STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

In the Matter of Remedial Action by: Mallinckrodt US LLC 675 McDonnell Blvd Hazelwood, MO 63042 and Olin Corporation 190 Carondelet Plaza #1530 Clayton, MO 63105	AGREED ORDER No. DE 9514

TO: Mallinckrodt US LLC
675 McDonnell Blvd
Hazelwood, MO 63042

Olin Corporation
190 Carondelet Plaza #1530
Clayton, MO 63105

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I. INTRODUCTION

The mutual objective of the State of Washington, Department of Ecology (Ecology) and Mallinckrodt US LLC, formerly known as **Mallinckrodt, Inc. (Mallinckrodt), and Olin Corporation (Olin)** under this Agreed Order (Order) is to provide for remedial action at a facility where there has been a release or threatened release of hazardous substances. This Order requires **Mallinckrodt and Olin** to **fulfill the requirements of the Cleanup Action Plan**. Ecology believes the actions required by this Order are in the public interest.

II. JURISDICTION

This Agreed Order is issued pursuant to the Model Toxics Control Act (MTCA), RCW 70.105D.050(1).

III. PARTIES BOUND

This Agreed Order shall apply to and be binding upon the Parties to the Order, their successors and assigns. The undersigned representative of each party hereby certifies that he or she is fully authorized to enter into this Order and to execute and legally bind such party to comply with this Order. **Mallinckrodt and Olin** agree to undertake all actions required by the terms and conditions of this Order. No change in ownership or corporate status shall alter **Mallinckrodt and Olin**'s responsibility under this Order. **Mallinckrodt and Olin** shall provide a copy of this Order to all agents, contractors, and subcontractors retained to perform work required by this Order, and shall ensure that all work undertaken by such agents, contractors, and subcontractors complies with this Order.

IV. DEFINITIONS

Unless otherwise specified herein, the definitions set forth in Chapter 70.105D RCW and Chapter 173-340 WAC shall control the meanings of the terms in this Order.

A. Site: The Site is referred to as **Frederickson Industrial Park** and is located at 18001 Canyon Road East, Puyallup, WA **(Exhibit A)**. The Site is defined by the extent of contamination caused by the release of hazardous substances at the Site. The Site is more precisely described in the Site Diagram (Exhibit B). The Site constitutes a Facility under RCW 70.105D.020(5).

B. Parties: Refers to the State of Washington, Department of Ecology and **Mallinckrodt and Olin.**

C. Potentially Liable Person (PLP): Refers to **Mallinckrodt and Olin.**

D. Agreed Order or Order: Refers to this Order and each of the exhibits to this Order. All exhibits are integral and enforceable parts of this Order. The terms “Agreed Order” or “Order” shall include all exhibits to this Order.

V. FINDINGS OF FACT

Ecology makes the following findings of fact, without any express or implied admissions of such facts by **Mallinckrodt and Olin**:

A. **Mallinckrodt and Olin** are the former owners and operators of property located at 18001 Canyon Road East, Puyallup, WA. **Mallinckrodt and Olin’s** former property is located south of 176th Street East and east of Canyon Road in the Frederickson area of Pierce County. The subject property consists of 527 acres (Exhibit B) and is located approximately 10 miles south of Tacoma and 8 miles southwest of Puyallup in Section 31, Township 19 North, Range 4 East of the Willamette Meridian, and a portion of Section 6, Township 18 North, Range 4 East of the Willamette Meridian. This property was used from 1935/1936 through 1976 to manufacture and process explosives (TNT, RDX, dynamite, and nitrocellulose-based propellants) for small arms and artillery. From 1935/36 to 1956, the Site was operated as an explosive manufacturing and processing plant (“powder plant”) under the names of J.A. Deen Powder Company and Columbia Powder Company. The Site property was conveyed to Olin Mathieson Chemical Corporation in July of 1956 as part of the Plan of Liquidation from the Columbia Powder Company. From 1956 to 1963, Olin Mathieson Chemical Corporation owned and operated the powder plant. On September 1, 1969, Olin Mathieson Chemical Corporation changed its name to Olin Corporation (“Olin”). The term “Olin” hereinafter refers to any predecessor companies or corporations. On October 1, 1963, Olin conveyed the Site property to

