_{goal}}{C_{start}}\right)}{-k}$$

where t is time in years, C_{goal} is the CTC cleanup concentration goal in µg/L, C_{start} is the most current concentration in µg/L, and k is the attenuation rate in inverse years.

FIGURE



Note:
Attenuation rate for BMW-18 was estimated by graphing CTC detections versus time in Microsoft Office Excel®. An exponential trend line was added to each graph, representing best-fit regression of the data. The equation of the exponential trend line followed the format shown below:

$$C_t = C_o \times e^{-k \times t}$$

where *t* is time in years, C_t is the CTC concentration at time *t* in µg/L, C_o is the regression-estimated initial CTC concentration in µg/L, and *k* is the attenuation rate in inverse years.

Using the above methodology, the attenuation rate for BMW-18 is estimated to be 0.042 year^{-1}.

Estimation of Carbon Tetrachloride (CTC) Attenuation Rate for BMW-18
Frederickson Industrial Park
Frederickson, Washington

Geosyntec consultants

Kennesaw, Georgia | 29-Sept-2011

Figure
C-1

N:\Frederickson\RIFS Report\Appendix C_MNA Rates

APPENDIX E

OVERVIEW OF TOTAL PETROLEUM HYDROCARBONS (TPHS) DISTRIBUTION AT THE FREDERICKSON INDUSTRIAL PARK

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TECHNICAL MEMORANDUM

Date: 22 February 2012

To: Rick McClure (Olin Corporation) and Kathy Zeigler (Covidien)

Copies: Dave Share (Olin Corporation), Patricia Duft (Covidien), and Jerry Ronecker (Husch Blackwell LLP)

From: Jim Deitsch and Evan Cox, Geosyntec Consultants

Subject: Overview of Total Petroleum Hydrocarbons (TPHs) Distribution at the Frederickson Industrial Park, Frederickson, Washington
Geosyntec Project: GR4631B.300.01

This *Technical Memorandum* was prepared by Geosyntec Consultants on behalf of Olin Corporation and Mallinckrodt US LLC (the Companies) to provide an overview of the historical investigations and remediation activities related to total petroleum hydrocarbons (TPHs) at the Frederickson Industrial Park in Frederickson, Washington (the Site). This *Technical Memorandum* addresses a 26 January 2012 email request from Guy Barrett (Washington Department of Ecology) to determine whether information is available that could provide confirmation that all contaminated soil at the Site has been remediated and thus eliminate the requirement for an environmental covenant for the property soil. The overview of TPH investigations and remediation activities are based on information presented in the reports titled *Environmental Site Assessment, Frederickson Industrial Park* (GeoEngineers, 1990) and *Report of Geoenvironmental Services, Remedial Excavation of Soil* (GeoEngineers, 1991). This *Technical Memorandum* also includes an evaluation that calculates TPH concentrations that may still be present at the Site and compares the calculated values to current Model Toxics Control Act (MTCA) cleanup levels for TPH.

TPH INVESTIGATIONS

This section presents an overview of the TPH investigations conducted at the Site in 1990 and is based on the report titled *Environmental Site Assessment, Frederickson Industrial Park* (GeoEngineers, 1990). Information pertinent to the distribution of TPH at the Site is summarized as follows:

- Centrum Properties conducted the removal of nine underground storage tanks and associated piping at four locations. Tanks included:
    - 15,000 and 7,000 gallon gasoline tanks located near guard house (Test Pit 14)
    - Bunker fuel and paraffin oil tank, size unknown (TP-4)
    - 500 gallon waste oil tank (TP-5)
    - Two 7,000 gallon tanks believed to have been used to store diesel fuel (TP-6)
    - Three additional tanks (TP-6) for which the information is not legible in the report
- Subsurface soil conditions investigated by drilling 12 borings, excavating 33 test pits, and performing an electromagnetic survey (Locations Shown in Figure 7; rationale in Table 1; provided in Attachment #1).
- Soil samples from borings, test pits, and shallow explorations were submitted for analytical testing, including total petroleum hydrocarbons (Method 418.1) and petroleum fuel identification (Modified Method 8105).
- Summary of TPH Results – Concentrations of TPH were greater than the cleanup standard for TPH (i.e., the 1990 DRAFT compliance cleanup level (CCL) established under MTCA of 200 mg/kg for TPH) in soil samples collected from Test Pits TP-1, TP-3, TP-4, TP-5, TP-9, TP-17, TP-19, and TP-26, and in shallow soil samples SS-1, SS-2, SS-6, and SS-8.
- Identification of proposed excavation areas **(Remediation Areas in Bold)**:
    - TP-1 – located in vicinity of Lot 9 disposal pit area, excavated at point of magnetic anomaly (Lot 9) – TPH = 320 mg/kg **(RE9-1)**
    - TP-3 – located within a former exfiltration basin that received water from pavement around the saw mill (Lot 20) – TPH = 630 mg/kg **(RE20-2)**
    - TP-4 – located at observed tar staining area near location of former bunker fuel UST and paraffin storage area (Lot 21) – TPH = 1,400 to 750,000 mg/kg **(RE21-1)**
    - TP-5 – Tank removal location (Lot 21) – TPH = 410 mg/kg **(RE21-2)**
    - TP-9 – soils near sawmill location (Lot 22) – TPH = 3,200 mg/kg **(RE22-1)**
    - TP-17 – Test pit at location of magnetic anomaly (Lot 21) - TPH = 51,000 mg/kg **(RE21-4)**
    - TP-19 – Test pit at location of magnetic anomaly (Lot 21) – TPH = 510 mg/kg **(RE21-1)**
    - TP-26 – outlet of storm drain line from impervious area around former lumber mill (Lot 23) – TPH = 11,000 mg/kg **(RE23-3)**
    - SS-1 – soil staining near electrical transformers (Lot 22) – TPH = 22,000 mg/kg **(RE22-4)**
    - SS-2 – stained soil from runoff of pavement (Lot 22) – TPH = 1,700 mg/kg **(RE22-4)**
    - SS-6 – stained soil near bunker (Lot 18) – TPH = 1,300 mg/kg **(RE18-1)**
    - SS-8 – soil from storm drain outlet (Lot 23) – TPH = 7,400 mg/kg **(RE23-1)**

- Test Pits TP-6 and TP-14 had concentrations of 78 mg/kg and 98 mg/kg, respectively. Both were below the cleanup criteria and thus were not targeted for further remediation.

