Issued by

Washington State Department of Ecology
Toxics Cleanup Program
Southwest Regional Office
Olympia, Washington

Prepared for

Olin Corporation

and

Mallinckrodt US, LLC

DRAFT CLEANUP ACTION PLAN

FREDERICKSON INDUSTRIAL PARK
FREDERICKSON, WASHINGTON

Prepared by

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Project Number GR4631

November 2013

EXECUTIVE SUMMARY

This *Cleanup Action Plan* (CAP) has been prepared by Geosyntec Consultants on behalf of Olin Corporation and Mallinckrodt US LLC (the Companies), and is being submitted to the Washington Department of Ecology (Ecology). An Agreed Order 9514 (Order), once signed by the Companies and Ecology following a 30-day public comment period on the RI/FS and CAP, will require implementation of the CAP remedy for the Site. The Order specifies that the Companies will provide for the remediation of carbon tetrachloride (CTC) in groundwater at and downgradient of the Frederickson Industrial Park (the Property) in Frederickson, Washington. The CAP is based upon the Ecology-approved remedy of monitored natural attenuation (MNA) to address CTC in groundwater. The rationale for the selection of MNA to remediate CTC was presented in the final *Remedial Investigation/Feasibility Study (RI/FS) Report* (RI/FS Report) [Geosyntec, 2012c] submitted to Ecology by the Companies on 28 March 2012. Ecology concurred with the MNA recommendation in its 7 October 2011 correspondence with the Companies titled *Ecology Comments on Draft Remedial Investigation/Feasibility Study, Frederickson Industrial Park, Frederickson, Washington*.

<u>Purpose</u>

As stated in the Model Toxics Control Act (MTCA) process, the purpose of the CAP is to present the key findings and recommendations of the RI/FS Report (Geosyntec, 2012c), including a summary and rationale for selection of the final proposed cleanup actions, with the specific intention to present to the public the following:

- the proposed final cleanup action(s);
- the cleanup standards that are expected to be achieved; and,
- the approach and schedule for implementing these actions at the Site.

Thus, consistent with the requirements of the MTCA and Chapter 173-340-380 of the Washington Administrative Code (WAC), the CAP includes the following elements:

- A general description of the proposed cleanup action developed;

- A summary of the rationale for selecting the proposed alternative;
- A brief summary of other cleanup action alternatives evaluated in the remedial investigation/feasibility study;
- The cleanup standards for the site;
- The schedule for implementation of the cleanup action plan including, if known, restoration time frame;
- Institutional controls, if any, required as part of the proposed cleanup action;
- Applicable state and federal laws, if any, for the proposed cleanup action; and,
- A preliminary determination by the department that the proposed cleanup action will comply with WAC 173-340-360.

As described in the RI/FS Report (Geosyntec, 2012c), the proposed cleanup action will meet the threshold requirements of WAC 173-340-360 to protect human health and the environment, comply with cleanup standards, comply with applicable state and federal laws, and provide for compliance monitoring.

Development, Detailed Analysis, and Selection of Remedial Alternatives

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

- Alternative 1: Site-wide Monitored Natural Attenuation (MNA)
- Alternative 2: Site-wide Groundwater Extraction and Treatment (P&T)
- Alternative 3: Permeable Reactive Barrier (PRB)

Each of the three 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. A disproportionate cost analysis was also performed for the Alternatives. Although not required under MTCA, a sustainability analysis was performed in the RI/FS Report (Geosyntec, 2012c) to aid in the detailed evaluation of the three alternatives. MNA had the smallest environmental footprint for each sustainability metric, and the best safety metric.

Through the RI/FS process, Alternative 1 (MNA) was 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. Ecology concurred with Companies' selection of MNA as the preferred cleanup action alternative for the Site in its 7 October 2011 correspondence with the Companies.

Proposed Cleanup Action Alternative - MNA

Implementation of MNA as the cleanup action for the Site will include the following:

- Concurrent submittal of the Compliance Monitoring Work Plan (CMWP) with the CAP;
- Concurrent review and approval of the CAP and CMWP by Ecology;
- Implementation of the CMWP by the Companies, including regular reporting of results to Ecology;
- Periodic review of the effectiveness of the cleanup action by the Companies, and implementation of contingency plans in the event the Companies or Ecology determines the cleanup action has not met expectations.

The CMWP for implementation of MNA is being submitted concurrently with the CAP and details the proposed strategy for monitoring remedial progress. The CMWP formally identifies: (i) the monitoring wells that comprise the compliance monitoring network; (ii) the monitoring frequency during performance monitoring and confirmational monitoring phases of compliance monitoring; (iii) the list of parameters to be collected and analyzed; (iv) proposed sampling and analytical methodologies; and (v) the reporting schedule. The CMWP will also include an updated Quality Assurance Project Plan and Sample Analysis Plan (QAPP and SAP).

Steady CTC concentration declines have been observed at the Site over the past 20 years, providing conclusive evidence that CTC in groundwater is attenuating at the Site. Given the relatively long history of analytical results and declining CTC concentration trends for the monitoring wells, semi-annual sampling for the monitoring wells is considered to be appropriate for the first two years of monitoring, and then changing to annual sampling thereafter. Assuming that the trends continue to decline, it is likely that the Companies will submit future requests to Ecology to reduce the sampling frequency.

Implementation Schedule

The preliminary schedule for the proposed cleanup action is assumed to begin after this CAP and the CMWP have been reviewed and approved by Ecology. Approval and implementation of the cleanup action is anticipated to occur during 2014. The CMWP provides a detailed schedule of monitoring and reporting. Implementation of the approved remedial approach will continue, until results indicate that MNA has achieved cleanup levels. If, during the Confirmational Monitoring phase, the cleanup criteria are not achieved, a contingency plan will be developed and provided to Ecology for review and approval.

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LIST OF ACRONYMS

ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
CAP	Cleanup Action Plan
CCC	Clover/Chambers Creek
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
ITRC	Interstate Technology and Regulatory Council
MCL	Maximum Contaminant Level
MNA	Monitored Natural Attenuation
MTCA	Model Toxics Control Act
NO_x	Nitrous Oxides
O&M	Operations and Maintenance
P&T	Pump and Treat
PM_{10}	Particulate Matter
PRB	Permeable Reactive Barrier
RCW	Revised Code of Washington
RDX	Research Department Explosive
RI/FS	Remedial Investigation and Feasibility Study

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SL	Screening Level
SOW	Scope of Work
SO_x	Sulfur Oxides
SRT	Sustainable Remediation Tool
SSL	Soil Screening Level
TEE	Terrestrial Ecological Evaluation
TNT	Trinitrotoluene
USEPA	United States Environmental Protection Agency
VI	Vapor Intrusion
VOC	Volatile Organic Compound
WAC	Washington Administrative Code
WSCP	Water Supply Conceptual Plan

1. INTRODUCTION

This *Cleanup Action Plan* (CAP) has been prepared by Geosyntec Consultants on behalf of Olin Corporation and Mallinckrodt US LLC (the Companies), and is being submitted to the Washington Department of Ecology (Ecology). An Agreed Order 9514 (Order), once signed by the Companies and Ecology following a 30-day public comment period on the RI/FS and CAP, will require implementation of the CAP remedy for the Site[1]. The Order specifies that the Companies will provide for the remediation of carbon tetrachloride (CTC) in groundwater at and downgradient of the Frederickson Industrial Park (the Property) in Frederickson, Washington (**Figure 1-1**). The CAP is based upon the Ecology-approved remedy of monitored natural attenuation (MNA) to address CTC in groundwater. The rationale for the selection of MNA to remediate CTC was presented in the final *Remedial Investigation/Feasibility Study (RI/FS) Report* (RI/FS Report) [Geosyntec, 2012c] submitted to Ecology by the Companies on 28 March 2012. Ecology concurred with the MNA recommendation in its 7 October 2011 correspondence with the Companies titled *Ecology Comments on Draft Remedial Investigation/Feasibility Study, Frederickson Industrial Park, Frederickson, Washington.* Ecology's issuance of the Order based on the final RI/FS Report confirmed the selection of MNA as the approved cleanup action for the Site.

1.1 Purpose

The purpose of the CAP in the Model Toxics Control Act (MTCA) process is to summarize the results of the RI/FS Report and the rationale for selection of the final proposed cleanup actions, with the specific intention to present to the public the following:

- the proposed final cleanup action(s);
- the cleanup standards that are expected to be achieved; and,
- the approach and schedule for implementing these actions at the Site.

Thus, consistent with the requirements of the MTCA and Chapter 173-340-380 of the Washington Administrative Code (WAC), the CAP includes the following elements:

[1] Per MTCA and Chapter 173-340-200 of the WAC, the Site is defined to be anywhere hazardous substances have come to be located, whereas the Property refers to the area contained within the property boundaries of the Frederickson Industrial Park.

- A general description of the proposed cleanup action developed;
- A summary of the rationale for selecting the proposed alternative;
- A brief summary of other cleanup action alternatives evaluated in the RI/FS;
- The cleanup standards for the site;
- The schedule for implementation of the cleanup action plan including, if known, restoration time frame;
- Institutional controls, if any, required as part of the proposed cleanup action;
- Applicable state and federal laws, if any, for the proposed cleanup action; and,
- A preliminary determination by the department that the proposed cleanup action will comply with WAC 173-340-360.

As described in the RI/FS Report (Geosyntec, 2012c), the proposed cleanup action will meet the requirements of WAC 173-340-360 to protect human health and the environment, comply with cleanup standards, comply with applicable state and federal laws, and provide for compliance monitoring.

1.2 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.

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.

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.

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 Order 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 Order, 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. 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 Order and the *Phase II RI/FS Work Plan*.

In early 2007, communications between the Companies and Ecology centered on Ecology's requests for additional 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 proposed new monitoring wells. This was conducted to confirm the suitability 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 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.

The Draft RI/FS Report (Geosyntec, 2011b) was completed in accordance with the requirements of Order No. DE 97TC-S121 and the 11 May 2011 correspondence from Ecology, and was submitted to Ecology on 30 September 2011. The Draft RI/FS Report proposed MNA as the cleanup action alternative to remediate CTC present above cleanup standards in both on-Site and off-Site groundwater. Ecology provided its comments on the Draft RI/FS Report on 7 October 2011 via correspondence with the Companies titled *Ecology Comments on Draft Remedial Investigation/Feasibility Study, Frederickson Industrial Park, Frederickson, Washington.* In the 7 October 2011 letter, Ecology concurred with Companies' selection of MNA as the preferred cleanup action alternative for the Site. On 14 March 2012, in correspondence titled *Response to Ecology Comments on Draft RI/FS Report, Frederickson Industrial Park, Frederickson, Washington* (Geosyntec, 2012b), the Companies provided their response to Ecology's comments on the Draft RI/FS Report. The Final RI/FS Report (Geosyntec, 2012c) was submitted to Ecology on 28 March 2012.

As noted, 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 remediation activities for total petroleum hydrocarbons (TPH) 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* (Geosyntec, 2012a). Subsequent to submittal of the technical memorandum, Boeing, the current Property owner, conducted a limited TPH investigation, the results of which were submitted to Ecology by Boeing on 15 June 2012. The data indicate that TPH is not present in the soils at concentrations above the current MTCA cleanup levels.

1.3 Report Organization

The remainder of this CAP is divided into the following sections:

- Section 2 – Summary of Site Characterization and Remediation,
- Section 3 – Cleanup Standards for the Site,
- Section 4 – Cleanup Action Alternative Selection,
- Section 5 – Proposed Cleanup Action Alternative, and
- Section 6 – References.

2. SUMMARY OF SITE CHARACTERIZATION & REMEDIATION

The purpose of Section 2 is to provide a concise summary of the Site characterization and remediation information presented in the RI/FS Report (Geosyntec, 2012c), focusing on the information needed to understand why MNA is the recommended cleanup action for CTC in Site groundwater. The reader is referred to the RI/FS Report (Geosyntec, 2012c) for additional details.

2.1 Summary of Site Activities – Investigations and Remedial Activities

2.1.1 Site Investigations

Numerous site investigations have been conducted at the Site over the past twenty-five years. The *Phase II RI/FS Work Plan* (Conestoga Rovers & Associates [CRA], 1998) provides a detailed summary of the activities from 1988 to 1998, including site inspections, site assessments, groundwater monitoring events, and completion of the Phase I RI/FS (from 1994 to 1995). Starting in 1998, the scope of work described in the *Phase II RI/FS Work Plan* was implemented. The RI/FS Report (Geosyntec, 2012c) provides a detailed account of the activities conducted from 1998 through 2012.

2.1.2. Site Remediation Actions

Multiple source area excavations and removals have been conducted at the Site, and are described in the RI/FS Report (Geosyntec, 2012c). A potential source of CTC to groundwater was not definitively identified during the source excavations and removals. 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 from these areas.

In January 1990, AHR began operation of a groundwater extraction and treatment system at the Site. 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).

From 2002 to 2007, the Companies devised and implemented permanent solutions regarding the CTC affected domestic drinking water wells, as required by the 1997 Order. 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.

2.2 <u>Site Conditions</u>

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, 2011a). **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 Hydrogeology

The major water producing zones or aquifers are referred to as Aquifers A and C. There is an interglacial layer that generally inhibits groundwater flow between Aquifers A and C and is referred to as Aquitard B.

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. Aquifer A is unconfined and groundwater flow at the Site is predominantly to the north and northwest.

Aquitard B consists primarily of an interglacial deposit of clay, silt and fine sand with occasional gravel lenses. Where identified, the thickness of Aquitard B is approximately 20 ft.

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. As described in *Technical Memorandum No. 2* (CRA, 2000), Groundwater flow within this unit is predominantly to the north and northwest.

2.2.2 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**). 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 (Geosyntec, 2010e).

2.2.3 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 currently is industrial for the Property. The Property is zoned as an "Employment Center," which may include industrial and commercial land uses. Based on WAC 173-340-720(1)(a), 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.

2.3 <u>Nature and Extent of Contamination</u>

The chemical of concern for the Site is CTC (CRA, 2001, 2002 and 2003; Geosyntec, 2010b, 2011a). The following sections briefly describe the nature and extent of CTC at the Site.

2.3.1 Soil

The locations where soil samples have been previously collected at the Property and analyzed for CTC were originally presented in Figure 2.5 of the *Phase II RI/FS Work Plan*. As summarized in the *Phase II RI/FS Work Plan*, 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. Using the highest soil gas detection, the estimated soil concentration of CTC was still less than the most conservative soil screening level. 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 RI/FS Report (Geosyntec, 2012c) concluded that the soils in the former process areas are not acting as continuing sources of CTC.

2.3.2 Groundwater

Several groundwater sampling events occurred as part of the *Phase II RI/FS Work Plan* implementation 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**. **Figure 2-2a** presents the sample locations, CTC results, and corresponding CTC contours for the most recent Aquifer A groundwater sampling event conducted in February 2011. **Figure 2-2b** presents the locations and CTC results for the most recent Aquifer C groundwater sampling event; CTC concentrations for Aquifer C were not contoured as there were no CTC detections.

Water level contours for Aquifer A from the February 2011 event are shown in **Figure 2-3**. Similar to historical monitoring events, groundwater flow in Aquifer A is to the north-northwest, generally towards Clover Creek. Based on an evaluation of vertical gradients and CTC concentrations at the P1 and P2 well clusters, it was concluded in the RI/FS Report (Geosyntec, 2012c) that groundwater in Aquifer A discharges to Clover Creek from both sides of the creek.