Commercial Solvents Corporation ("CSC"). CSC continued to operate the powder plant until 1976 under the names of CSC, Trojan-US Powder Division of CSC, and International Minerals and Chemical Company ("IMC"). CSC was merged into IMC in a 1975 merger and continued to operate the facility under that legal entity. In 1990, IMC changed its name to IMCERA Group, Inc., and then in 1994 to Mallinckrodt Group Inc., and then in 1996 to Mallinckrodt Inc., a New York corporation ("Mallinckrodt"). Through a series of internal company reorganizations Mallinckrodt and its assets and liabilities were assigned through an assignment and assumption agreement to Mallinckrodt US LLC which is the legal entity responsible for the IMC obligations in connection with this Order. The term "Mallinckrodt" hereinafter refers to any predecessor companies or corporations. Mallinckrodt transferred its ownership interest in the Site in 1976. As set out more fully in Agreed Order DE 97TC-S121, the Site was owned and operated from 1976 to 1986 by several individuals and corporations for timber cutting, lumber milling and related storage purposes, and subsequently transferred to several banks and in 1987 to Centrum Properties. In 1990, Centrum Properties conveyed the property to the Boeing Company (Boeing), the current owner.

B. Effective April 3, 1997, Ecology and Mallinckrodt and Olin entered into Agreed Order No. DE 97TC-S121 requiring Mallinckrodt and Olin to complete a remedial investigation/feasibility study (RI/FS) and interim action.

C. The interim action consisted of providing bottled water to businesses and residents affected by carbon tetrachloride in their drinking water until a permanent solution could be found. Between 2002 and 2007 all affected businesses and residents were hooked up to a municipal water supply as a permanent solution.

D. The Remedial Investigation/Feasibility Study was completed in March 2012 and a supplemental RE 22-2 Soil TPH Investigation was completed by Boeing in August 2012.

E. By letter dated August 20, 2012 Ecology determined that Mallinckrodt and Olin have met the requirements of Agreed Order No. DE 97TC-S121.

F. The Frederickson Industrial Park Cleanup Action Plan is attached as Exhibit C.

G. The Frederickson Industrial Park Compliance Monitoring Work Plan is attached as Exhibit D.

VI. ECOLOGY DETERMINATIONS

A. PLP is an "owner or operator" as defined in RCW 70.105D.020(17) of a "facility" as defined in RCW 70.105D.020(5).

B. Based upon all factors known to Ecology, a “release” or “threatened release” of “hazardous substance(s)” as defined in RCW 70.105D.020(25) and RCW 70.105D.020(10), respectively, has occurred at the Site.

C. Based upon credible evidence, Ecology issued a PLP status letter to **Mallinckrodt and Olin** dated November 1, 1995, pursuant to RCW 70.105D.040, -.020(21) and WAC 173-340-500. After providing for notice and opportunity for comment, reviewing any comments submitted, and concluding that credible evidence supported a finding of potential liability, Ecology issued a determination that **Mallinckrodt and Olin** are PLPs under RCW 70.105D.040 and notified **Mallinckrodt and Olin** of this determination by letter dated **December 1, 1995.**

D. Pursuant to RCW 70.105D.030(1) and 70.105D.050(1), Ecology may require PLPs to investigate or conduct other remedial actions with respect to any release or threatened release of hazardous substances, whenever it believes such action to be in the public interest. Based on the foregoing facts, Ecology believes the remedial actions required by this Order are in the public interest.

VII. WORK TO BE PERFORMED

Based on the Findings of Fact and Ecology Determinations, it is hereby ordered that **Mallinckrodt and Olin** take the following remedial actions at the Site and that these actions be conducted in accordance with Chapter 173-340 WAC unless otherwise specifically provided for herein:

A. **Mallinckrodt and Olin** are required to implement the Cleanup Action Plan (Exhibit C).

B. Groundwater monitoring for CTC will occur as specified in the Compliance Monitoring Work Plan (Exhibit D). Following completion of the Compliance Monitoring Work Plan, if criteria are not achieved, **Mallinckrodt and Olin** will submit to Ecology for review and approval a Contingency Plan (with schedule) within 30 days of receipt of final validated data.