TPH REMEDIATION

This section presents an overview of the TPH remediation conducted at the Site in 1990 and is based on the report titled *Geoenvironmental Services, Remedial Excavation of Soil* (GeoEngineers, 1991). Information pertinent to the remediation of TPH at the Site is summarized as follows:

- Gasoline-related contamination was not detected in the soil at the site. The 1990 DRAFT CCL under MTCA for TPH in the absence of gasoline products is 200 mg/kg.
- Approximately 7,120 cubic yards of soil with petroleum at concentrations greater than 200 mg/kg were excavated from 20 locations (Figure 2; provided in Attachment #1).
- Excavation completed successfully at 17 of 20 sites; the three locations not completed successfully are the following:
    - **RE22-1** – Approximately 1,420 yards excavated; maximum depth of 9 ft bgs. Four confirmation sidewall samples indicated that TPH in excess of 200 mg/kg was left in place along the northwest and southwest excavation walls due to the presence of the sawmill building. Residual sample concentrations along the two excavation walls ranged from 300 to 690 mg/kg. The sampling grid and results are shown in Figure 17 (Attachment #1); analytical results are presented in Table 22 (Attachment #1).
    - **RE-22-2** – Approximately 100 cubic yards excavated; maximum depth of 8 ft bgs. Two confirmation sidewall samples indicated that TPH in excess of 200 mg/kg was left in place along the north excavation wall due to the presence of a concrete pad. Residual sample concentrations along the excavation wall were 12,000 mg/kg at 2.5 ft bgs and 1,100 mg/kg at 6 ft bgs. The sampling grid and results are shown in Figure 18 (Attachment #1); analytical results are presented in Table 23 (Attachment #1).
    - **RE-22-3** – Approximately 110 cubic yards excavated; maximum depth of 12 ft bgs. Sidewall confirmation samples could not be collected due to the depth of the excavation; the base confirmation sample collected was below 10 mg/kg. The sampling grid and results are shown in Figure 19 (Attachment #1); analytical results are presented in Table 24 (Attachment #1).

EVALAUTION OF CURRENT TPH DISTRIBUTION

At the time the original remediation activities were conducted, the DRAFT MTCA cleanup level for TPH was 200 mg/kg (in the absence of gasoline range hydrocarbons). The current MTCA cleanup levels for TPHs are summarized in the following table:

	TPH, diesel range organics	TPH, heavy oils	TPH, mineral oil	TPH: gasoline range organics, benzene present*	TPH: gasoline range organics, no detectable benzene
Soil: MTCA Method A – Unrestricted	2,000 mg/kg	2,000 mg/kg	4,000 mg/kg	30 mg/kg	100 mg/kg
Soil: MTCA Method A – Industrial	2,000 mg/kg	2,000 mg/kg	4,000 mg/kg	30 mg/kg	100 mg/kg

As noted in the TPH Remediation section, gasoline-related contamination was not detected in the soil at the site and thus the appropriate MTCA cleanup level for this evaluation is 2,000 mg/kg. The three locations where remediation was not completed successfully were evaluated against the current MTCA cleanup level for TPH:

- **RE22-1:** Residual sample concentrations along the two excavation walls ranged from 300 to 690 mg/kg. Since these concentrations are well below the current MTCA cleanup level, no further action is needed in this area.
- **RE22-2:** Residual sample concentrations along the excavation wall were 12,000 mg/kg at 2.5 ft bgs and 1,100 mg/kg at 6 ft bgs. The 12,000 mg/kg sample is above the current MTCA cleanup level and thus this location requires further consideration.
- **RE22-3:** Excavation was continued until visual staining was no longer observed. Given the low concentration of the base confirmation sample, it is reasonable to assume that the sidewall samples would have been less than the current CCL of 2,000 mg/kg.

Given that soil containing TPH in excess of 2,000 mg/kg was left in place at RE22-2, a TPH degradation analysis was performed to estimate the potential, present day TPH concentration at RE22-2. A literature survey was conducted to identify potential degradation rates for petroleum hydrocarbons. The most comprehensive reference identified was the ASTM document *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (ASTM, 2010). Although petroleum hydrocarbons are typically composed of multiple constituents, the ASTM guidance states that aromatic hydrocarbons (e.g., benzene, toluene, ethylbenzene, xylenes [BTEX], polycyclic aromatic hydrocarbon [PAHs]) are typically the risk drivers. Based on toxicity, water solubility, subsurface mobility, and concentration in specific fuels, the ASTM guidance identifies BTEX and PAH constituents, as well as methyl tertiary butyl ether (MTBE), as commonly selected chemicals of concern (COCs) at petroleum release sites. **Table 1** (attached) provides attenuation rates for BTEX compounds, MTBE, and naphthalene and benzo(a)pyrene as representative PAHs. Consideration of these individual constituents is anticipated to be representative of a wide range of petroleum products, including gasoline, kerosene, jet fuels, diesel, and fuel oils (ASTM, 2010). The range of attenuation rates identified for representative individual TPH constituents is summarized in **Table 2**.

First-order attenuation rate constants can be used to characterize natural attenuation processes and evaluate the rate at which contaminant concentrations change temporally (EPA, 2002). Given historical concentrations and first-order attenuation rates, current contaminant concentrations can be estimated using the following equation:

$$C_t = C_0 \times e^{-k \times t} \qquad (1)$$

where t is time in days since collection of the historical sample, C_t is the contaminant at time t in mg/kg, C_o is the historical concentration in mg/kg, and k is the attenuation rate in inverse days. In Fall 1990, a single soil sample at the Frederickson Industrial Park contained 12,000 mg/kg TPH. Therefore, C_o is equal to 12,000 mg/kg, and t is 21 years (7,665 days). Additionally, groundwater attenuation rates are assumed to be applicable to soil contamination, which is reasonable given the wide range of groundwater attenuation rates observed. The minimum and maximum attenuation rates identified in the literature review (**Table 2**) were used to estimate ranges of current TPH concentrations.

Calculations of current TPH concentrations are provided in **Table 2**. Most of the attenuation rates derive TPH concentrations less than 1 mg/kg, while two of the attenuation rates derive concentrations levels of 12 and 56 mg/kg may still be present. These concentrations would still be more than an order of magnitude less than the current CCL of 2,000 mg/kg. It is also important to note that the estimated 2012 concentrations are conservative in that the 1991 sample was likely composed of a range of petroleum hydro carbon fractions and not a single fraction as assumed in the calculations presented in Table 2. Stated another way, the 56 mg/kg estimate (i.e., the maximum calculated value) assumes that the entire 1991 sample was composed of benzo(a)pyrene which is typically the most recalcitrant TPH constituent.

The approximate location of RE22-2 is shown in **Figure 1**. It is situated outside the operational fence of the Boeing facility and appears to be covered by a pile of gravel.