The February 2011 CTC groundwater data refined and delineated the distribution of CTC in groundwater, resulting in the following conclusions:

- The current extent of CTC in Aquifer A occupies a smaller footprint than the extent measured in November 2002, suggesting that the CTC plume is naturally attenuating;
- 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 currently limited to Aquifer A wells;
- Groundwater at the Site flows in a north-northwest direction; and,
- Aquifer A groundwater discharges to Clover Creek from both sides of the creek.

2.3.3 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, 2010c). The four sample locations along Clover Creek are depicted in

Figure 2-1. Surface water and sediment samples were submitted for CTC analysis. 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 surface water and sediment data demonstrate that CTC is not impacting surface water and sediments near the Site.

2.3.4 Concentration Trend Analysis for CTC

Figure 2-4 shows the concentration trends for CTC in Aquifer A through February 2011 at the on- and off-Property monitoring wells. The time-trend data demonstrate that the CTC concentrations in Aquifer A have consistently declined over time resulting in a receding plume. 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. These wells also show a downward trend in CTC concentrations over the past 20 years of monitoring, indicating that the CTC plume is undergoing natural attenuation.

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 in June 2010 and February 2011. 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 described in Section 4.2.1.

2.4 <u>Site Risk & Exposure Pathway Evaluation</u>

The RI/FS Report presented a detailed evaluation of site risk and exposure pathways for groundwater, soil, soil gas (i.e., potential vapor intrusion (VI) pathway), and surface water and sediments. The results of the evaluation are summarized as follows:

- **Groundwater –** Groundwater at, or potentially affected by the Site, is not currently being used as drinking water and is not a reasonable future source of drinking water. The drinking water pathway is, therefore, incomplete.

- **Soil –** Potential exposure pathways and receptors for CTC in Property soil were evaluated. Evaluation of the terrestrial ecological evaluation (TEE) criteria was conducted pursuant to WAC 173-340-7490, and it was concluded that the presence of CTC in soil will not pose an ecological risk. Further, there is no evidence of the presence of CTC in the Property soils exceeding soil screening levels (SSLs) within the former process areas. Thus, there are no unacceptable potential exposures associated with CTC in soil.

- **Soil Gas –** The original VI evaluation was conducted in 2011 and presented as Appendix B to the RI/FS (Geosyntec, 2012c). In a letter dated August 27, 2013, Ecology acknowledged that with submittal of the Final RI/FS report, the Companies had satisfactorily completed the Agreed Order requiring the RI/FS. At the request of the current Property owner, an updated VI evaluation was conducted in 2013 to include an evaluation of potential future use of the Property and updated soil gas screening levels. The updated VI evaluation, provided in Appendix A, includes the use of MTCA Method B and Method C cleanup levels for the on-property evaluation as a means to consider potential future land uses, including unrestricted and industrial, respectively. The following paragraphs summarize findings of the updated VI evaluation.

  For the Property, the updated assessment is based upon the following lines of evidence: (1) comparison of the measured soil gas CTC concentrations to Method B and C soil gas SLs, (2) comparison of Method B and C Indoor Air Cleanup Levels to indoor air concentrations predicted from the 1999 maximum soil gas concentrations using conservative assumptions, and (3) comparison of measured groundwater concentrations to Method B and C site-specific groundwater SLs developed using the JEM with site-specific groundwater conditions and conservative assumptions. Current and potential future industrial land uses and potential future unrestricted land uses were assessed. The current industrial land use and potential future industrial land use were assessed using Method C. Potential unrestricted land use was assessed using Method B. For vadose zone soils, the assessment used measured soil gas CTC concentrations from 1999 in areas where CTC was previously handled and shows that the soil conditions in those areas do not pose an unacceptable risk to indoor air for the current or potential future industrial land uses or for potential future unrestricted land use. For groundwater, the assessment used measured groundwater CTC concentrations and shows that conditions do not pose an unacceptable risk to indoor air for either current or potential future industrial land use, as groundwater concentrations are less than the Method C site-specific SL (54 µg/L). A small part of the Property is underlain by groundwater having CTC concentrations that are greater than the Method B site-specific SL (1.4 µg/L) that pertains to future unrestricted land use.

The Ecology-approved groundwater cleanup level identified in the RI/FS is the value for CTC in drinking water (0.63 µg/L). This cleanup level was selected in accordance with Method B and is more stringent (i.e., lower) than both the Method B (1.4 µg/L) and Method C (54 µg/L) site-specific groundwater SLs developed in this updated VI assessment for unrestricted and industrial land use of the Property, respectively. The Method C SL for VI on the Property has already been attained indicating that there are no current or potential future unacceptable risks related to industrial use of the Property. Industrial use is consistent with the current zoning of the Property. Once the groundwater cleanup level (0.63 µg/L) has been attained, the Method B SL for unrestricted use of the Property (1.4 µg/L) will also be attained. In the event that property use changes from industrial to unrestricted use before the groundwater cleanup level has been attained, the Companies and Property Owner will reassess VI for the new land use.

For the area downgradient of the Property, conservative assumptions regarding groundwater CTC concentrations and building construction were used in the original assessment in order to evaluate commercial and unrestricted land uses. No unacceptable indoor air exposures were identified for current or future land use.

- **Surface Water & Sediments –** There is no evidence of the presence of CTC in surface water or sediments in Clover Creek, thus there is no risk associated with the potential exposure pathways and receptors identified in the RI/FS Report.

3. 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 CAP development process. The cleanup standards proposed in the RI/FS Report (Geosyntec, 2012c) were developed in accordance with WAC 173-340-700 through -730. Based on Ecology's acceptance of the RI/FS Report, the cleanup standards proposed in the RI/FS Report will be the final cleanup standards for the Site. The cleanup standards are presented in the following sections.

3.1 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. For convenience, this CAP uses the ARAR terminology in the development of cleanup standards and the subsequent evaluation of cleanup action alternatives.

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 ARARs for the Site are presented in **Table 3-1**.

3.2 Cleanup Levels

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). Based on evaluation of potential exposure pathways, the development of cleanup levels for CTC was limited to groundwater and groundwater to surface water pathways. Groundwater cleanup criteria were developed 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). The groundwater cleanup levels are presented in **Table 3-2**.

The selection process required that the most stringent cleanup level from the groundwater and surface water ARARs be selected. As detailed in the RI/FS Report (Geosyntec, 2012c), 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**).

3.3 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 standard point of compliance will be enforced at the Site, and 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)).

4. CLEANUP ACTION ALTERNATIVE SELECTION

This section provides a concise summary of the multiple step remedial evaluation process that was presented in the RI/FS Report (Geosyntec, 2012c) and culminated in the recommendation that MNA is the preferred cleanup action alternative for the Site.

4.1 <u>Process Overview & Conclusion</u>

Following an initial identification and screening of potentially-applicable remedial technologies and process options, three remedial alternatives were developed. The three alternatives developed for the Site are listed below:

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

These alternatives represent an appropriate range of cleanup approaches capable of achieving the Site cleanup standards.

Each of the three Alternatives was subjected to a detailed evaluation using the two categories of cleanup action requirements under WAC 173-340-360: (i) threshold requirements and (ii) additional requirements. The criteria for the threshold and additional requirements are the following:

- Threshold Requirements (WAC 173-340-360(2)(a)): 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.
- Additional Requirements (WAC 173-340-360(2)(b)): i) Use Permanent Solutions to the Maximum Extent Practicable; ii) Provide for Reasonable Restoration Time Frame; and iii) Consider Public Concerns.

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. 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.

Through the RI/FS process, Alternative 1 (MNA) was 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. Ecology concurred with Companies' selection of MNA as the preferred cleanup action alternative for the Site in its 7 October 2011 correspondence with the Companies.

4.2 MTCA Threshold Requirement Evaluation of Cleanup Action Alternatives

This section presents a brief description of each of the three cleanup action alternatives, including cost, and discusses the extent to which each alternative satisfies the MTCA Threshold Requirements for a cleanup action

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

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 2.3.4 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 2-4**. 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 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 (Geosyntec, 2012c). 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 existing monitoring wells 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.

Alternative 1 was evaluated against the four minimum threshold requirements specified under MTCA. Based on the evaluation presented in the RI/FS Report (Geosyntec, 2012c), Alternative 1 is considered compliant with the four MTCA Threshold Requirements and meets the minimum requirements of an acceptable cleanup action.

4.2.2 Alternative 2 – Site-Wide Pump and Treat

The conceptual layout of a Site-wide pump and treat (P&T) system is presented in **Figure 4-1**. Extraction Well Number 1 (i.e., EW-01) would be located along the plume centerline inside the northern Property boundary. Extraction Well Number 2 (i.e., EW-02) would be located along the plume centerline, approximately 750 ft north of MW-13. 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. 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 and discharged under appropriate permit(s).

Using an empirical formula (Javandel and Tsang, 1986), the likely extraction rates of EW-01 and EW-02 were estimated to be 200 and 170 gallons per minute (gpm), respectively. Using standard USEPA (1997) estimation methods based on current Site conditions, it was estimated that EW-01 and EW-02 would both need to operate for approximately 18 years to achieve cleanup standards.

Capital costs associated with implementation of Alternative 2 are estimated to be approximately $2,421,000. The alternative proposes to make use of existing monitoring wells 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 Alternative 2 is estimated to be $4,143,000 based on a discount rate of 7% and an operational period of 18 years.

Alternative 2 was evaluated against the four minimum threshold requirements specified under MTCA. Based on the evaluation presented in the RI/FS Report (Geosyntec, 2012c), Alternative 2 is considered compliant with the four MTCA Threshold Requirements and meets the minimum requirements of an acceptable cleanup action.

4.2.3 Alternative 3 – Permeable Reactive Barrier

The conceptual layout of the PRB is depicted in **Figure 4-2**. 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. 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. 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 existing monitoring wells 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.

Alternative 3 was evaluated against the four minimum threshold requirements specified under MTCA. Based on the evaluation presented in the RI/FS Report (Geosyntec, 2012c), Alternative 3 is considered compliant with the four MTCA Threshold Requirements and meets the minimum requirements of an acceptable cleanup action.

4.3 Additional Requirements Evaluation

4.3.1 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. For each cleanup action alternative, rating values ranging from 1 (least favorable) to 5 (most favorable) were assigned for each of the MTCA criteria.

The absolute ratings were adjusted using DCA weighting factors. The weighted ratings and the estimated benefit of each alternative were presented in the RI/FS Report (Geosyntec, 2012c). The estimated benefit of Alternative 1 (normalized to a value of 5) was 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 was not required per MTCA. Although not required, the DCA metric of cost per benefit (i.e., cost/benefit) clearly indicated that Alternative 1 is protective to the maximum extent practicable.

4.3.2 Reasonable Restoration Timeframe Analysis

The MTCA specified factors were considered in the RI/FS Report (Geosyntec, 2012c) to determine whether Alternative 1 (i.e., the highest rated alternative based on the DCA) provided for a reasonable restoration time frame. For example, one of the criteria is that the potential risks posed by the site to human health and the environment be considered. Given that there are no current or likely future unacceptable risks at the Site, the estimated restoration time frame of 28 years for the highest concentration areas was concluded to be reasonable. Based on the full analysis presented in the RI/FS Report, the estimated restoration time frame for Alternative 1 is considered reasonable.

4.3.3 Consider Public Concerns

Several potential public concerns were considered in the RI/FS Report (Geosyntec, 2012c). It is anticipated that the public will support the acceptance of Alternative 1 for several reasons. Examples include:

- 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); and

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

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

4.4 Sustainability Analysis of Cleanup Alternatives

Although not required under MTCA, a sustainability analysis was performed in the RI/FS Report (Geosyntec, 2012c) to aid in the detailed evaluation of the three alternatives. The sustainability analysis was performed using the commercially available *Sustainability Remediation Tool* (SRT, version 2). 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}). 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.

4.5 Recommended Cleanup Action Alternative

Based on the analyses presented in the RI/FS Report (Geosyntec, 2012c), 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.

Based on the review of Ecology expectations for cleanup action alternatives that was presented in the RI/FS Report (Geosyntec, 2012c), Alternative 1 is consistent MTCA requirements and thus is proposed as the recommended alternative for the Site.

5. PROPOSED CLEANUP ACTION ALTERNATIVE

5.1 Implementation of Selected Cleanup Action

5.1.1 Public Involvement

Upon approval of this CAP and CMWP by Ecology, public notification of the documents and Order availability for review will be provided by Ecology. As described in Section 4.3, the additional requirements for cleanup actions performed under MTCA are listed in WAC 173-340-360(2)(b), and require that public concerns be considered. The intent of this CAP is to inform the public of the cleanup action being implemented at the Site and to provide the public the opportunity to comment on the proposed cleanup action. Subsequent public notifications, as needed, may be provided by Ecology as periodic review of implementation of the selected remedial alternative occurs.

As part of remedy implementation, educational mailings will be sent to properties that overly the groundwater plume at least every 5 years. Ecology will determine whether mailings need to be sent out more frequently as part of periodic reviews. Ecology will send a mailing every 18 to 24 months prior to the first periodic review.

5.1.2 Overall Implementation Approach

Implementation of MNA as the cleanup action for the site will include the following:

- Concurrent submittal of the Compliance Monitoring Plan (CMWP) with the CAP;
- Concurrent review and approval of the CAP and CMWP by Ecology;
- Implementation of the CMWP by the Companies, including regular reporting of results to Ecology; and
- Periodic review of the effectiveness of the cleanup action by the Companies, and implementation of contingency plans in the event the Companies or Ecology determines the cleanup action has not met expectations.

The CMWP for implementation of MNA is being submitted concurrently with the CAP and details the proposed strategy for monitoring remedial progress. Per WAC 173-340-410, there are three types of compliance monitoring: 1) Protection Monitoring; 2)

Performance Monitoring; and 3) Confirmational Monitoring. Protection Monitoring is not required at the Site, thus the CMWP includes the following elements:

- Performance Monitoring to confirm that the cleanup action progresses towards and ultimately achieves cleanup standards site-wide; and

- Confirmational Monitoring to confirm the long-term effectiveness of the cleanup action once cleanup standards have been attained site-wide (i.e., upon completion of Performance Monitoring).

The CMWP formally identifies: (i) the monitoring wells that comprise the compliance monitoring network; (ii) the monitoring frequency during performance monitoring and confirmational monitoring phases of compliance monitoring; (iii) the list of parameters to be collected and analyzed; (iv) proposed sampling and analytical methodologies; and (v) the reporting schedule. The CMWP will also include an updated Quality Assurance Project Plan and Sample Analysis Plan (QAPP and SAP). A brief overview of the key CMWP components is provided below.

The CMWP proposes that the compliance monitoring network consist of the 11 Aquifer A monitoring wells shown in **Figure 5-1**. The rationale for each well is provided below:

- **11-CL, HLA-1, BMW-18, MW-1, MW-13 and P2-S –** these six wells were selected for compliance monitoring because each well had a CTC concentration in excess of the cleanup standard of 0.63 µg/L during the most recent sampling event in February 2011 (**Table 2-1**).

- **11-BL, MW-4, and P2-I –** these three wells were selected for compliance monitoring because each well had a CTC concentration in excess of the cleanup standard of 0.63 µg/L during the June 2010 sampling event and the November 2002 sampling event (**Table 2-1**).