*****

TABLES

Table 1
Reported Attenuation Rates for Petroleum Hydrocarbons
Fredrickson Industrial Park
Frederickson, Washington

Class	Compound	Medium	Half-Life (day)	Attenuation Rate (day^{-1})	Type	Source
BTEX	benzene	Groundwater?	10 to 730	0.0009 to 0.069	-	ASTM, 2010
	benzene	Groundwater	58	0.01200	field	Buscheck et al. 1993
	benzene	Groundwater	165	0.0042	field	Buscheck et al. 1993
	benzene	Groundwater	231	0.003	field	Buscheck et al. 1993
	benzene	Groundwater	165	0.0042	field	Buscheck et al. 1993
	benzene	Groundwater	301	0.0023	field	Buscheck et al. 1993
	benzene	Groundwater	433	0.0016	field	Buscheck et al. 1993
	benzene	Groundwater	693	0.001	field	Buscheck et al. 1993
	toluene	Groundwater?	7 to 28	0.025 to 0.099	-	ASTM, 2010
	toluene	Groundwater	178	0.0039	field	Buscheck et al. 1993
	ethylbenzene	Groundwater?	6 to 228	0.003 to 0.116	-	ASTM, 2010
	ethylbenzene	Groundwater	103	0.0067	field	Buscheck et al. 1993
	xylenes	Groundwater?	14 to 365	0.0019 to 0.0495	-	ASTM, 2010
	xylenes	Groundwater	58	0.012	field	Buscheck et al. 1993
MTBE	MTBE	Groundwater?	8 to 365	0.0019 to 0.0866	-	ASTM, 2010
PAH	naphthalene	Groundwater?	258	0.0027	-	ASTM, 2010
	benzo(a)pyrene	Groundwater?	114 to 1058	0.0007 to 0.0061	-	ASTM, 2010
TPH	TPH (C23 - C40)	Soil	0.5	1.435	lab	Bento et al. 2005
	TPH (C23 - C40)	Soil	1	0.735	lab	Bento et al. 2005
	TPH (heavy fractions)	Groundwater	54	0.0128	lab	Lassen, 2005
	TPH (heavy fractions)	Groundwater	30	0.023	lab	Dreyer, 2005
	TPH (heavy fractions)	Groundwater	21	0.0329	lab	Cummingham, 2004

NOTES
1. BTEX = benzene, toluene, ethylbenzene, xylenes
2. MTBE = methyl tertiary butyl ether
3. PAH = polycyclic aromatic hydrocarbon
4. TPH = total petroleum hydrocarbons
5. - = Type not provided by cited reference.
6. References:

- ASTM, 2010. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, ASTM E1739 - 95(2010)e1.
- Buscheck, T.E., P.E. Kirk, T. O'Reilly, and S.N. Nelson, 1993. Evaluation of Intrinsic Bioremediaiton at Field Sites, Proceedings of the 1993 Petroleum Hydrocarbons and Organic Chemicals in Groudnwater: Prevention, Retention, and Restoration, Houston, TX, November 10-12, 1993.
- Bento, F.M., F.A.O. Camargo, B.C. Okeke, W.T. Frankenberger, 2005. Comparative bioremediation of soils contaminated with diesel oil by natural attenuation, biostimulation and bioaugmentation, Bioresource Technology, 96:1049-1055.
- Lassen, D.T., 2005. Monitoring Natural Attenuation of Hydrocarbons along Vertical Profiles using Nested Wells. Master's Thesis, California Polytechnic State University, San Luis Obispo, 2005.
- Dreyer, M.G, Y.M. Nelson, and C. Kitts, 2005. Weathering Effects on Biodegradation and Toxicity of Hydrocarbons in Groundwater, Proceedings of the Eight International In Situ and On-Site Bioremediaiton Symposium, Baltimore, MD, June 6 - 9, 2005.
- Cummingham, C.R. 2004. Biodegradation Rates of Weathered Hydrocarbons in Controlled Laboratory Microcosms and Soil Columns Simulating Natural Attenuation Field Conditions, Master's Thesis, California Polytechnic State University, San Luis Obispo, 2004.

Table 2
Estimated TPH Concentration
Frederickson Industrial Park
Frederickson, Washington

Class	Compound	Minimum Attenuation Rate (day-1)	Maximum Attenuation Rate (day-1)	Assumed 1991 TPH Concentration (mg/kg)	Estimated Current TPH Concentration	
					Minimum (mg/kg)	Maximum (mg/kg)
BTEX	benzene	0.0009	0.069	12,000	<1	12.11
	toluene	0.0039	0.099	12,000	<1	<1
	ethylbenzene	0.003	0.116	12,000	<1	<1
	xylenes	0.0019	0.0495	12,000	<1	<1
MTBE	MTBE	0.0019	0.0866	12,000	<1	<1
PAH	naphthalene	0.0027	0.0027	12,000	<1	<1
	benzo(a)pyrene	0.0007	0.0061	12,000	<1	56.10
TPH	TPH (C23 - C40)	0.735	1.435	12,000	<1	<1
	TPH (heavy fractions)	0.0128	0.0329	12,000	<1	<1