- **BMW-3 and MW-7 –** these two wells were selected for compliance monitoring because each well had a CTC concentration in excess of the cleanup standard of 0.63 µg/L during the November 2002 sampling event (**Table 2-1**), but not in subsequent events. During the first round of compliance monitoring, if BMW-3 and MW-7 are still below the cleanup standard, the Companies will request that Ecology allow removal of these two wells from the compliance monitoring network.

Compliance monitoring of Aquifer C is not included as part of the CMWP given the recent absence of CTC detections in Aquifer C (i.e., Aquifer C does not exceed the 0.63 µg/L cleanup standard for CTC). Thus, with Ecology concurrence, compliance monitoring will focus on Aquifer A.

Steady CTC concentration declines have been observed at the Site over the past 20 years, providing conclusive evidence that CTC in groundwater is attenuating at the Site. Given the relatively long history of analytical results and declining CTC concentration trends for the monitoring wells, semi-annual sampling for the monitoring wells is considered to be appropriate for the first two years of monitoring, and then changing to annual sampling thereafter; the rationale for two years of semi-annual sampling followed by annual sampling is discussed in the CMWP. Assuming that the declining trends continue, it is likely that the Companies will submit future requests to Ecology to reduce the sampling frequency.

The proposed parameter list includes:

- Carbon Tetrachloride;
- pH;
- Dissolved oxygen (DO);
- Temperature;
- Turbidity;
- Conductivity; and
- Oxidation/reduction potential (ORP).

As noted, the initial monitoring periods will provide data to confirm that variation in MNA parameters is minimal. Given the low level CTC concentrations observed at the Site, sampling for CTC degradation products is not recommended. At the CTC concentrations observed, it is not likely that CTC degradation products will be present at quantifiable levels. Further, as noted previously, steady CTC concentration declines have been observed at the Site over the past 10 to 20 years, and it appears conclusive that CTC in groundwater is attenuating at the Site primarily through physical mechanisms. Given the very low concentrations of CTC, coupled with the conclusive attenuation trends, in-depth monitoring of biological and/or chemical attenuation mechanisms does not appear to be warranted or beneficial.

The criteria for determining when the transition from Performance Monitoring to Confirmational Monitoring and Site closure are discussed in the CMWP.

5.2 Additional Requirements

5.2.1 Institutional Controls

For groundwater, a restrictive covenant for property groundwater that precludes its use for drinking water will be implemented. Regarding off-property groundwater, 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. The combination of the restrictive covenant for property groundwater and the Pierce County Urban Growth Area well installation restriction is anticipated to be an effective and reliable means to prevent human exposure to CTC in groundwater. As noted in Section 5.1.1, educational mailings to properties overlying the groundwater plume will be also distributed periodically by Ecology as part of the institutional controls for groundwater.

For soil, as discussed in Section 2.1.2 and 2.3.1, institutional controls are not required given the absence of CTC and TPH concentrations exceeding soil cleanup levels.

5.2.2 Financial Assurances

WAC 173-340-440(11) states that "The department shall, as appropriate, require financial assurance mechanisms at sites where the cleanup action selected includes engineered and/or institutional controls." The purpose of the financial assurances is to cover costs associated with the operation and maintenance of the cleanup action, including institutional controls, compliance monitoring, and corrective measures. As noted, additional institutional controls and corrective measures are not required as part of the MNA remedy. Compliance monitoring will be implemented using the approach described in Section 5.1.2. The Companies have informed Ecology that they will maintain control of the existing compliance monitoring wells (**Figure 5-1**). Based on this commitment, the Order does not specify the need for additional financial assurances.

5.2.3 Substantive Requirements

The selected remedial alternative will be conducted in compliance with all requirements of local and State regulations.

5.2.4 Compliance Monitoring Work Plan

The CMWP has been prepared and is being submitted concurrently with this CAP to Ecology for review and approval. The contents of the CMWP are discussed in Section 5.1.2.

5.3 Implementation Schedule

The preliminary schedule for the proposed cleanup action is assumed to begin after this CAP and the CMWP have been reviewed and approved by Ecology. Approval and implementation of the cleanup action is anticipated to occur during 2014. The CMWP provides the schedule for monitoring and reporting. Implementation of the approved remedial approach will continue, until results indicate that MNA has achieved cleanup levels. If, during the Confirmational Monitoring phase, the cleanup criteria are not achieved, a contingency plan will be developed and provided to Ecology for review and approval.

6. REFERENCES

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TABLES

Table 2-1
Summary of Carbon Tetrachloride Groundwater Data
Draft Cleanup Action Plan
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 3-1
Applicable, Relevant and Appropriate Requirements (ARARs)
Draft Cleanup Action Plan
Frederickson 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
Draft Cleanup Action Plan
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

FIGURES

Legend

Property Boundary

Source:
Bing Aerial Photography, October 2006

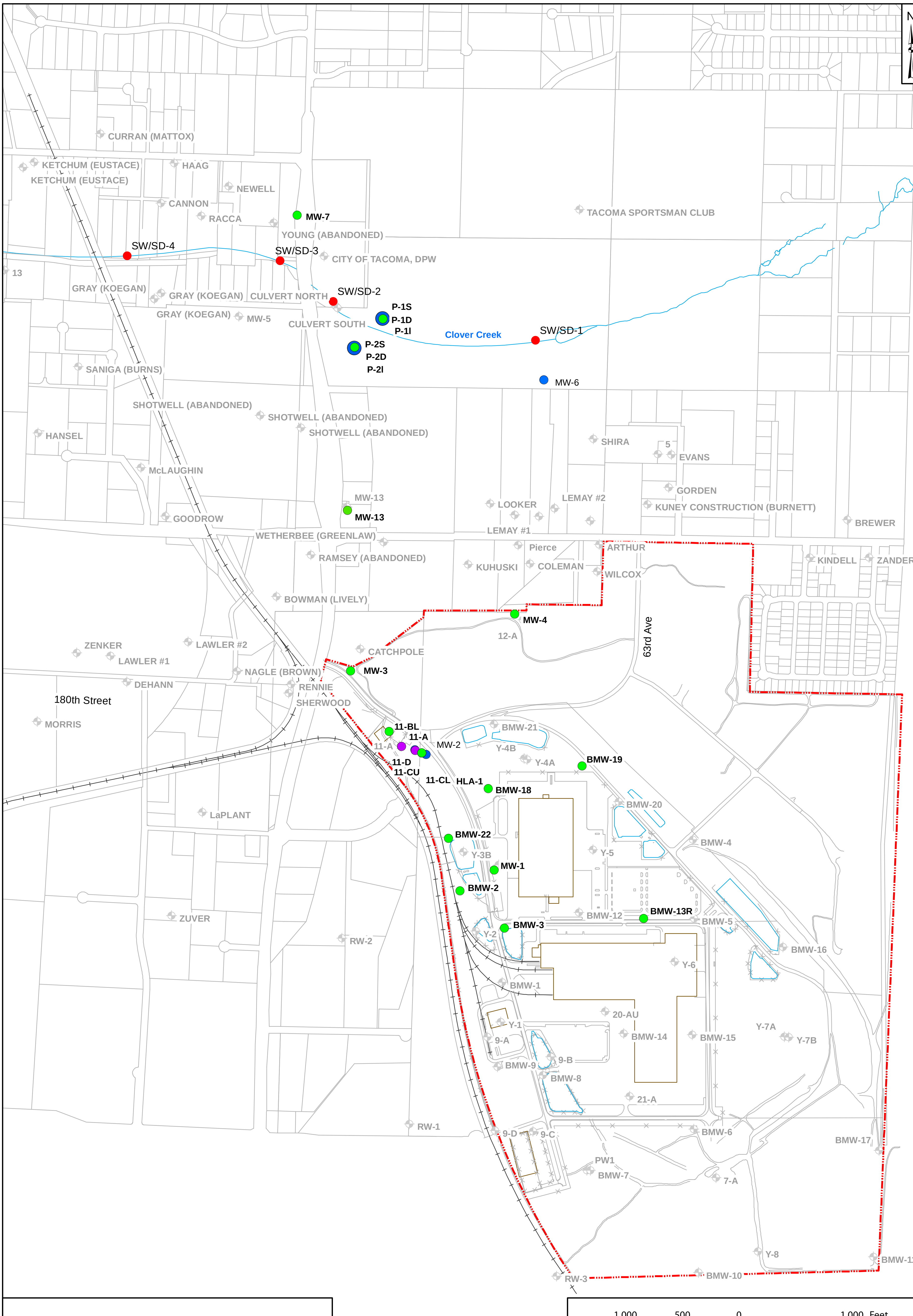
Property Location

Fredrickson Industrial Park
Frederickson, WA

Geosyntec consultants

Kennesaw, GA | 06-Sep-2013

Figure
1-1



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\DCAP\MXD\Figure 2-1.mxd NHeron 9/6/2013

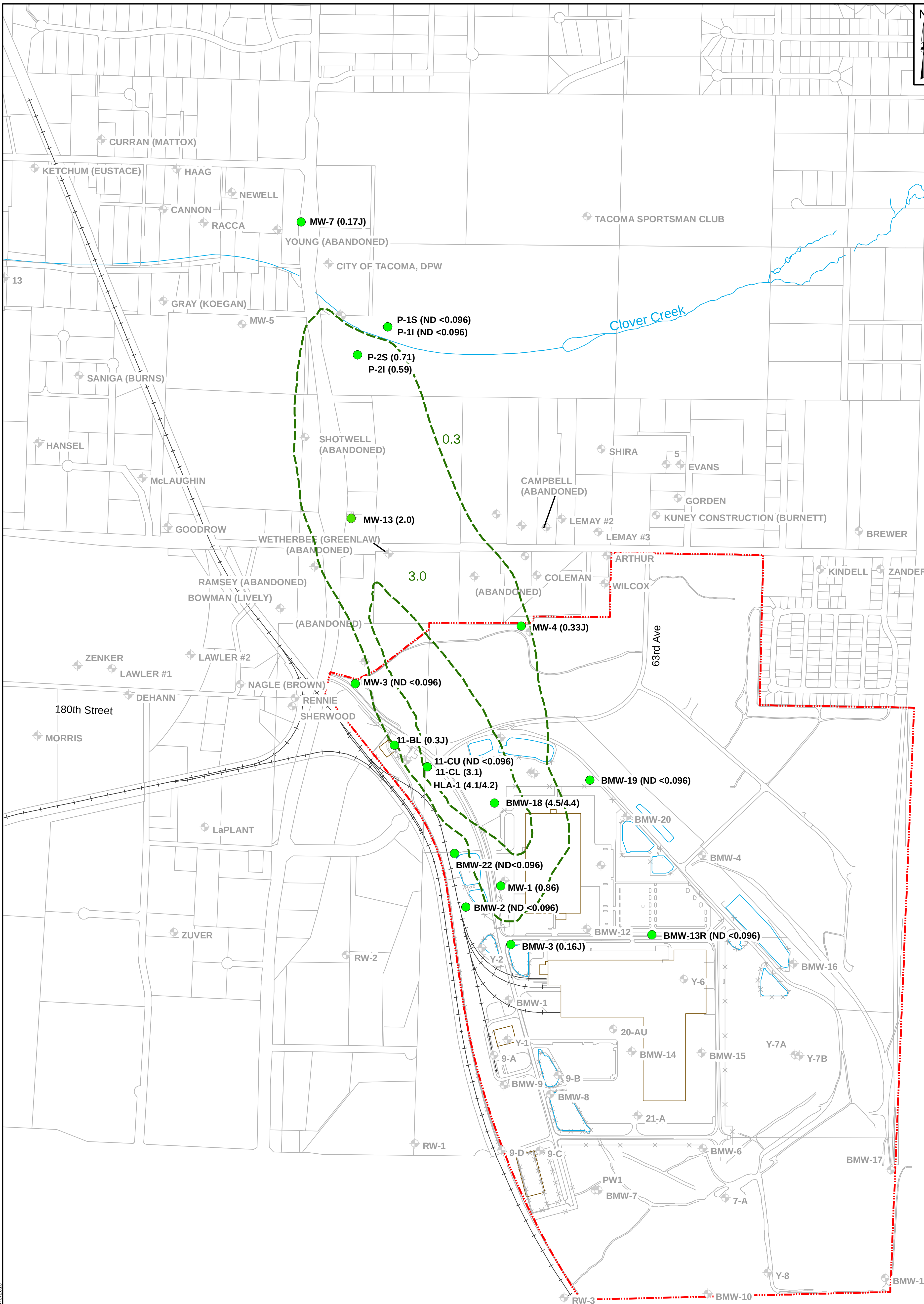
Site Plan

Fredrickson Industrial Park
Frederickson, WA

Geosyntec consultants

Figure **2-1**

Kennesaw, GA | 06-Sep-2013



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)

1,000 500 0 1,000 Feet

Aquifer A Carbon Tetrachloride Groundwater Results February 2011

Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Figure 2-2a

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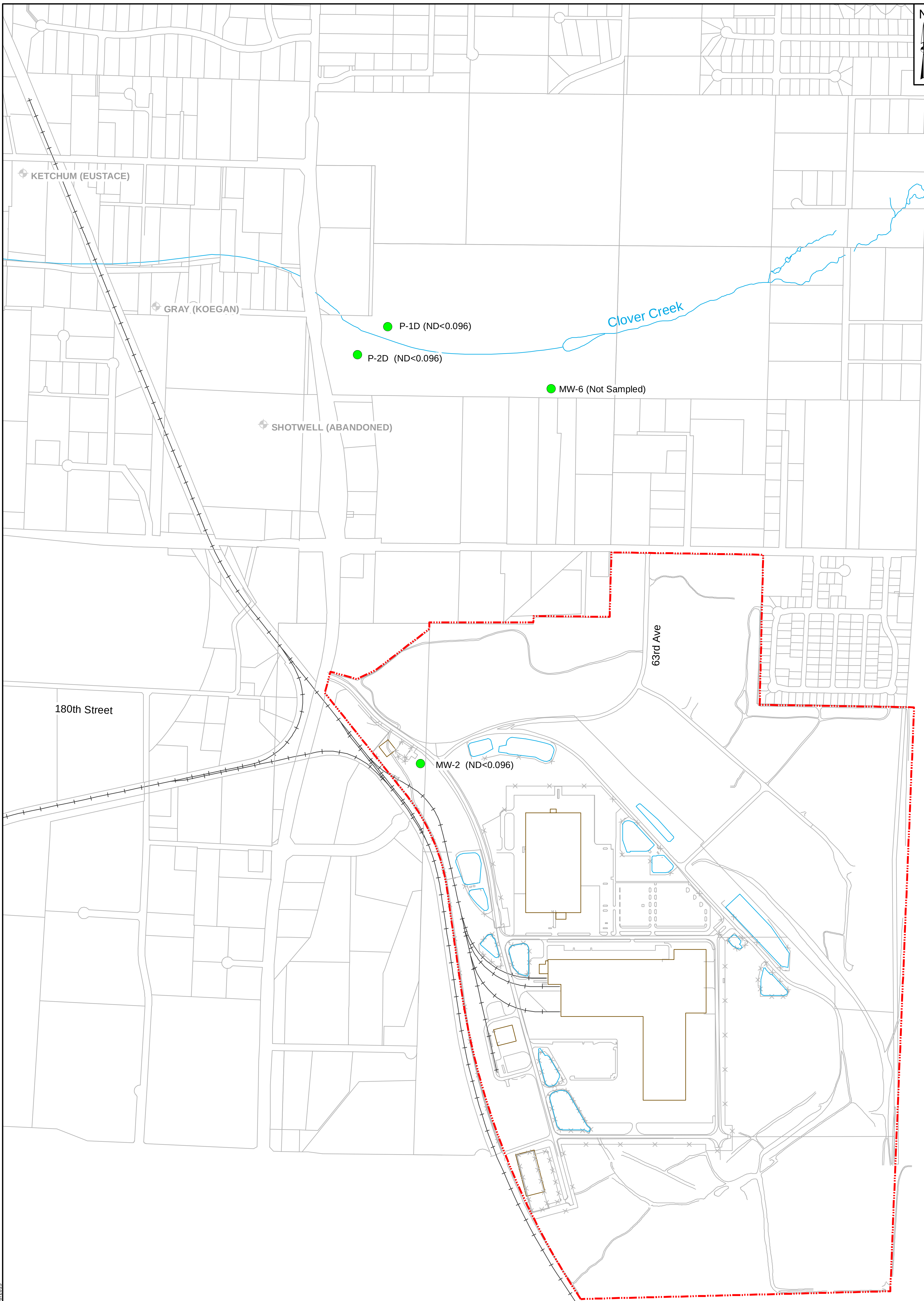