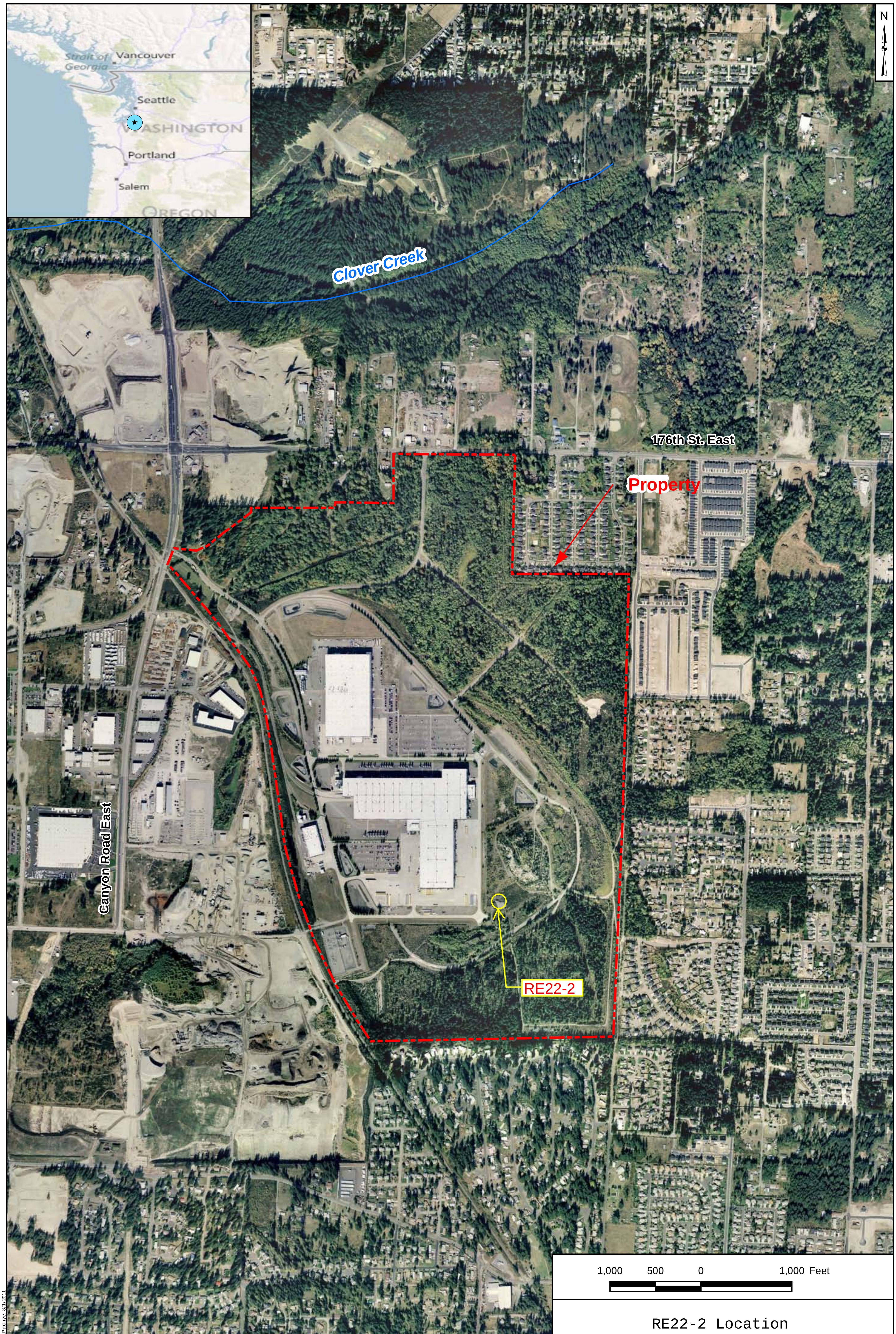
NOTES

1. The current TPH concentration was estimated using the method outlined in *Calculation and Use of First-order Rate Constants for Monitored Natural Attenuation Studies* (EPA, 2002), using the following equation:

$$C_t = C_o e^{-kt}$$

where t is time in days, C_t is the TPH concentration in mg/kg at time t, C_o is the 1991 TPH concentration in mg/kg, and k is the attenuation rate in inverse days.

FIGURES



RE22-2 Location

Fredericksen Industrial Park
Frederickson, WA

Geosyntec consultants

Kennesaw, GA

12-February-2012

Figure 1

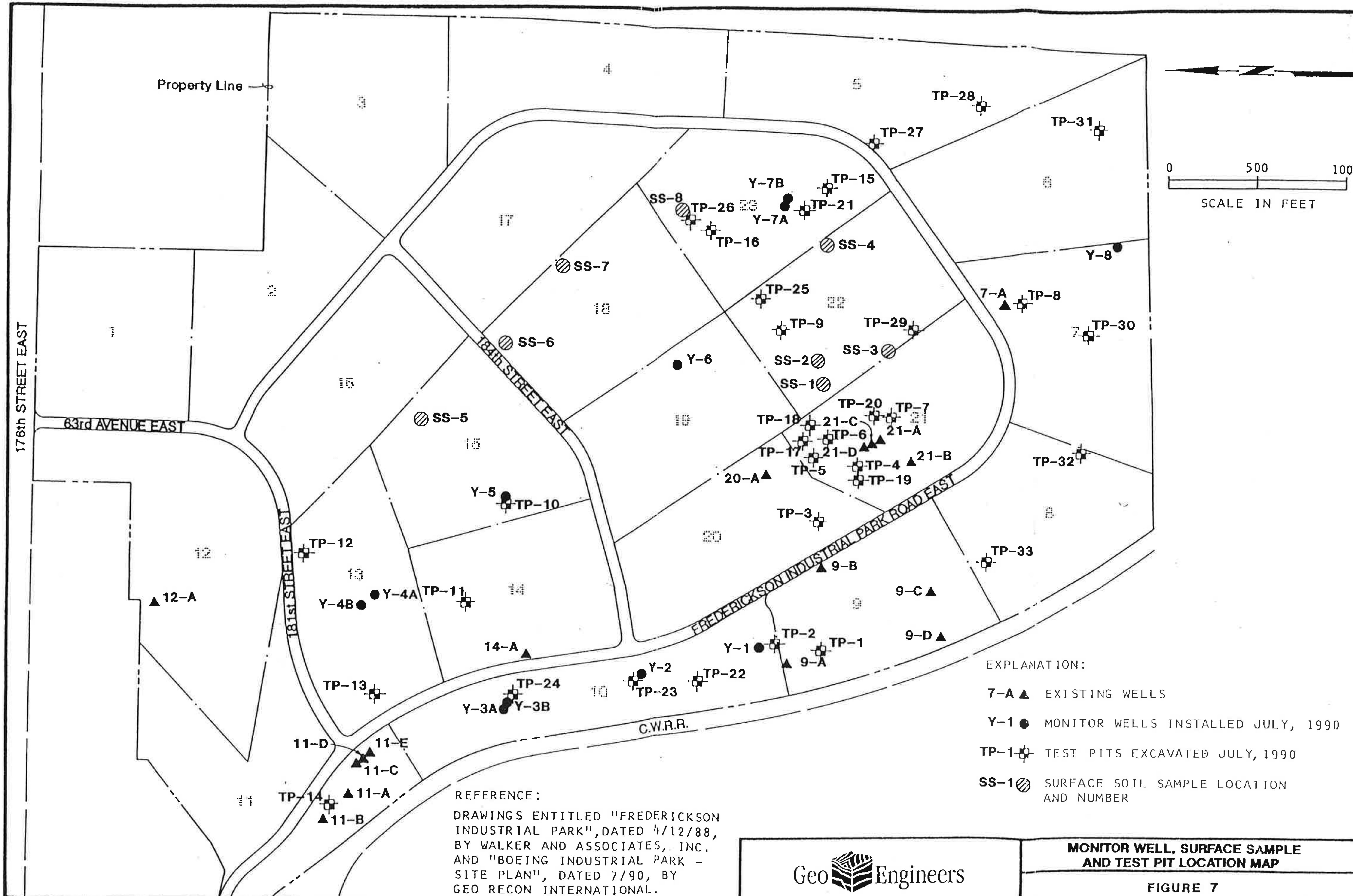
Legend

Property Boundary

Source:
Bing Aerial Photography, October 2006

N:\Frederickson\GIS\Figure 1-1 Site Location.mxd; LPadhye; 8/1/2011

ATTACHMENT #1



MONITOR WELL, SURFACE SAMPLE AND TEST PIT LOCATION MAP

FIGURE 7

TABLE 1 (PAGE 1 OF 2)
EXPLORATION LOCATIONS
AND OBJECTIVES

Well or Test Pit Number	Lot Number	Depth (feet)	Objective of Exploration	Exploration Method
Y-1	10	79.5	Search for carbon tetrachloride plume	Air Rotary
Y-2	10	164	Search for carbon tetrachloride plume	Air Rotary
Y-3A Y-3B	10	100.5 60	Search for carbon tetrachloride plume	Air Rotary
Y-4A Y-4B	13	116 65.5	Investigate soils at proposed building site	Air Rotary
Y-5	15	163	Investigate soils at proposed building site and search for carbon tetrachloride plume lateral boundary	Air Rotary
Y-6	19	49.5	Investigate impact of sawmill	Air Rotary
Y-7A Y-7B	23	95 53	Investigate soils at nitro building	Air Rotary
Y-8	6	41	Upgradient well	Air Rotary
TP-1	9	21	Confirm landfill cleanup	Trackhoe
TP-2	10	21	Confirm landfill cleanup	
TP-3	20	21	Investigate soils in unlined stormwater detention basin	Trackhoe
TP-4	21	21	Evaluate observed tar and unknown material on ground at tank removal location	Trackhoe
TP-5	21	22	Tank removal location	Trackhoe
TP-6	21	21	Tank removal location	Trackhoe
TP-7	21	21	Evaluate observed soil staining	Trackhoe
TP-8	7	23	Confirm landfill cleanup	Trackhoe
TP-9	22	10	Investigate soils in sawmill building	Trackhoe
TP-10	15	21	Investigate soils at proposed building site	Trackhoe
TP-11	14	21	Investigate soils at proposed building site	Trackhoe
TP-12	13	22	Investigate soils at proposed building site	Trackhoe