Legend

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

1,000 500 0 1,000 Feet

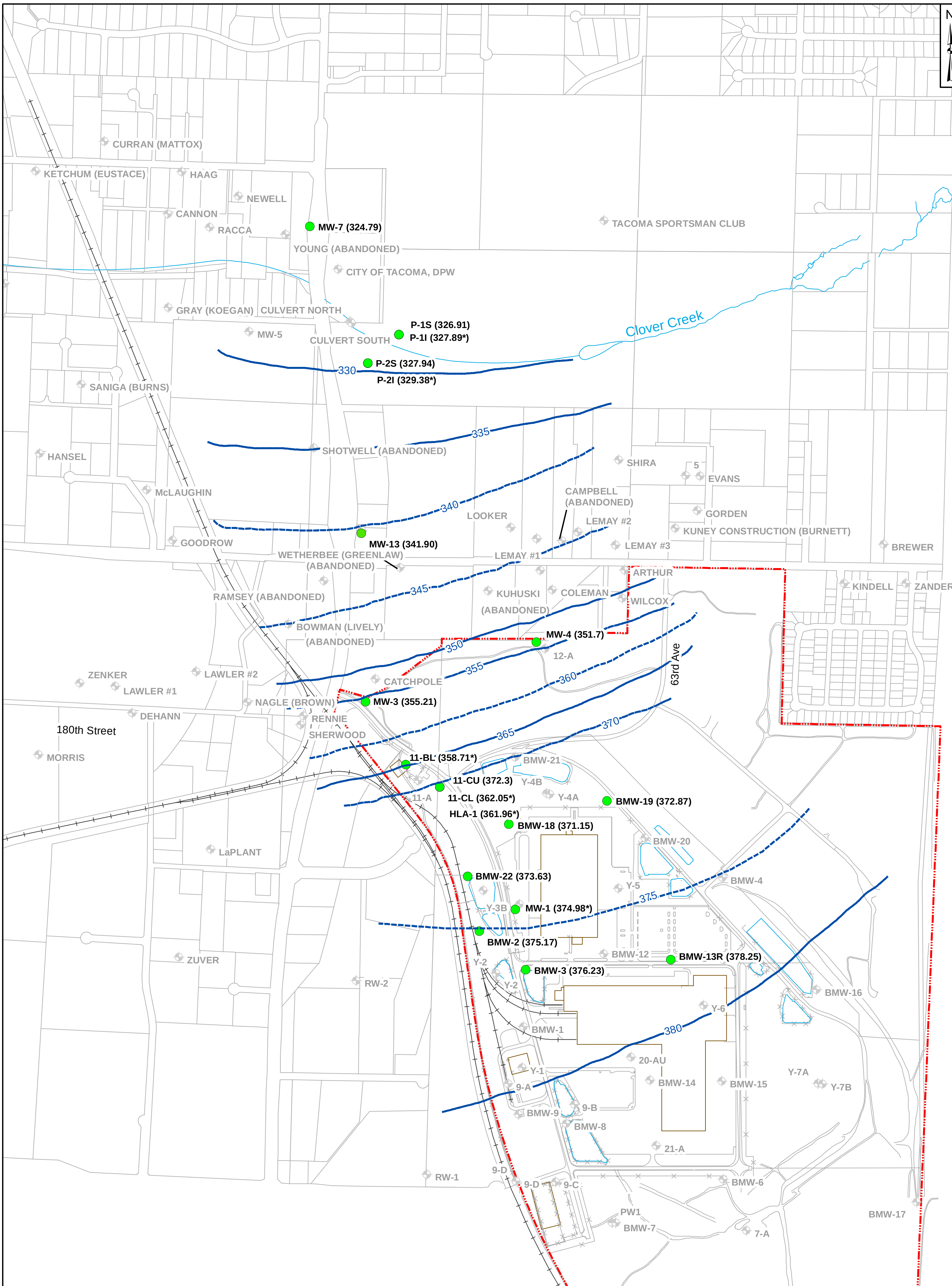
Aquifer C Carbon Tetrachloride Groundwater Results
February 2011
Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Figure **2-2b**

Kennesaw, GA | 06-Sep-2013

N:\Frederickson\GIS\DCAP\MXD\Figure 2-2b Olin_CTC_Conc_Aquifer C.mxd; NHirons; 9/6/2013



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

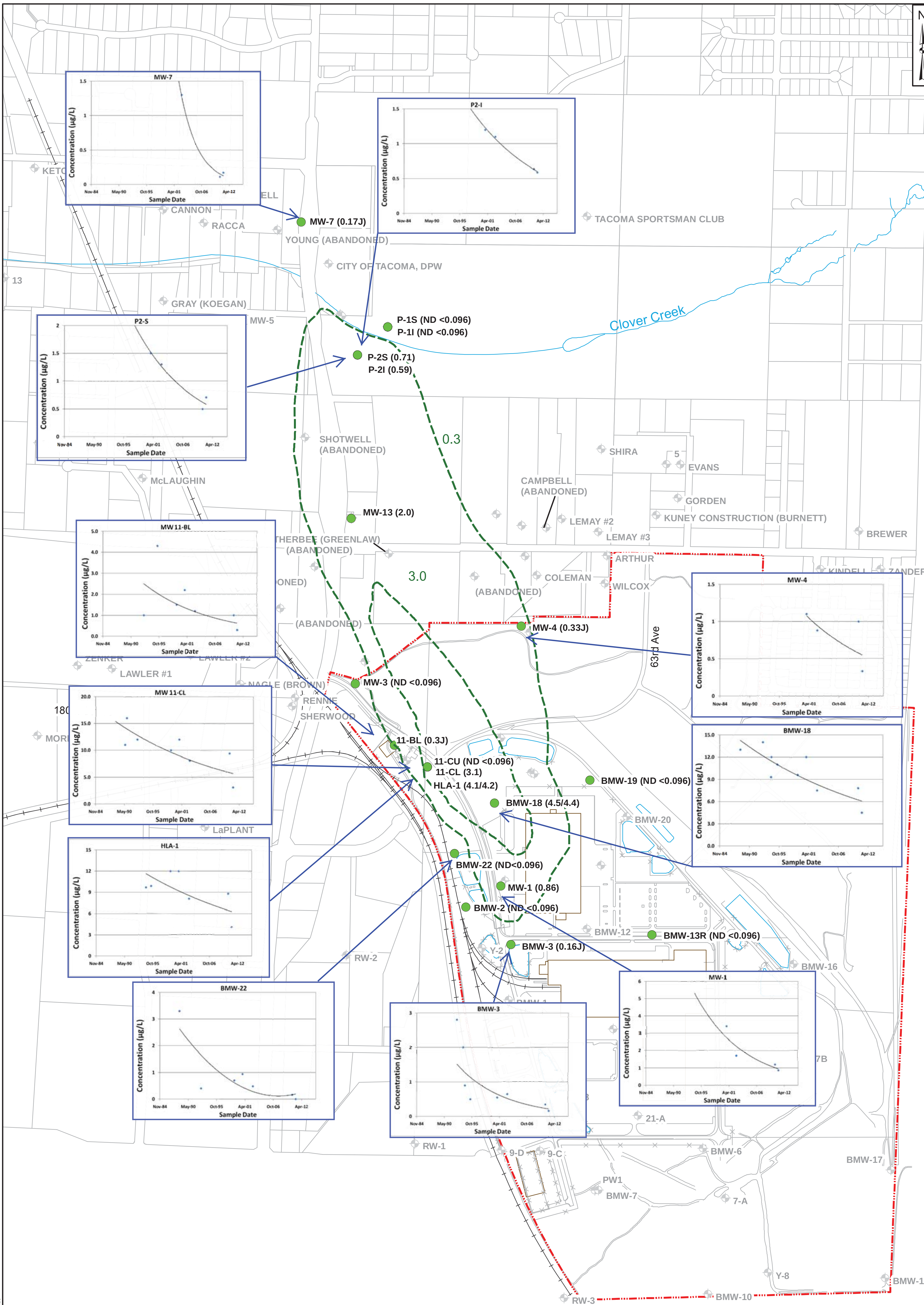
Aquifer A Groundwater Levels
February 2011

Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Figure **2-3**

Kennesaw, GA | 06-Sep-2013



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)

1,000 500 0 1,000 Feet

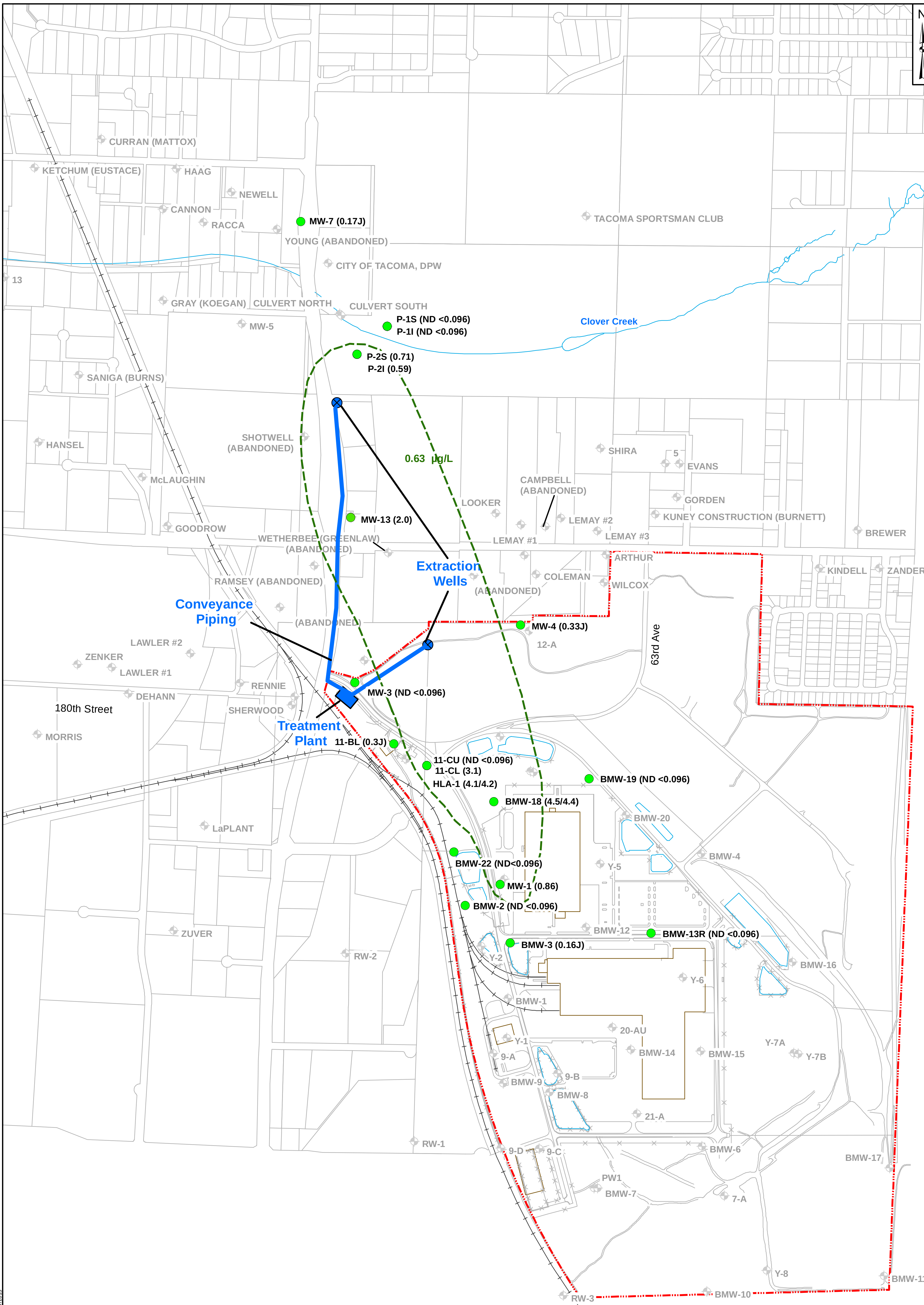
Concentration Trends for Carbon Tetrachloride
February 2011

Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Figure **2-4**

Kennesaw, GA | 06-Sep-2013



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)

Conceptual Layout for Alternative 2

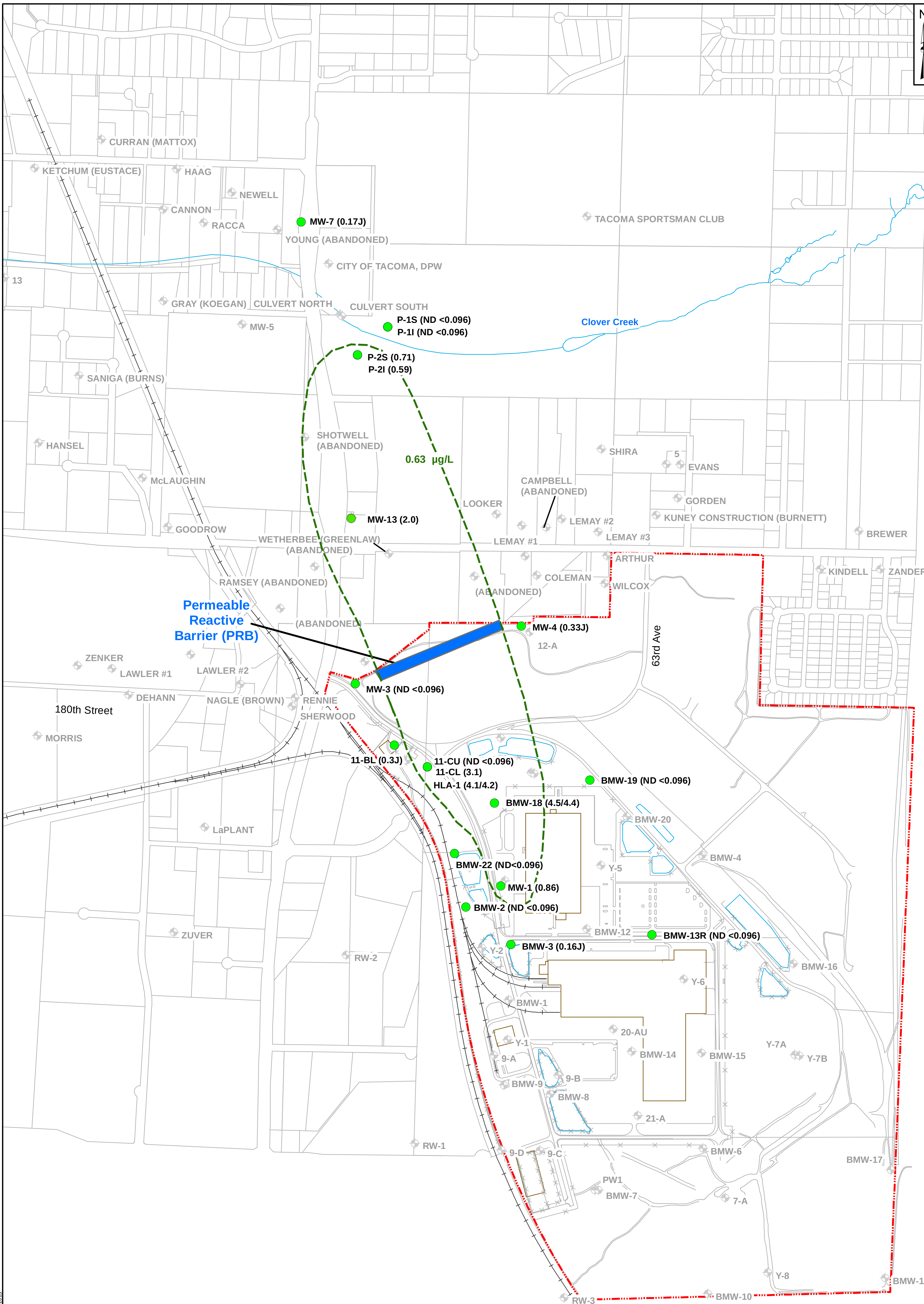
Frederickson Industrial Park
Fredericksen, WA