TABLE 1 (PAGE 2 OF 2)

Well or Test Pit Number	Lot Number	Depth (feet)	Objective of Exploration	Exploration Method
TP-13	13	20	Investigate soils at proposed building location	Trackhoe
TP-14	11	17.5	Confirm landfill cleanup	Trackhoe
TP-15	23	22	Investigate soils at nitro building	Trackhoe
TP-16	23	21	Investigate soils at nitro building	Trackhoe
TP-17	21	10	Magnetic anomaly	Trackhoe
TP-18	21	15	Magnetic anomaly	Trackhoe
TP-19	21	7	Magnetic anomaly	Trackhoe
TP-20	21	3.5	Magnetic anomaly	Trackhoe
TP-21	23	6	Magnetic anomaly	Trackhoe
TP-22	10	11	Magnetic anomaly	Trackhoe
TP-23	10	21	Former landfill	Trackhoe
TP-24	10	18	Check for debris	Trackhoe
TP-25	22	10.5	Magnetic anomaly	Trackhoe
TP-26	23	21	Investigate effect of stormwater discharge	Trackhoe
TP-27	5	21	Investigate soils at proposed building location	Trackhoe
TP-28	5	21	Investigate soils at proposed building location	Trackhoe
TP-29	22	21	Evaluate potential pentachlorophenol source	Trackhoe
TP-30	7	21	Investigate soils at proposed building location	Trackhoe
TP-31	6	21	Investigate soils at proposed building location	Trackhoe
TP-32	8	22	Investigate soils at proposed building location	Trackhoe
TP-33	8	18	Investigate soils at proposed building location	Trackhoe
SS1-SS4	22	0 - 6	Investigate soil staining	Trackhoe
SS5-SS8	15,18,23	0 - 3	Investigate soil staining	Trackhoe

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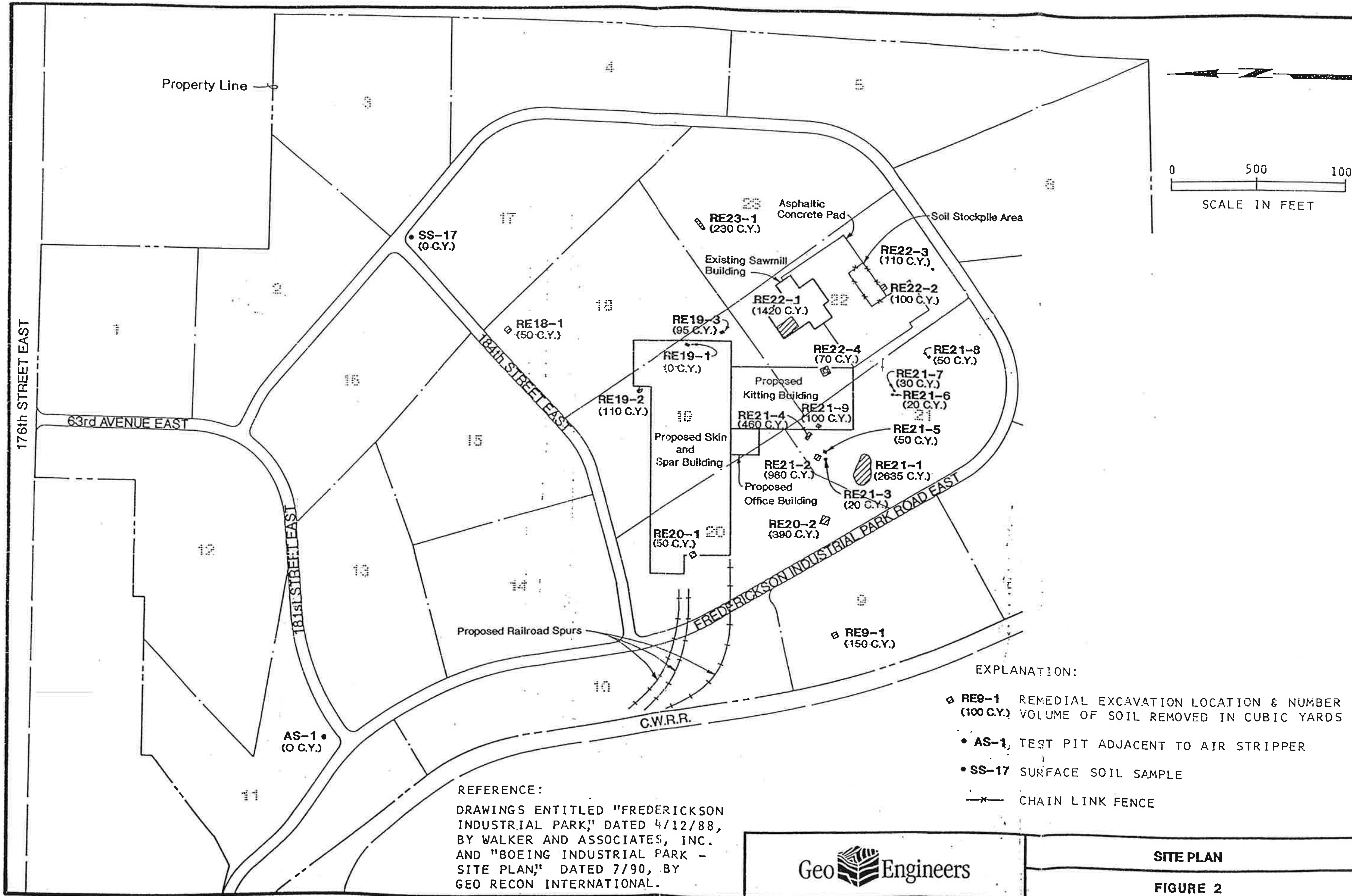
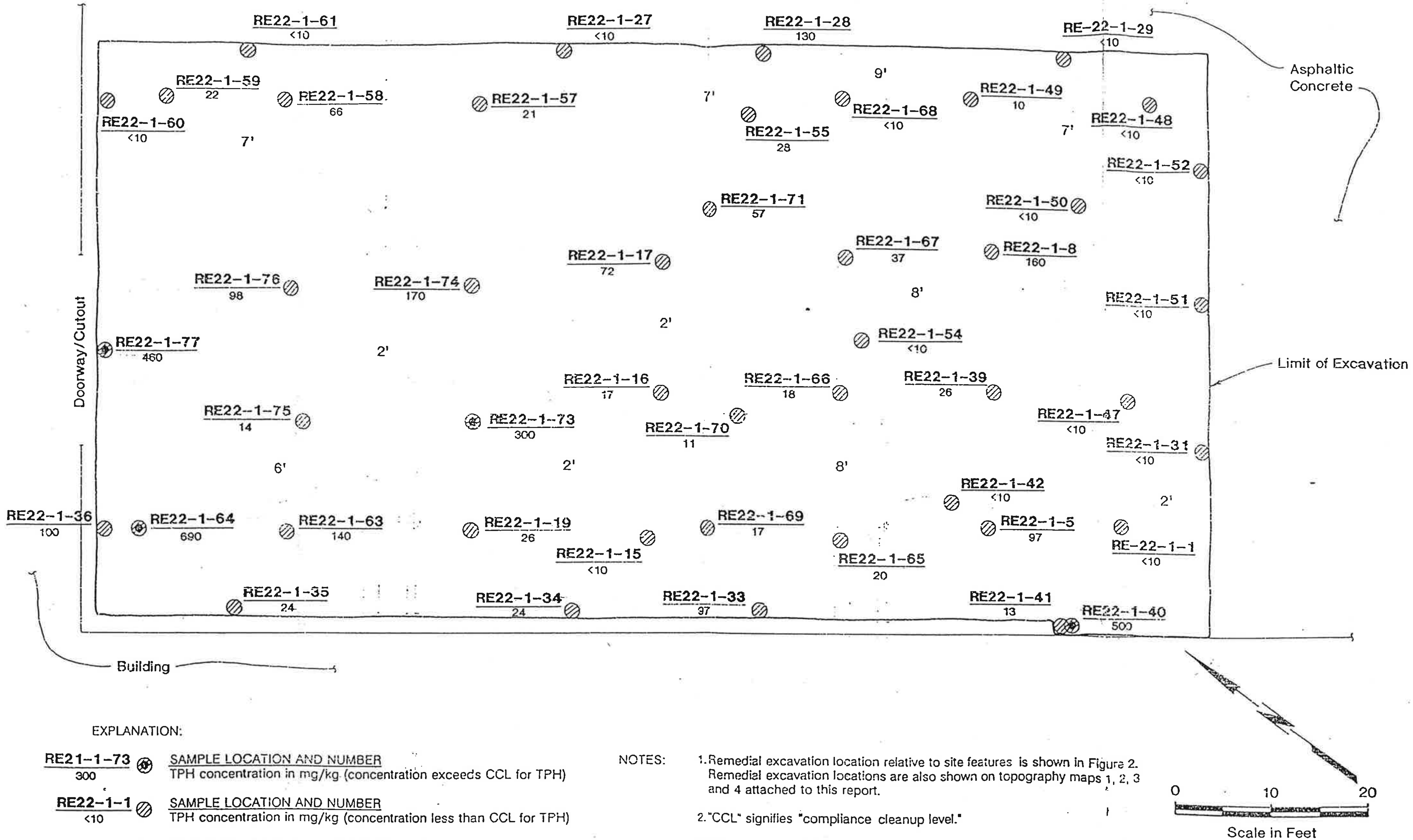