Geosyntec consultants

Figure **4-1**

Kennesaw, GA | 06-Sep-2013

N:\Fredericksen GS\DCAP\MXD\Figure 4-1 Conceptual Layout Alt2.mxd NHerlons 9/6/2013



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

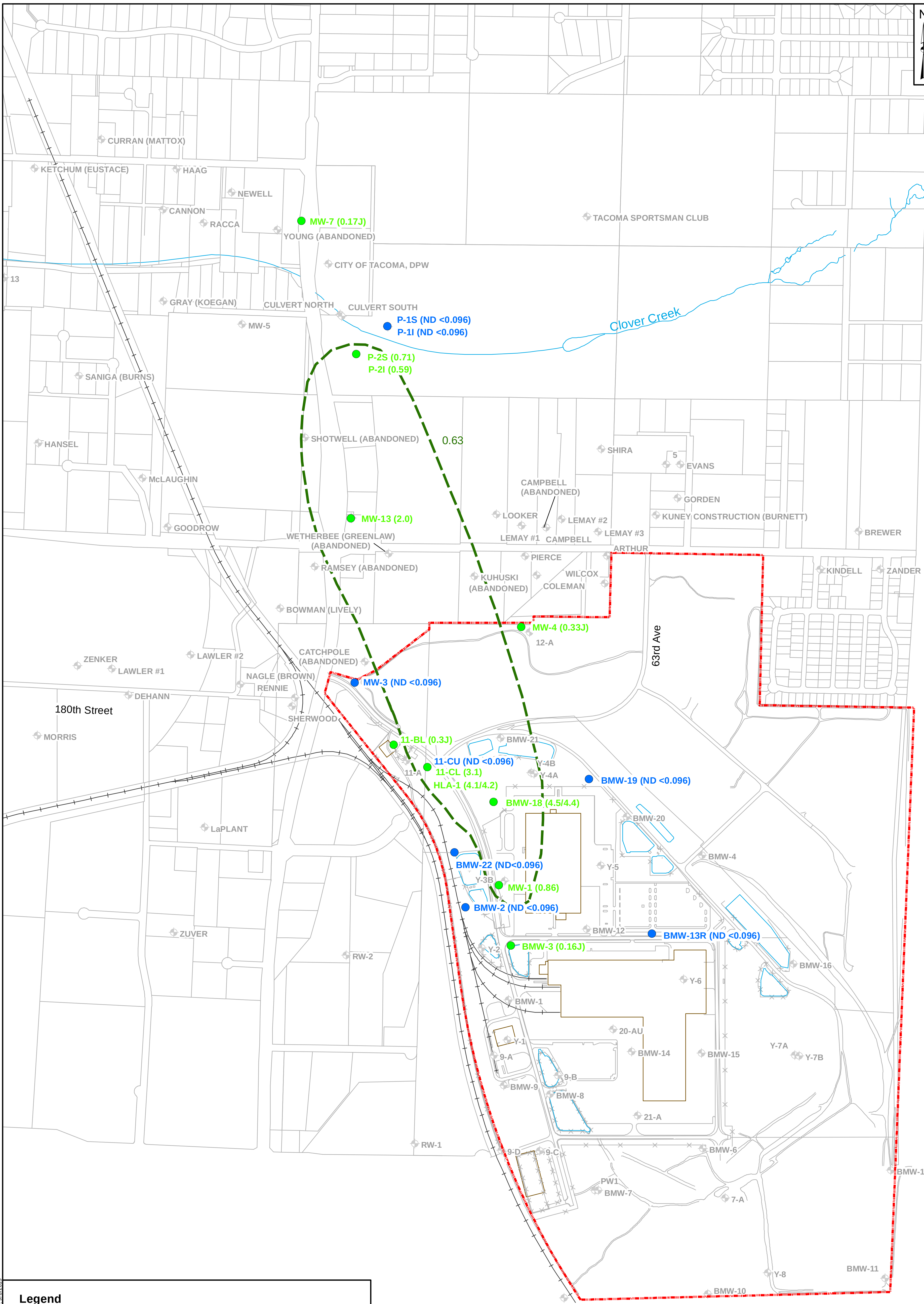
Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Kennesaw, GA | 06-Sep-2013

Figure 4-2

N:\Fredrickson GIS\DCAP\MXD\Figure 4-2 Conceptual Layout Alt3.mxd NHerons 9/6/2013



Legend

- Aquifer A Compliance Monitoring Well (CTC Concentration µg/L))
- Aquifer A Monitoring Well Not Included in Compliance Monitoring Network (CTC Concentration (µg/L))
- Private/Domestic Wells
- CTC Contour of 0.63 µg/L (Based on Feb. 2011 Data)
- Property Boundary

MTCA Method B Cleanup Level for CTC = 0.63 ug/L

(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

Proposed Compliance Monitoring Network

Frederickson Industrial Park
Fredericksen, WA

Geosyntec
consultants

Figure **5-1**

Kennesaw, GA | 06-Sep-2013

ATTACHMENT A

UPDATED VAPOR INTRUSION EVALUATION

APPENDIX A

UPDATED VAPOR INTRUSION EVALUATION
FREDERICKSON INDUSTRIAL PARK, FREDERICKSON, WASHINGTON

This Appendix presents the results of an updated evaluation of the potential for subsurface carbon tetrachloride (CTC) vapors related to the Frederickson Industrial Park (the Property) to pose a potential risk to current and future buildings under a range of land use scenarios. The original VI evaluation was conducted in 2011 and presented as Appendix B to the Draft Remedial Investigation / Feasibility Study[1] (RI/FS). The Department of Ecology (Ecology) issued comments on the Draft RI/FS on 11 October 2011; none of the comments were related to the VI evaluation. The Final RI/FS, including the original VI evaluation, was submitted to Ecology on 28 March 2012. In a letter dated 27 August 2013, Ecology acknowledged that with submittal of the Final RI/FS report, the Companies had satisfactorily completed the Agreed Order requiring the RI/FS.

This updated VI evaluation was conducted in 2013 at the request of the current Property owner to include an evaluation of potential future industrial and unrestricted uses of the Property and updated soil gas screening levels. Consistent with the original VI evaluation, the Department of Ecology Draft Guidance for Evaluating Vapor Intrusion[2] (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.

1. 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 A1. CTC was detected in the Site groundwater, but groundwater sampling during the Remedial Investigation[3] did not identify any other significant detections of volatile organic compounds (VOCs)[3]. Excavation and removal of the disposal areas was conducted in 1989

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[1] Geosyntec Consultants, Inc. Draft Remedial Investigation / Feasibility Study. September 30, 2011.

[2] 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.

[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.

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[4].

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 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 the 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 the 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 the 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 have declined over time or are stable, as discussed in Section 2.3.6 of the 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.

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[4]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.

2. 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 A1 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 A2 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.

3. 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.

3.1 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.

3.2 Evaluation of Existing Buildings by 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 at the Property. 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 $\mu g/L$).

The original VI evaluation compared CTC soil gas concentrations to Tier 1 screening levels (SLs) presented in the Draft Guidance which were based upon the Method B and C Indoor Air Cleanup Levels of 0.17 $\mu g/m^3$ and 1.7 $\mu g/m^3$, respectively, for unrestricted and industrial land use. However, the Department of Ecology posted updates to the values on 13 April 2011[5] that changed the Method B and C Indoor Air Cleanup Levels to 0.42 $\mu g/m^3$ and 4.2 $\mu g/m^3$, respectively. These changes result in revised Method C Tier 1 soil gas SLs of 42 and 420 $\mu g/m^3$ (0.042 and 0.420 $\mu g/L$) for shallow (<15 ft bgs) and deep ($\geq$15 ft bgs) soil gas, respectively. Comparing the 1999 soil gas CTC concentrations to the revised SLs indicates that samples from two of the five areas exceed the SLs, as described below.

- Area 3 – Area 3 is located adjacent to the southwest portion of the southern industrial building at the Property. Only 1 of the 33 soil gas samples had a CTC concentration greater than the SL. The 9.5 ft bgs sample at location E4 (47.4 $\mu g/ m^3$) slightly exceeds the SL for shallow soil gas (42 $\mu g/ m^3$) but the shallower sample (5 ft bgs) that is closer to the existing building foundation at this location (3.5 $\mu g/ m^3$) does not. No other Area 3 samples had CTC concentrations that were greater than the SLs. Based on the 1999 CTC concentrations and distribution, none of the CTC detections in Area 3 are considered to pose a risk to the indoor air of the adjacent industrial building.

- Area 5 – Area 5 is located over 300 feet east of the southern industrial building at the Property. Five of the 22 shallow samples obtained in 1999 had CTC concentrations greater than the current SL for shallow soil gas (42 $\mu g/ m^3$). The five shallow samples are: (i) 4.5 ft bgs at location E3 (122 $\mu g/m^3$); (ii) 5 ft bgs at location F2 (53.8 $\mu g/m^3$); and (iii) 5 ft bgs at location D4 (118.5 $\mu g/m^3$). None of the deep soil gas samples exceed the SL for deep soil gas (420 $\mu g/m^3$) but the 14.5 ft bgs sample at location D4 (186.3 $\mu g/m^3$) and the 14.5 ft bgs sample at location C7 (157.2 $\mu g/m^3$) exceed the SL for shallow soil gas. Other Area 5 samples located closer to the building do not exceed the SL. Based upon the large distance of Area 5 to the nearest building and the concentration and distribution of CTC in soil gas within Area 5, none of the 1999 CTC detections in Area 5 are considered to pose a risk to the indoor air of existing industrial buildings at the Property.

3.3 Evaluation of Existing Property Buildings using Soil Gas Data and JE Model

Despite the conclusion that the 1999 soil gas data are not considered to pose a risk to the current indoor air of the existing industrial buildings at the Property, the soil gas data were further evaluated as part of the Tier 1 assessment. The Johnson and Ettinger model (JEM) was used to predict indoor air concentrations for comparison to Method C Indoor Air Cleanup Levels. Method C levels were used because the current building use is industrial.

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[5] 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.

The United States Environmental Protection Agency (US EPA) spreadsheet implementation of the JEM model (GW-SG Version 3.1 02/04[6]) was used with conservative input parameters that are consistent with Appendix D of the Draft Guidance. Conservative default values were used for input parameters, except where Site-specific information was available. Site-specific values of soil gas sampling depth, soil type, and soil temperature were used. From the 1999 data set, the maximum measured CTC concentration in Area 3 was used. There are two industrial buildings on the Property, which 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. Therefore, a slab-on-grade foundation was modeled. Conservative default building dimensions and air exchange rates were used. Table A1 lists the model input parameter values used and source of each value, as well as generic default values where applicable. The JEM spreadsheet input parameters and INTERCALCS pages are provided in Attachment B1.

The predicted CTC indoor air concentration calculated using the maximum measured soil gas concentration in Area 3 (47.4 μg/ m^3 at 9.5 ft bgs sample at location E4) is shown on the INTERCALCS page in Attachment B1. The predicted CTC indoor air concentration (0.043 μg/m^3) is nearly 100 times lower than the Method C Indoor Air Cleanup Level (4.2 μg/ m^3).

3.4 Evaluation of Future Property Buildings using Soil Gas Data and JE Model

Potential future buildings on the Property were also evaluated using the 1999 soil gas data and the JEM. This evaluation considered that a new slab-on-grade building could be constructed anywhere on the Property. Indoor air CTC concentrations were predicted using the JEM with conservative input parameters (Table A1) consistent with unrestricted and industrial land uses, and were compared to Method B and Method C Indoor Air Cleanup Levels, respectively. As in Section 3.3, conservative default values were used for input parameters, except where Site-specific information was available. Site-specific values of soil gas sampling depth, soil type, and soil temperature were used. The maximum measured shallow (<15 ft bgs) and deep (≥15 ft bgs) CTC soil gas concentrations from 1999 were used in the modeling.

This evaluation assumes that the future land use will be either industrial or unrestricted. Future industrial land use was assessed using Method C model default input parameters for a future slab-on-grade industrial building and predicted indoor air concentrations were compared to Method C Indoor Air Cleanup Levels. Future unrestricted land use was assessed using Method B model default input parameters for a future slab-on-grade building and predicted indoor air concentrations were compared to Method B Indoor Air Cleanup Levels. The JEM spreadsheet input parameters and INTERCALCS pages are provided in Attachments B2 and B3. Predicted indoor air CTC concentrations are summarized below.

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

Scenario	Soil Gas Sample Depth (ft bgs)	Measured CTC Soil Gas Concentration (1) (µg/m³)	Indoor Air Cleanup Level (µg/m³)	Predicted Indoor Air CTC Concentration (µg/m³)
Future Industrial	4.5	122.0	4.2	0.17
	14.5	186.3	4.2	0.13
Future Unrestricted	4.5	122.0	0.42	0.34
	14.5	186.3	0.42	0.25

The indoor air CTC concentrations predicted using maximum measured soil gas concentrations from 1999 are less than both the Method B and Method C Indoor Air Cleanup Levels.

Based on these modeling results and the comparison to soil gas SLs in Section 3.3, vadose zone soil in areas where CTC was previously handled is not evaluated further as a potential source of CTC vapors for indoor air.

3.5 Comparison of Groundwater Data to Tier 1 Screening Levels

Figure A2 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. This evaluation assumes that commercial buildings could be constructed on these lands in the future. Further, as described in Section 3.4, this evaluation also considers unrestricted and industrial land uses for potential new buildings that could be constructed anywhere on the Property.

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 A2); 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 Method B and C Tier 1 groundwater SLs. Table A1 of the Draft Guidance shows values of 0.22 and 2.2 µg/L, for Methods B and C, respectively. However, as discussed in Section 3.2, the Department of Ecology posted updates to their Method B and C values on 13 April 2011 that changed the screening values to 0.56 and 5.6 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 the RI/FS Report) and in February 2011 ranged from non-detect to 4.5 µg/L (Figure 2-6a of the RI/FS Report). Given that CTC concentrations at several locations are greater than the SLs, the next step in the Tier 1 process, predictive modeling, was conducted for groundwater.

3.6 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 JEM to predict indoor air concentrations.

Geosyntec used the US EPA spreadsheet implementations of the JEM (GW-ADV Version 3.1 02/04[7]). Conservative default values 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 A1 lists the model input parameter values used and source of each value, as well as generic default values where applicable.

The Property's current land use is industrial. The Property is zoned as an "Employment Center," which may include industrial and commercial land uses. 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

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

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 thinner 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[4]) 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 A3, 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 A2) 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 the RI/FS Report, groundwater CTC concentrations have been declining at many monitoring locations over the last decade. All scenarios were assessed assuming slab-on-grade buildings with conservative building default dimensions and air exchange rates (Table A1) consistent with the prescribed scenario land use. The scenarios are listed below.

- Scenarios 1A and 1B: Scenario 1A considers the current/future industrial use of the Property 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 1B considers future unrestricted land use in this same area of the Property.

- Scenario 2: Scenario 2 considers current commercial land use 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: Scenario 3 considers current unrestricted land use 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: Scenario 4 considers current unrestricted land use 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: Scenario 5 considers current unrestricted land use 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: Scenario 6 considers future commercial land use 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 of 0.42 µg/m^3 and 4.2 µg/m^3 for Method B (to assess unrestricted and commercial land uses) and Method C (to assess industrial land use), respectively. The corresponding groundwater concentration was then established as the site-specific groundwater SL. The JEM spreadsheet input parameters and INTERCALCS pages for each scenario are provided in Attachment C. The table below compares the range of measured CTC concentrations to the site-specific groundwater SL.

Scenario (Land use, depth to water table)	Range of Measured Groundwater CTC Concentration (µg/L)	Site-Specific Groundwater CTC Screening Level (µg/L)
Scenario 1A – Current/future industrial, 38 ft Scenario 1B - Future unrestricted, 38 ft	0.35 to 14 0.35 to 14	54 1.4
Scenario 2 - Current commercial, 30 ft	<0.096 to 0.71	4.6
Scenario 3 - Current unrestricted, 35 ft	<0.096 to 0.1	1.3
Scenario 4 - Current unrestricted, 100 ft	<0.096 to 1.1	2.8
Scenario 5 - Current unrestricted, 120 ft	<0.096 to 1.0	3.3
Scenario 6 - Future commercial, 15 ft	<0.096 to 1.5	3.2

Observed groundwater concentrations do not exceed the site-specific groundwater SLs calculated for the current/future industrial on-Property land use scenario (i.e., Scenario 1A) and the five off-property land use scenarios (i.e., Scenarios 2 through 6); Scenario 1B is discussed in the following paragraph. 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.

Under Scenario 1B (future unrestricted land use for the Property), the calculated site-specific groundwater SL of 1.4 µg/L is lower than the groundwater concentrations measured historically (0.35 to 14 µg/L). This comparison to historical data is conservative, as the more recent data shown on Figure A2 suggest that on-Property CTC groundwater concentrations have declined (≤4.5 µg/L). Furthermore, as shown on Figure A2, only a small part of the Property is underlain by groundwater having CTC concentrations that are greater than the Method B site-specific SL (1.4 µg/L) that pertains to future unrestricted land use, and the land use is currently industrial. Regardless, the cleanup level of 0.63 µg/L that has been identified in the RI/FS is lower than the site-specific groundwater SL. The Ecology-approved RI/FS cleanup level is protective of indoor air for current/future industrial and future unrestricted land use at the Property. Once the cleanup level has been attained, the groundwater SL for unrestricted land use will also be attained. In the event that property use changes from industrial to unrestricted use before the groundwater cleanup level has been attained, the Companies and Property Owner will reassess VI for the new land use.

4. SUMMARY

This updated vapor intrusion assessment considered CTC in both vadose zone soil and groundwater as potential sources of CTC vapors to indoor air. Preliminary and Tier 1 assessments were conducted using draft state guidance.

For the Property, the updated assessment is based upon the following lines of evidence: (1) comparison of the measured soil gas CTC concentrations to Method B and C soil gas SLs, (2) comparison of Method B and C Indoor Air Cleanup Levels to indoor air concentrations predicted from the 1999 maximum soil gas concentrations using conservative assumptions, and (3) comparison of measured groundwater concentrations to Method B and C site-specific groundwater SLs developed using the JEM with site-specific groundwater conditions and conservative assumptions. Current and potential future industrial land uses and potential future unrestricted land uses were assessed. The current industrial land use and potential future industrial land use were assessed using Method C. Potential unrestricted land use was assessed using Method B. For vadose zone soils, the assessment used measured soil gas CTC concentrations from 1999 in areas where CTC was previously handled and shows that the soil conditions in those areas do not pose an unacceptable risk to indoor air for the current or potential future industrial land uses or for potential future unrestricted land use. For groundwater, the assessment used measured groundwater CTC concentrations and shows that conditions do not pose an unacceptable risk to indoor air for either current or potential future industrial land use, as groundwater concentrations are less than the Method C site-specific SL (54 μg/L). As shown in Figure A2, a small part of the Property is underlain by groundwater having CTC concentrations that are greater than the Method B site-specific SL (1.4 μg/L) that pertains to future unrestricted land use.

The Ecology-approved groundwater cleanup level identified in the RI/FS is the value for CTC in drinking water (0.63 μg/L). This cleanup level was selected in accordance with Method B and is more stringent (i.e., lower) than both the Method B (1.4 μg/L) and Method C (54 μg/L) site-specific groundwater SLs developed in this updated VI assessment for unrestricted and industrial land use of the Property, respectively. The Method C SL for VI on the Property has already been attained indicating that there are no current or potential future unacceptable risks related to industrial use of the Property. Industrial use is consistent with the current zoning of the Property. Once the groundwater cleanup level (0.63 μg/L) has been attained, the Method B SL for unrestricted use of the Property (1.4 μg/L) will also be attained. In the event that the Property use changes from industrial to unrestricted before the groundwater cleanup level has been attained, the Companies will reassess VI for the proposed new land use and implement mitigation measures, if necessary.

For the area downgradient of the Property, conservative assumptions regarding groundwater CTC concentrations and building construction were used in the original assessment in order to evaluate commercial and unrestricted land uses. No unacceptable indoor air exposures were identified for current or future land use.

TABLES

Table A1
Input Parameters for the Johnson and Ettinger Model (1991)
Fredrickson Industrial Park
Fredrickson, Washington

Input Parameter	Symbol	Site-Specific Inputs	Units	Justification
Soil Gas Model Inputs				
Depth Below Grade to Bottom of Enclosed Space Floor	L_F	15	cm	US EPA JEM default value for slab on grade
Soil Gas Sampling Depth Below Grade - shallow soil gas	L_S	137.16	cm	Site-specific: 4.5 feet bgs (depth of maximum concentration within 0 to≤ 5 feet bgs interval)
Soil Gas Sampling Depth Below Grade - deep soil gas	L_S	441.96	cm	Site-specific: 14.5 feet bgs (depth of maximum concentration in >5 feet bgs interval)
Average Soil/Groundwater Temperature	T_S	11	^oC	Figure 8 of USEPA User's Guide for Evaluating Subsurface VI into Buildings (June 19, 2003)
Thickness of Soil Stratum A - shallow soil gas	h_A	137.16	cm	Set equal to Ls; actual thickness of soil stratum is >100 feet thick.
Thickness of Soil Stratum A - deep soil gas	h_A	441.96	cm	Set equal to Ls; actual thickness of soil stratum is >100 feet thick.
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}	10	cm	US EPA JEM & Ecology default value 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 & Ecology default value
Enclosed Space Floor Width	W_B	1000	cm	US EPA JEM & Ecology default value
Enclosed Space Height	H_B	244	cm	US EPA JEM default value (8 ft ceiling)
Floor-Wall Seam Crack Width	w	0.1	cm	US EPA JEM & Ecology default value
Indoor Air Exchange Rate - Industrial Building	ER	0.50	1/h	Default value specified for commercial building by Ecology's Draft VI Guidance Appendix D
Indoor Air Exchange Rate - Unrestricted Land Use	E	0.2	1/h	Most conservative default value specified by Ecology's Draft VI Guidance Appendix D
Average Vapor Flow Rate into Building	Q_{soil}	5	L/min	Default value specified by Ecology's Draft VI Guidance Appendix D
Averaging Time for Carcinogens	AT_C	70	yr	Defaults were input in order for the model to run, but these are not used in calculating the indoor air concentration.
Averaging Time of Non-Carcinogens	AT_{NC}	30	yr	
Exposure Duration	ED	30	yr	
Exposure Frequency	EF	350	days/yr	
Soil Gas Sampling Depth Below Grade - existing building	L_S	289.56	cm	Site-specific: 9.5 feet bgs (depth of maximum concentration within Area 3)

Table A1
Input Parameters for the Johnson and Ettinger Model (1991)
Fredrickson Industrial Park
Fredrickson, Washington

Input Parameter	Symbol	Site-Specific Inputs	Units	Justification
Groundwater Model Inputs				
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	$\rho_b{}^A$	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	$\theta_w{}^A$	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	Ecology default value for unrestricted scenario and Ecology 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	Ecology 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 A2
Historic Data for Water Supply Wells
Fredrickson 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

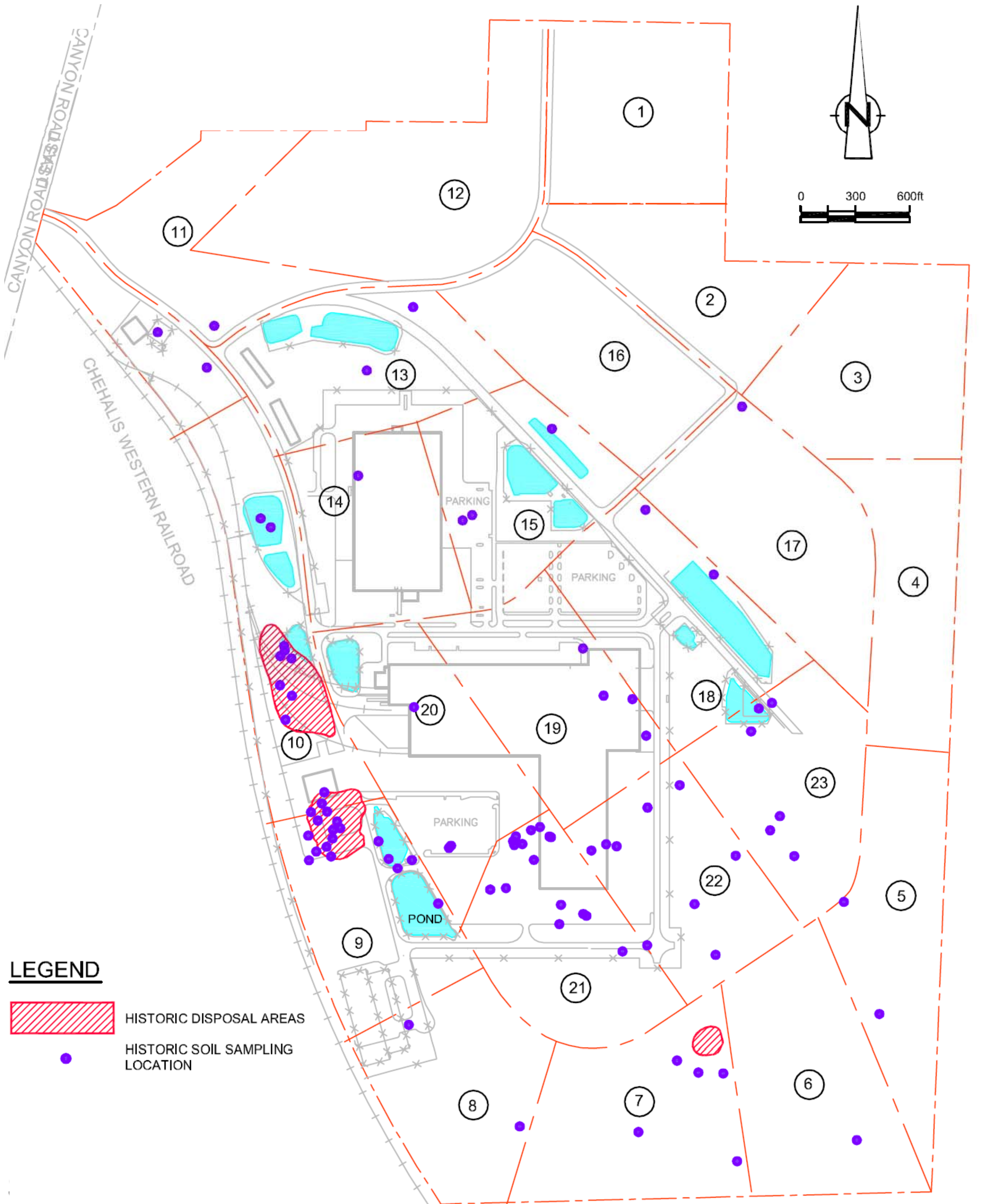


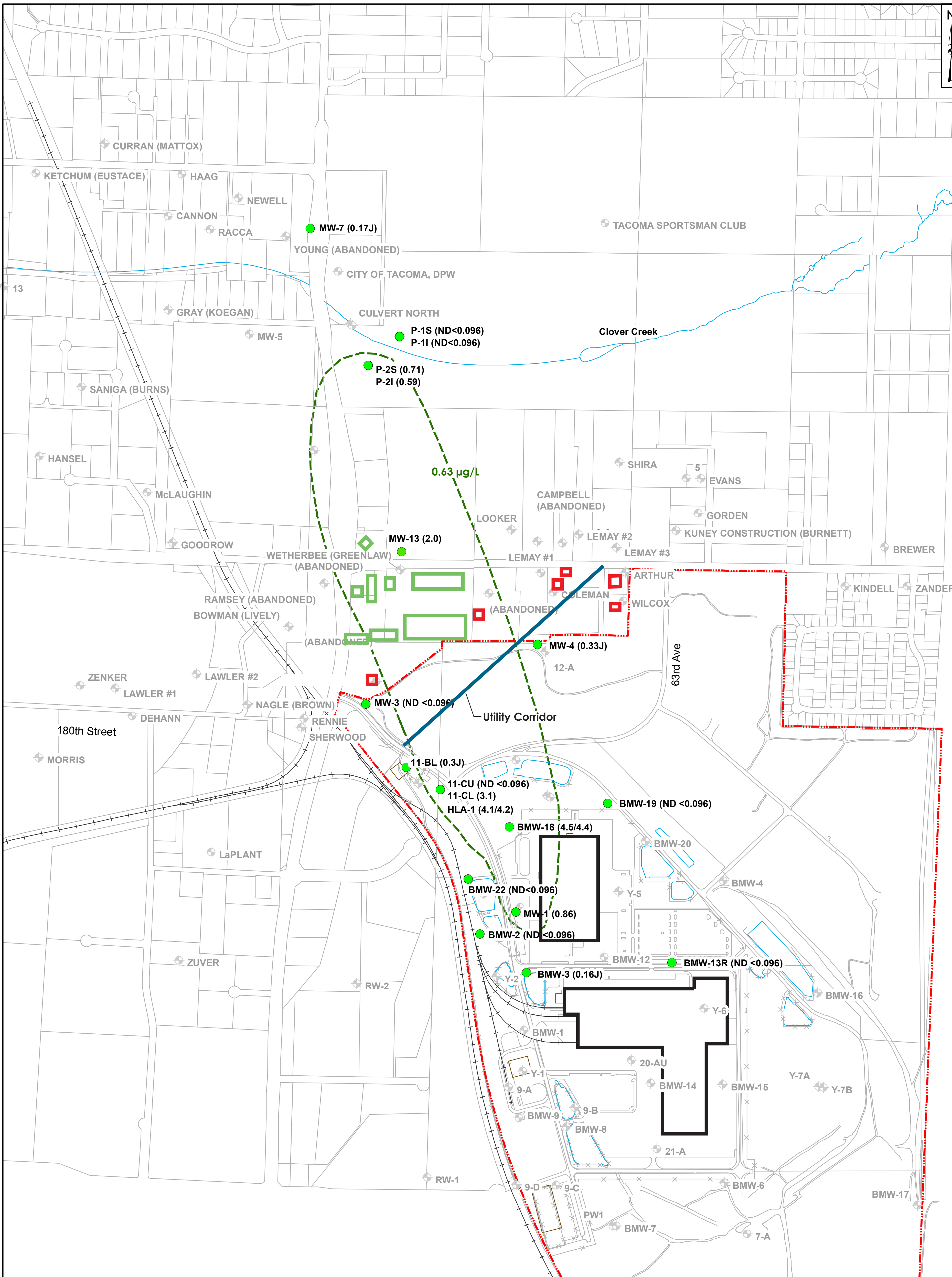
Figure Source is 24 February 2010 Presentation to Ecology