SITE PLAN

FIGURE 2



EXPLANATION:

RE21-1-73 300 — SAMPLE LOCATION AND NUMBER
TPH concentration in mg/kg (concentration exceeds CCL for TPH)

RE22-1-1 <10 — SAMPLE LOCATION AND NUMBER
TPH concentration in mg/kg (concentration less than CCL for TPH)

2' Approximate depth of remedial excavation in feet

NOTES:

1. Remedial excavation location relative to site features is shown in Figure 2. Remedial excavation locations are also shown on topography maps 1, 2, 3 and 4 attached to this report.
2. "CCL" signifies "compliance cleanup level."
3. "TPH" signifies "total petroleum hyrocarbons."

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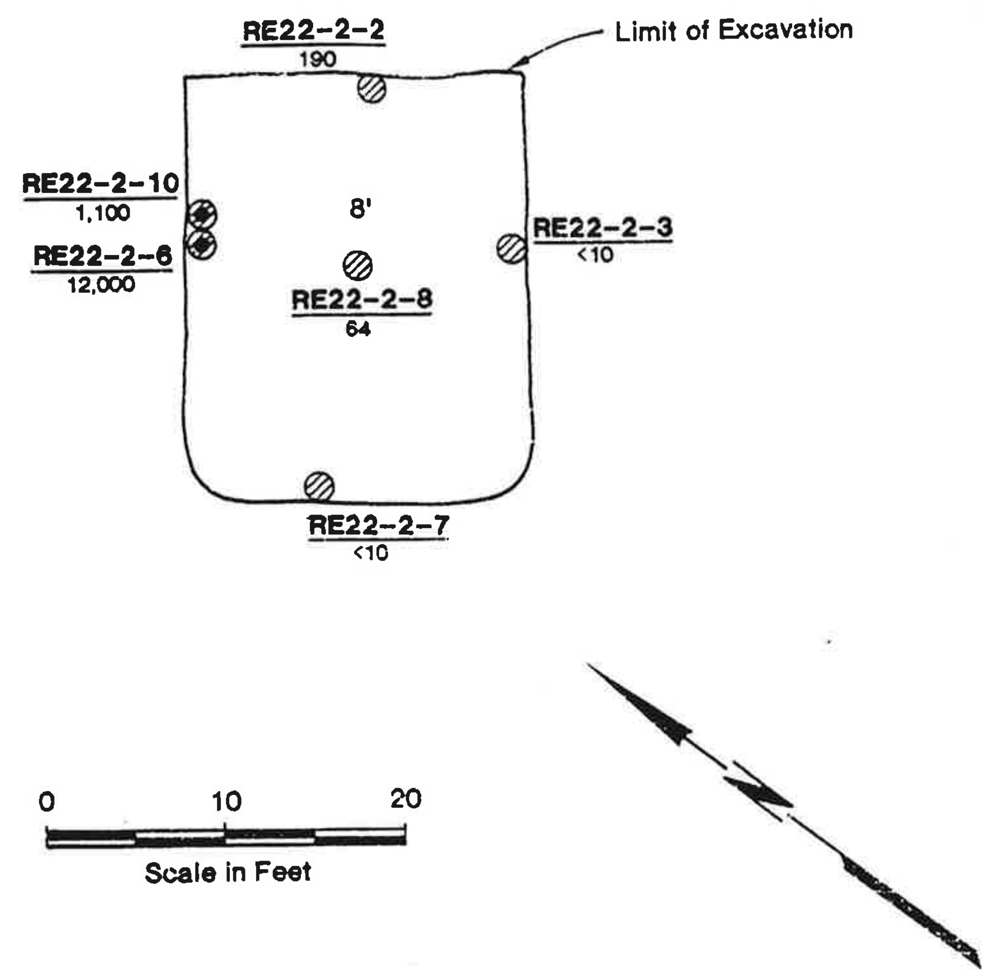
REMEDIAL EXCAVATION RE22-1

FIGURE 17

0120-082-B14 RNM:KET 11-27-90



EXPLANATION:

RE22-2-6 12,000 — SAMPLE LOCATION AND NUMBER
TPH concentration in mg/kg (concentration exceeds CCL for TPH)

RE22-2-2 190 — SAMPLE LOCATION AND NUMBER
TPH concentration in mg/kg (concentration less than CCL for TPH)

8' Approximate depth of remedial excavation in feet

NOTES:

1. Remedial excavation location relative to site features is shown in Figure 2. Remedial excavation locations are also shown on topography maps 1, 2, 3 and 4 attached to this report.
2. "CCL" signifies "compliance cleanup level."
3. "TPH" signifies "total petroleum hyrocarbons."