Historical Disposal Areas and Soil Sample Locations

Fredrickson (Brazier) Site Proposal
Fredrickson, WA

Geosyntec consultants
Kennesaw, Georgia

Figure A1



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

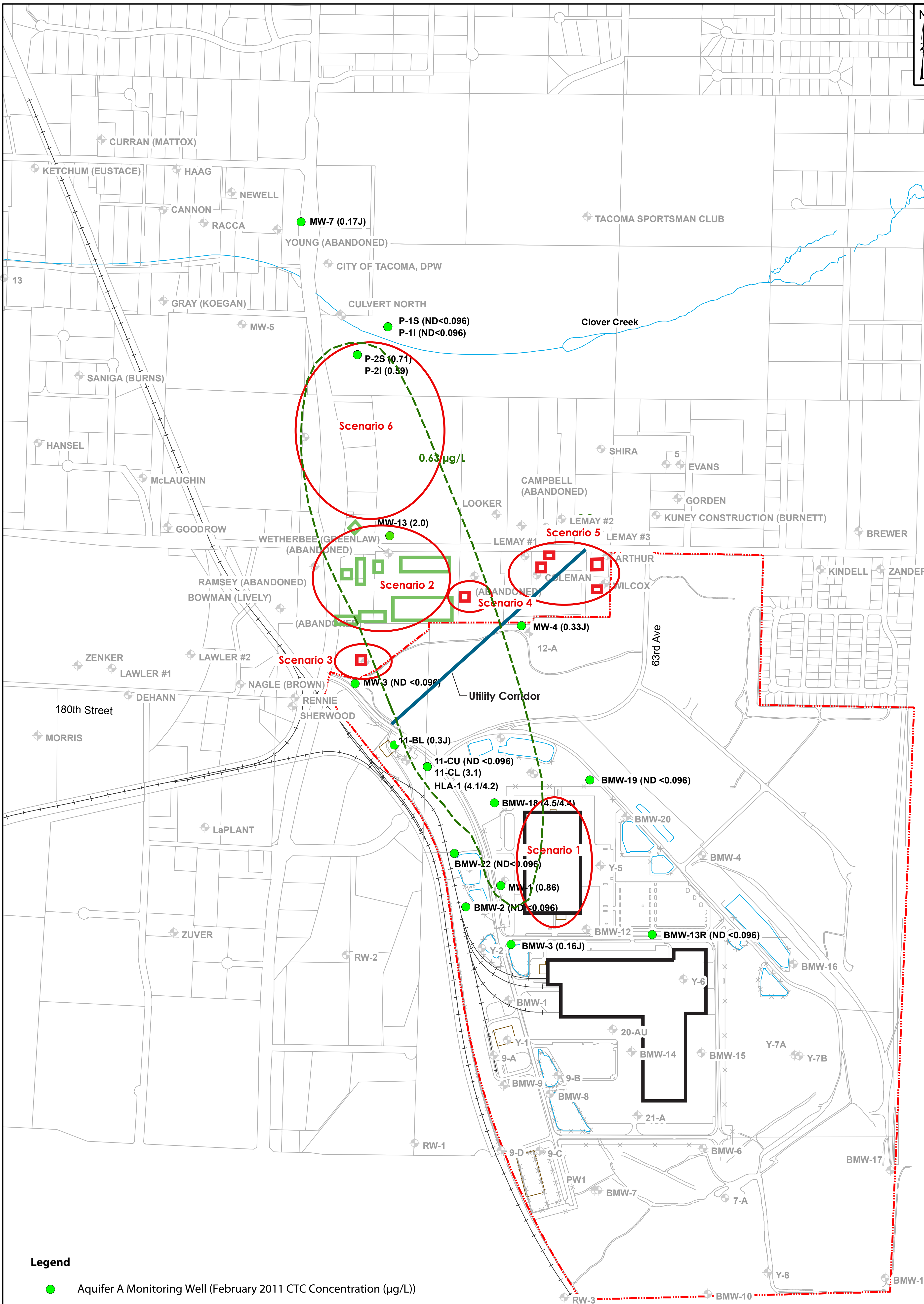
Building Locations Relative to CTC in Groundwater
Frederickson Industrial Park
Frederickson, WA

Geosyntec consultants

Figure
A2

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
Fredericksen, WA

Geosyntec consultants

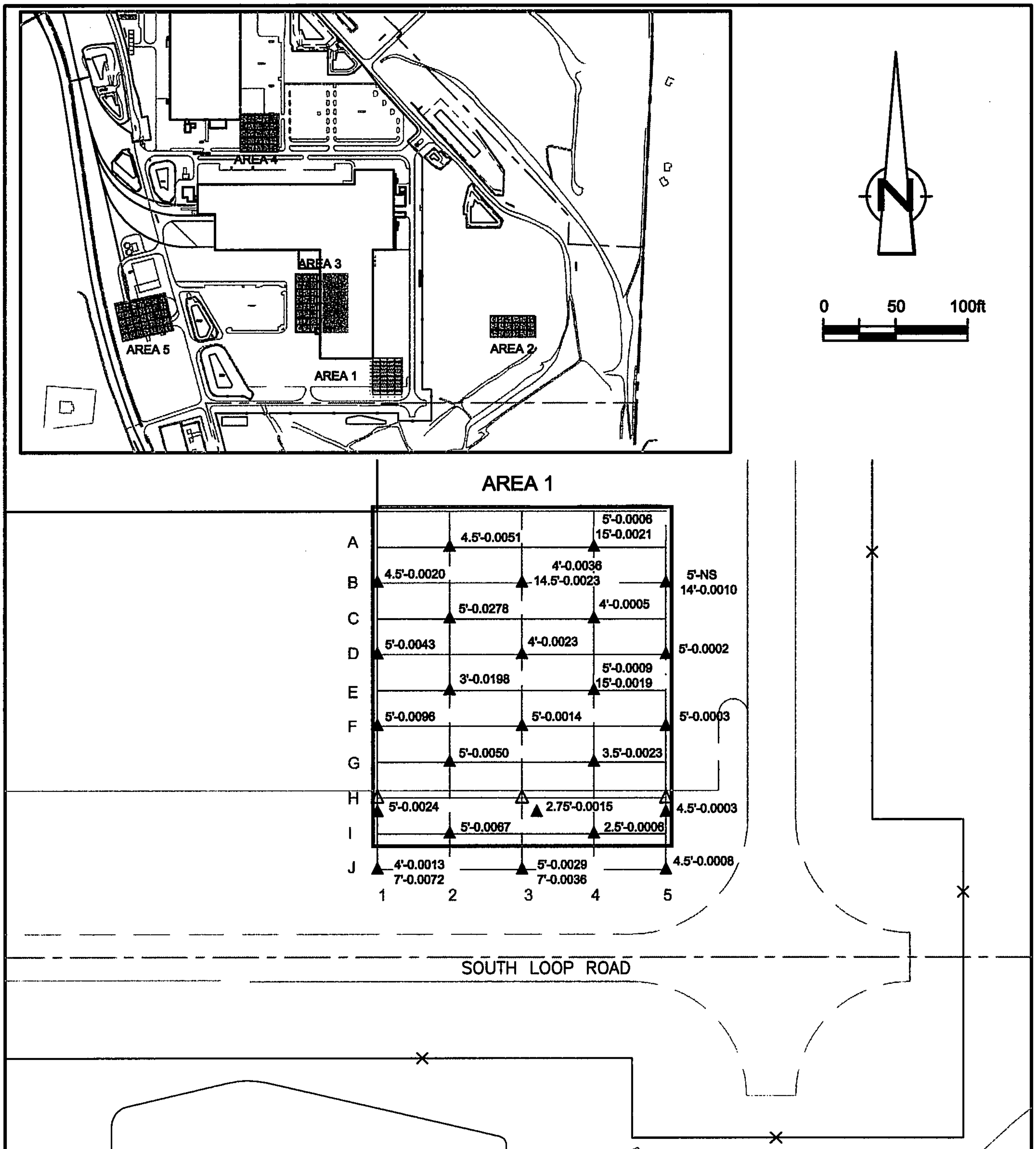
Figure
A3

Kennesaw, GA | 1-August-2011

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)