0120-082-B14 RHM:KKT 11-28-90

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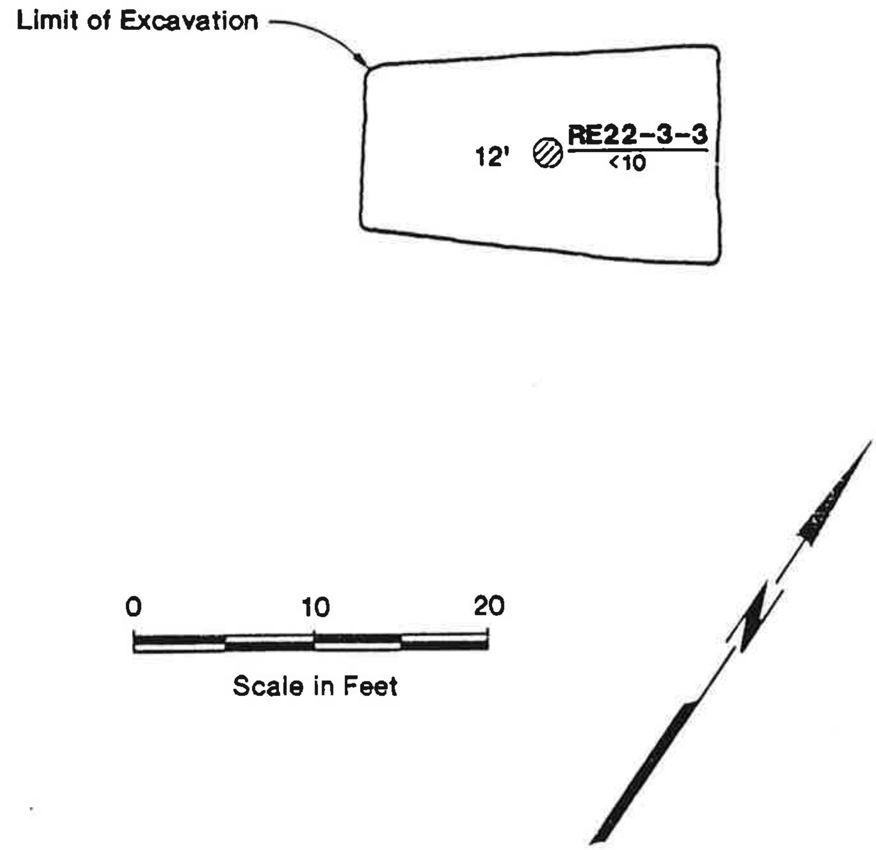
REMEDIAL EXCAVATION RE22-2

FIGURE 18



EXPLANATION:

RE22-3-3 / <10 — SAMPLE LOCATION AND NUMBER
TPH concentration in mg/kg (concentration less than CCL for TPH)

12' Approximate depth of remedial excavation in feet

NOTES:

1. Remedial excavation location relative to site features is shown in Figure 2. Remedial excavation locations are also shown on topography maps 1, 2, 3 and 4 attached to this report.
2. "CCL" signifies "compliance cleanup level."
3. "TPH" signifies "total petroleum hyrocarbons."

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REMEDIAL EXCAVATION RE22-3

FIGURE 19

TABLE 22 (Page 1 of 3)
REMEDIAL EXCAVATION RE22-1
SOIL CHEMICAL ANALYTICAL RESULTS (TPH)

Sample Number	Sample Location (2)	Sample Depth (feet)	Field Screening Field IR, TPH (mg/kg)	Analytical Results (1) TPH (mg/kg) EPA Method 418.1	Modified EPA Method 8015
RE22-1-1	Southeast base	3.0	13	<10	<25
RE22-1-2	Southeast base(4)	2.0	68	44	<25
RE22-1-3	Southeast base(4)	4.0	--	<10	<25
RE22-1-4	Southeast base(3)	4.0	--	460	<25
RE22-1-5	Southwest base(4)	3.0	68	97	<25
RE22-1-6	RE22-1-2(5)	2.0	--	480	<25
RE22-1-7	Southeast base(3)	2.0	1290	--	--
RE22-1-8	Southeast base	2.0	27	160	110
RE22-1-9	Northeast base(3)	2.0	550	--	--
RE22-1-10	Southwest base(3)	2.0	49	200	110
RE22-1-11	Central base(3)	2.0	54	240	<25
RE22-1-12	Central base(3)	2.0	48	120	<25
RE22-1-13	Northeast base(3)	3.0	2100	--	--
RE22-1-14	RE22-1-12(5)	2.0	--	300	<25
RE22-1-15	Southwest base	2.0	2	<10	<25
RE22-1-16	Central base	2.0	4	17	<25
RE22-1-17	Central base	2.0	38	72	<25
RE22-1-18	Northeast base(4)	2.0	41	51	<25
RE22-1-19	Southwest base	2.0	13	26	<25
RE22-1-20	Southwest base(4)	3.0	37	28	<25
RE22-1-21	Northwest base(3)	3.0	2350	--	--
RE22-1-22	Northeast base(3)	3.0	107	210	<25
RE22-1-23	Northeast base(3)	3.0	360	--	--
RE22-1-24	Northwest base(4)	3.0	152	95	<25
RE22-1-25	Northwest wall(4)	2.0	184	140	<25
RE22-1-26	Northeast wall(4)	1.0	66	55	<25
RE22-1-27	Northeast wall	1.0	55	<10	<25

Notes:
(1) Chemical analysis conducted by Analytical Resources, Inc. Laboratory reports are presented in Appendix B.
(2) Soil sample locations on the base of the excavation and on the remaining walls are shown in Figure 17.
(3) Not shown in Figure 17. Additional remedial excavation conducted in this location based on TPH result greater than MTCA draft CCL (200 mg/kg).
(4) Not shown in Figure 17. Removed during additional remedial excavation.
(5) Duplicate sample.
"mg/kg" signifies "milligrams per kilogram."
"MTCA" signifies "Model Toxics Control Act."
"CCL" signifies DRAFT "Compliance Cleanup Level" (July 18, 1990).
"—" signifies "not tested."

TABLE 22 (Page 2 of 3)

Sample Number	Sample Location (2)	Sample Depth (feet)	Field Screening Field IR, TPH (mg/kg)	Analytical Results (1) TPH (mg/kg) EPA Method 418.1	Modified EPA Method 8015
RE22-1-28	Northeast wall	1.0	22	130	<25
RE22-1-29	Northeast wall	1.0	10	<10	<25
RE22-1-30	Southeast wall(4)	1.0	8	<10	<25
RE22-1-31	Southeast wall	1.0	9	<10	<25
RE22-1-32	Southwest wall(3)	1.0	640	--	--
RE22-1-33	Southwest wall	1.0	12	97	<25
RE22-1-34	Southwest wall	1.0	10	24	<25
RE22-1-35	Southwest wall	1.0	7	24	47
RE22-1-36	Northwest wall	1.0	176	100	<25
RE22-1-37	RE22-1-24(5)	3.0	152	130	<25
RE22-1-38	RE22-1-34(5)	1.0	10	17	<25
RE22-1-39	Southeast base	7.0	22	26	<25
RE22-1-40	Southwest wall	2.0	106	500	<25
RE22-1-41	Southwest base	6.0	21	13	<25
RE22-1-42	Inner wall	4.0	8	<10	<25
RE22-1-43	Inner wall(4)	4.0	2	--	--
RE22-1-44	RE22-1-40(5)	2.0	--	350	<25
RE22-1-45	Inner wall(4)	4.0	--	--	--
RE22-1-46	Inner wall(4)	4.0	4	--	--
RE22-1-47	Southeast base	7.0	7	<10	<25
RE22-1-48	Southeast base	7.0	6	<10	<25
RE22-1-49	Northeast base	7.0	15	10	<25
RE22-1-50	Southeast base	7.0	7	<10	<25
RE22-1-51	Southeast wall	4.0	7	<10	<25
RE22-1-52	Southeast wall	4.0	9	<10	<25

Notes:

(1) Chemical analysis conducted by Analytical Resources, Inc. Laboratory reports are presented in Appendix B.

(2) Soil sample locations on the base of the excavation and on the remaining walls are shown in Figure 17.

(3) Not shown in Figure 17. Additional remedial excavation conducted in this location based on TPH result greater than MTCA draft CCL (200 mg/kg).

(4) Not shown in Figure 17. Removed during additional remedial excavation.

(5) Duplicate sample.

"mg/kg" signifies "milligrams per kilogram."

"MTCA" signifies "Model Toxics Control Act."

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"—" signifies "not tested."

TABLE 22 (Page 3 of 3)

Sample Number	Sample Location (2)	Sample Depth (feet)	Field Screening	Analytical Results (1) TPH (mg/kg)	
			Field IR, TPH (mg/kg)	EPA Method 418.1	Modified EPA Method 8015
RE22-1-53	Northeast base(3)	7.0	98	110	<25
RE22-1-54	Inner wall(3)	4.0	12	<10	<25
RE22-1-55	Inner wall	4.0	18	28	<25
RE22-1-56	RE22-1-52(4)	4.0	--	<10	<25
RE22-1-57	Northeast base	7.0	25	21	<25
RE22-1-58	Northeast base	7.0	66	66	<25
RE22-1-59	Northeast base	7.0	32	22	<25
RE22-1-60	Northwest wall	2.0	11	<10	<25
RE22-1-61	Northwest wall	2.0	9	<10	<25
RE22-1-62	RE22-1-64(4)	7.0	160	470	<25
RE22-1-63	Northwest base	7.0	72	140	<25
RE22-1-64	Northeast wall	2.0	--	690	<25
RE22-1-65	Southwest base	8.0	--	20	57
RE22-1-66	Central base	8.0	--	18	56
RE22-1-67	Central base	8.0	--	37	58
RE22-1-68	Northeast base	9.0	--	<10	57
RE22-1-69	Southwest base	5.0	--	17	69
RE22-1-70	Central base	4.0	--	11	47
RE22-1-71	Central base	5.0	--	57	81
RE22-1-72	RE22-1-70(4)	4.0	--	<10	63
RE22-1-73	Central base	2.0	--	300	<25
RE22-1-74	Central base	2.0	--	170	<25
RE22-1-75	Northwest base	2.0	--	14	<25
RE22-1-76	Northwest base	2.0	--	98	<25
RE22-1-77	Northwest wall	1.0	--	460	<25

Notes:

(1) Chemical analysis conducted by Analytical Resources, Inc. Laboratory reports are presented in Appendix B.

(2) Soil sample locations on the base of the excavation and on the remaining walls are shown in Figure 17.

(3) Not shown in Figure 17. Additional remedial excavation conducted in this location based on TPH result greater than MTCA draft CCL (200 mg/kg).

(4) Not shown in Figure 17. Removed during additional remedial excavation.

(5) Duplicate sample.

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"—" signifies "not tested."

TABLE 23
REMEDIAL EXCAVATION RE22-2
SOIL CHEMICAL ANALYTICAL RESULTS (TPH)

Sample Number	Sample Location (2)	Sample Depth (feet)	Field Screening Field IR, TPH (mg/kg)	Analytical Results (1) TPH (mg/kg) EPA Method 418.1	Modified EPA Method 8015
RE22-2-1	North wall(3)	2.0	750	1,400	<25
RE22-2-2	East wall	2.0	90	190	<25
RE22-2-3	South wall	2.0	8	<10	<25
RE22-2-4	South wall(3)	4.0	630	--	--
RE22-2-5	Central base(3)	7.0	164	150	<25
RE22-2-6	North wall	2.5	--	12,000	35
RE22-2-7	West wall	3.0	--	<10	97
RE22-2-8	Central base	8.0	--	64	<25
RE22-2-9	RE22-2-7(4)	3.0	--	<10	34
RE22-2-10	North wall	6.0	--	1,100	<25

Notes:
(1) Chemical analysis conducted by Analytical Resources, Inc. Laboratory reports are presented in Appendix B.
(2) Soil sample locations on the base of the excavation and on the remaining walls are shown in Figure 18.
(3) Not shown in Figure 18. Additional remedial excavation conducted in this location based on TPH result greater than MTCA draft CCL (200 mg/kg).
(4) Duplicate sample.
"mg/kg" signifies "milligrams per kilogram."
"MTCA" signifies "Model Toxics Control Act."
"CCL" signifies DRAFT "Compliance Cleanup Level" (July 18, 1990).
"—" signifies "not tested."

TABLE 24
REMEDIAL EXCAVATION RE22-3
SOIL CHEMICAL ANALYTICAL RESULTS (TPH)

Sample Number	Sample Location (2)	Sample Depth (feet)	Field Screening Field IR, TPH (mg/kg)	Analytical Results (1) TPH (mg/kg) EPA Method 418.1	Modified EPA Method 8015
RE22-3-1	Central base(3)	1.5	--	300	66
RE22-3-2	Central base(3)	5.5	--	220	<25
RE22-3-3	Central base	12.0	--	<10	<25

Notes:

(1) Chemical analysis conducted by Analytical Resources, Inc. Laboratory reports are presented in Appendix B.

(2) Soil sample location on the base of the excavation is shown in Figure 19.

(3) Not shown in Figure 19. Additional remedial excavation conducted in this location based on TPH result greater than MTCA draft CCL (200 mg/kg).

"mg/kg" signifies "milligrams per kilogram."

"MTCA" signifies "Model Toxics Control Act."

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