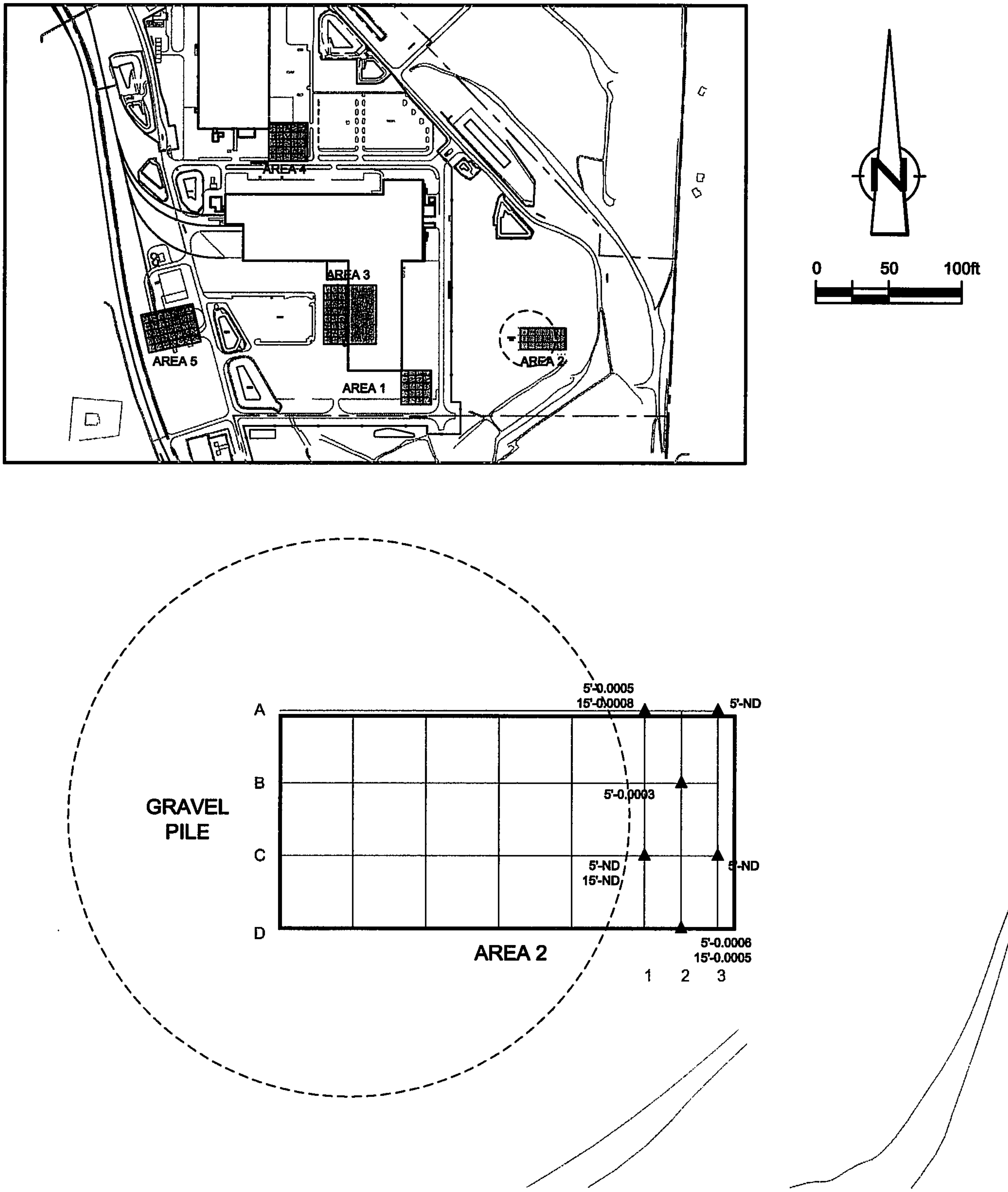
NS NOT SAMPLED

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

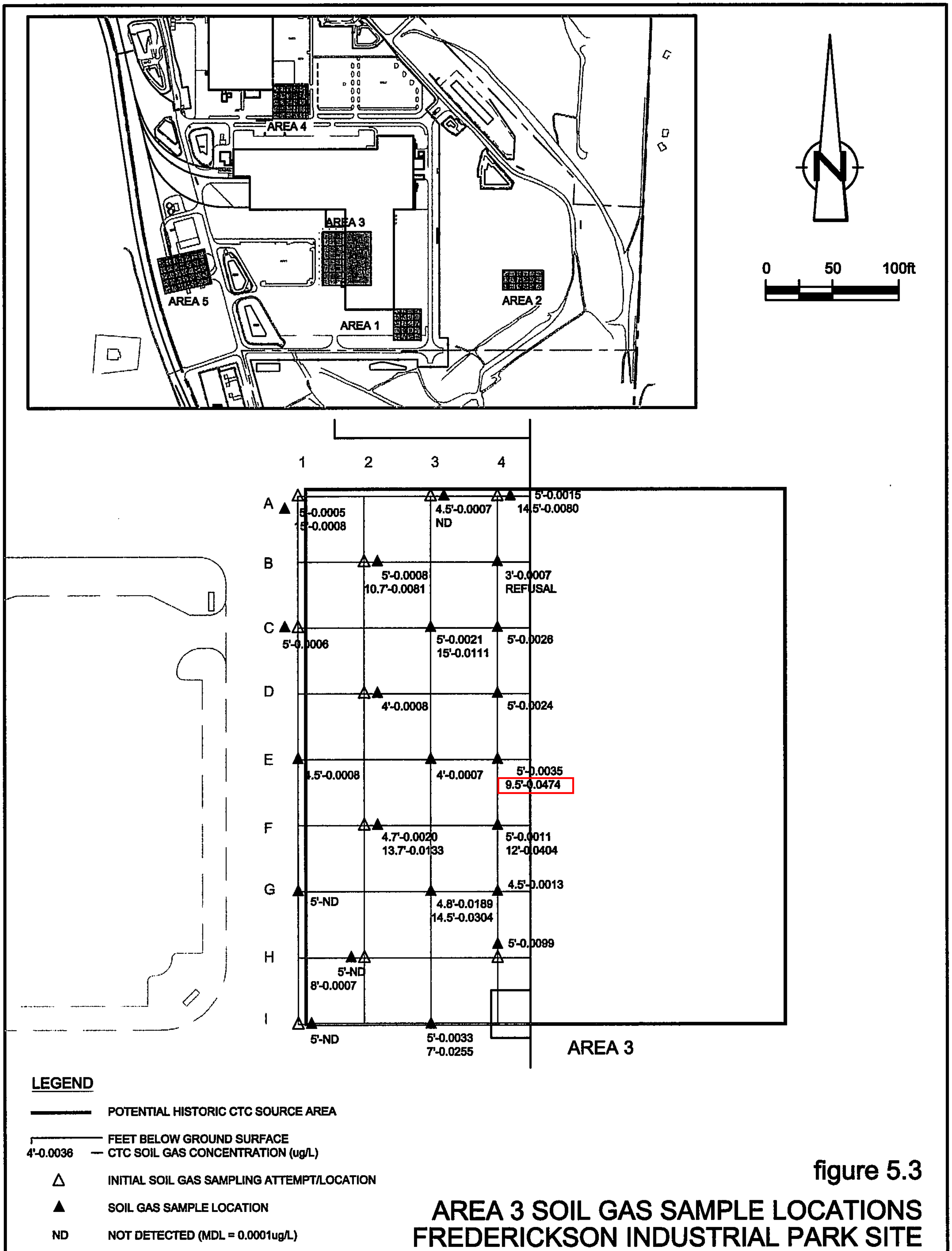
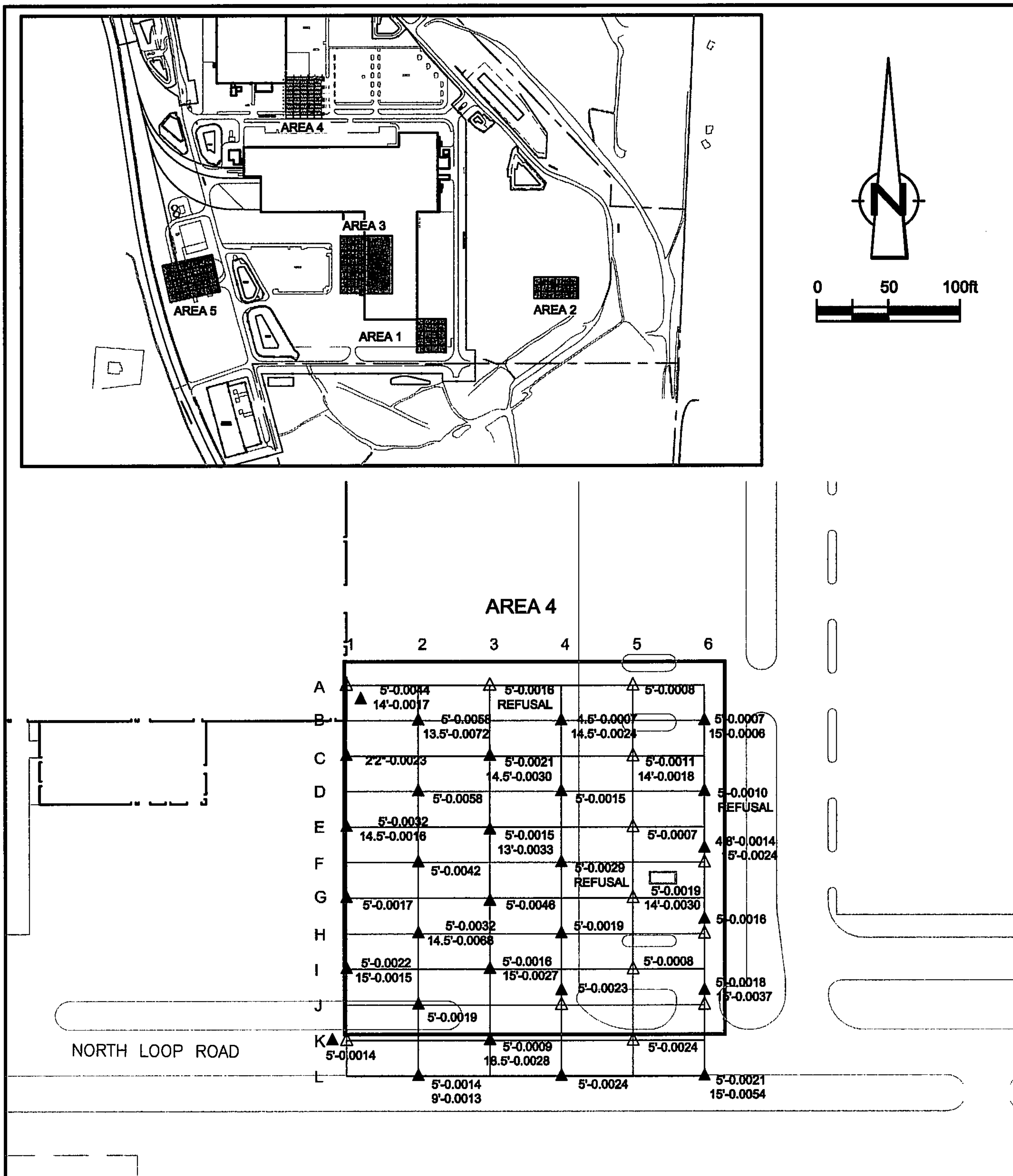


figure 5.3

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

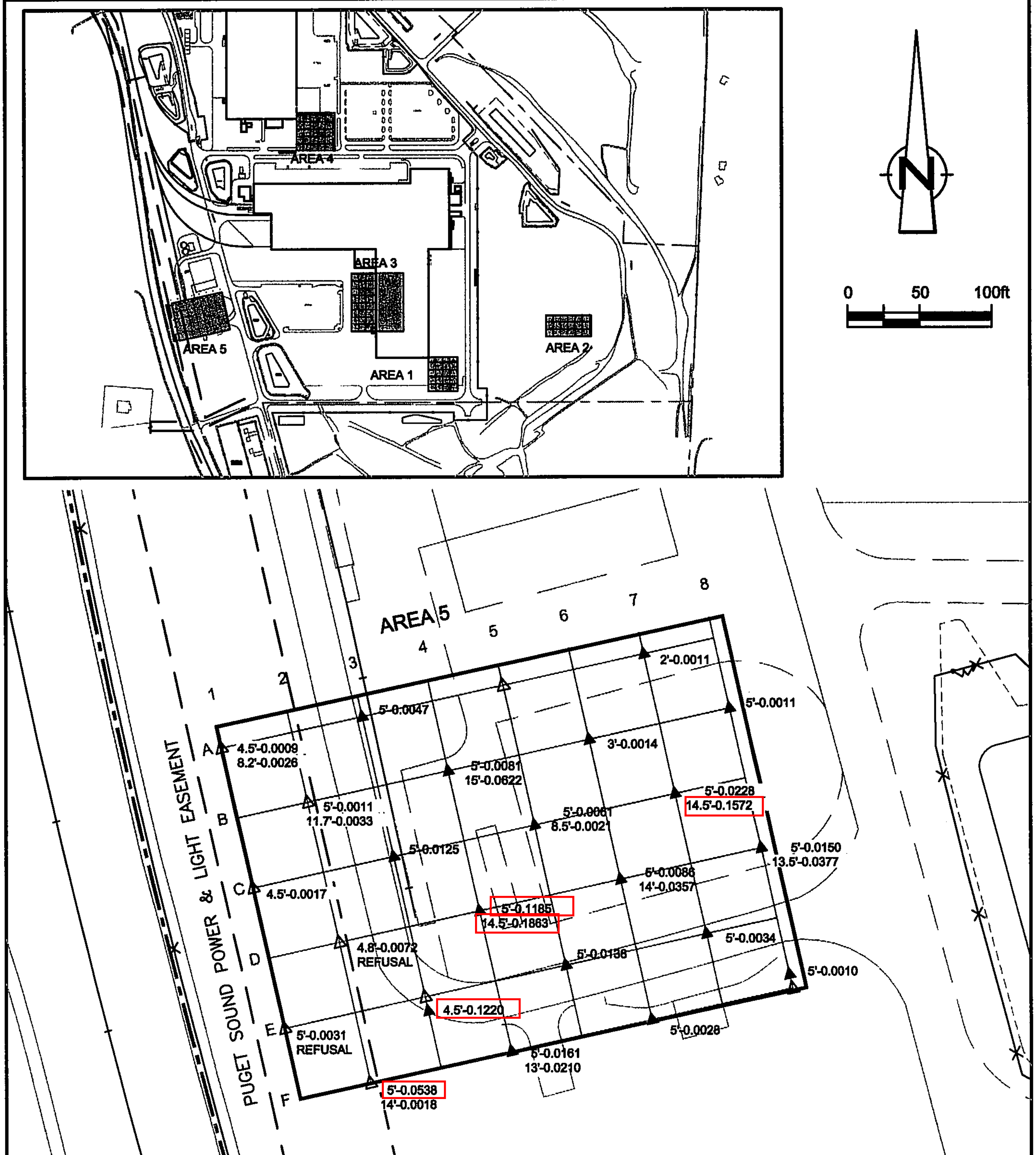
▲ SOIL GAS SAMPLE LOCATION

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

ATTACHMENT B

JOHNSON & ETTINGER MODEL SOIL GAS SCENARIOS

Attachment B1:	JE Soil Gas Model – Existing Industrial Building
Attachment B2:	JE Soil Gas Model – Future Industrial Building
Attachment B3:	JE Soil Gas Model – Future Unrestricted Land Use

ATTACHMENT B1

JE Soil Gas Model – Existing Industrial Building

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m^3)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical	ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m^3)	OR	ENTER Soil gas conc., C_g (ppmv)
56235	4.74E+01							

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	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 A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
			Totals must add up to value of Ls (cell F24)					
15	289.56	11	289.56			S		

MORE ↓

ENTER Stratum A SCS soil type	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	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	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)
Lookup Soil Parameters				Lookup Soil Parameters				Lookup Soil Parameters			
S	1.66	0.375	0.054								

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	0.5	5

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)
70	30	30	350

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)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	274.56	0.321	ERROR	ERROR	0.003	9.94E-08	0.998	9.92E-08	4,000	4.74E+01	3.39E+04

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. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil 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)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
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	1.26E-02	274.56

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	4.74E+01	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	9.07E-04	4.30E-02	1.5E-05	NA

END

ATTACHMENT B2

JE Soil Gas Model – Future Industrial Building

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
56235	1.22E+02			

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^oC)	ENTER Totals must add up to value of Ls (cell F24) 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 A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
15	137.16	11	137.16			S		

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								

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	0.5	5

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)
70	30	30	350

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)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	122.16	0.321	ERROR	ERROR	0.003	9.94E-08	0.998	9.92E-08	4,000	1.22E+02	3.39E+04

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. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil 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)	Total overall effective diffusion coefficient, $D^{eff}{}_T$ (cm^2/s)	Diffusion path length, L_d (cm)
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	1.26E-02	122.16

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	1.22E+02	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	1.40E-03	1.70E-01	1.5E-05	NA

END

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical	ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)
56235	1.86E+02							

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^oC)	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 A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
			Totals must add up to value of Ls (cell F24)					
15	441.96	11	441.96			S		

MORE ↓

ENTER Stratum A SCS soil type	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	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	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)
Lookup Soil Parameters				Lookup Soil Parameters				Lookup Soil Parameters			
S	1.66	0.375	0.054								

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	0.5	5

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)
70	30	30	350

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)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	426.96	0.321	ERROR	ERROR	0.003	9.94E-08	0.998	9.92E-08	4,000	1.86E+02	3.39E+04

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. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil 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)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
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	1.26E-02	426.96

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	1.86E+02	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	6.71E-04	1.25E-01	1.5E-05	NA

END

ATTACHMENT B3

JE Soil Gas Model – Future Unrestricted Land Use

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m^3)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical	ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m^3)	OR	ENTER Soil gas conc., C_g (ppmv)	
56235	1.22E+02								

MORE

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^oC)	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 A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
			Totals must add up to value of Ls (cell F24)					
15	137.16	11	137.16			S		

MORE

ENTER Stratum A SCS soil type	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	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	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)
Lookup Soil Parameters				Lookup Soil Parameters				Lookup Soil Parameters			
S	1.66	0.375	0.054								

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

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)
70	30	30	350

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, $_a^A$ (cm^3/cm^3)	Stratum B soil air-filled porosity, $_a^B$ (cm^3/cm^3)	Stratum C soil air-filled porosity, $_a^C$ (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)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. (g/m^3)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	122.16	0.321	ERROR	ERROR	0.003	9.94E-08	0.998	9.92E-08	4,000	1.22E+02	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, $_{TS}$ (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)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
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	1.26E-02	122.16

Convection path length, L_p (cm)	Source vapor conc., C_{source} (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, (unitless)	Infinite source bldg. conc., $C_{building}$ (g/m^3)	Unit risk factor, URF ($g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	1.22E+02	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	2.79E-03	3.41E-01	1.5E-05	NA

END

DATA ENTRY SHEET

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m^3)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical	ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m^3)	OR	ENTER Soil gas conc., C_g (ppmv)
56235	1.86E+02							

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^oC)	ENTER Totals must add up to value of Ls (cell F24) 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 A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
15	441.96	11	441.96			S		

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								

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

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)
70	30	30	350

END

Exposure duration, (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, $_a^A$ (cm^3/cm^3)	Stratum B soil air-filled porosity, $_a^B$ (cm^3/cm^3)	Stratum C soil air-filled porosity, $_a^C$ (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)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. (g/m^3)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	426.96	0.321	ERROR	ERROR	0.003	9.94E-08	0.998	9.92E-08	4,000	1.86E+02	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, $_{TS}$ (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)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
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	1.26E-02	426.96

Convection path length, L_p (cm)	Source vapor conc., C_{source} (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, (unitless)	Infinite source bldg. conc., $C_{building}$ (g/m^3)	Unit risk factor, URF (g/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
15	1.86E+02	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	1.34E-03	2.50E-01	1.5E-05	NA

END

ATTACHMENT C

JOHNSON & ETTINGER MODELING GROUNDWATER SCENARIOS

SCENARIO 1 A

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 (°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 (cm²)
11	15	1158	1158	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/cm³)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)	ENTER Stratum B SCS soil type (Lookup Soil Parameters)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)	ENTER Stratum C SCS soil type (Lookup Soil Parameters)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)
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-s²)	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-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} (μg/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., $C_{building}$ (μg/m^3)	Unit risk factor, URF (μg/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 1B

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	1.35E+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	1158	1158	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

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-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	9.27E-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	9.14E+02	0.10	8.33E+01	1.26E-02	4.00E+02	5.68E+71	4.60E-04	4.20E-01	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-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

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 (°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	457	457	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-fillec 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} ($atm\text{-}m^3/mol$)	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	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

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 ↓

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	3658	3658	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 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 ↓

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	3048	3048	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 ($g/cm\text{-}s^2$)	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 (^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	1067	1067	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 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-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 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

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 ($g/cm\text{-}s^2$)	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	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