C. Within 60 days of the effective date of this agreed order, and after Ecology review, the Boeing Company will record an environmental covenant at the Pierce County Auditor's Office for groundwater contaminated with CTC on their property.

D. Institutional controls in the form of prevailing use limitations are in place to restrict withdrawal or use of groundwater until the cleanup level for CTC is achieved. The Site resides in the Pierce County Urban Growth Area where the Pierce County Comprehensive Plan prohibits installation of new water wells. There are also no longer any drinking water well users within the CTC plume and no known planned use of the groundwater for future drinking water supply.

E. Institutional controls will include educational mailings to properties overlying the groundwater plume. Ecology, **Mallinckrodt and Olin** will send out mailings 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 1 ½ - 2 years prior to the first periodic review.

F. Groundwater monitoring data reports will be submitted to Ecology as specified in the Compliance Monitoring Work Plan.

G. If, at any time after the first exchange of comments on drafts, Ecology determines that insufficient progress is being made in the preparation of any of the deliverables required by this Section, Ecology may complete and issue the final deliverable.

VIII. TERMS AND CONDITIONS OF ORDER

A. Public Notice

RCW 70.105D.030(2)(a) requires that, at a minimum, this Order be subject to concurrent public notice. Ecology shall be responsible for providing such public notice and reserves the right to modify or withdraw any provisions of this Order should public comment disclose facts or considerations which indicate to Ecology that this Order is inadequate or improper in any respect.

B. Remedial Action Costs

Mallinckrodt and Olin shall pay to Ecology costs incurred by Ecology pursuant to this Order and consistent with WAC 173-340-550(2). These costs shall include work performed by Ecology or its contractors for, or on, the Site under Chapter 70.105D RCW, including remedial actions and Order preparation, negotiation, oversight, and administration. These costs shall include work performed both prior to and subsequent to the issuance of this Order. Ecology's costs shall include costs of direct activities and support costs of direct activities as defined in WAC 173-340-550(2). Ecology has accumulated **$2,836.97** in remedial action costs related to this facility as of September 30, 2013. Payment for this amount shall be submitted within thirty (30) days of the effective date of this Order. For all costs incurred subsequent to **September 30, 2013**, **Mallinckrodt and Olin** shall pay the required amount within thirty (30) days of receiving from Ecology an itemized statement of costs that includes a summary of costs incurred, an identification of involved staff, and the amount of time spent by involved staff members on the project. A general statement of work performed will be provided upon request. Itemized statements shall be prepared quarterly. Pursuant to WAC 173-340-550(4), failure to pay Ecology's costs within ninety (90) days of receipt of the itemized statement of costs will result in interest charges at the rate of twelve percent (12%) per annum, compounded monthly.

In addition to other available relief, pursuant to RCW 19.16.500, Ecology may utilize a collection agency and/or, pursuant to RCW 70.105D.055, file a lien against real property subject to the remedial actions to recover unreimbursed remedial action costs.

C. Implementation of Remedial Action

If Ecology determines that **Mallinckrodt and Olin** have failed without good cause to implement the remedial action, in whole or in part, Ecology may, after notice to **Mallinckrodt and Olin** , perform any or all portions of the remedial action that remain incomplete. If Ecology performs all or portions of the remedial action because of **Mallinckrodt and Olin**'s failure to comply with its obligations under this Order, **Mallinckrodt and Olin** shall reimburse Ecology for the costs of doing such work in accordance with Section VIII. (Remedial Action Costs), provided that **Mallinckrodt and Olin** are not obligated under this Section to reimburse Ecology for costs incurred for work inconsistent with or beyond the scope of this Order.

Except where necessary to abate an emergency situation, **Mallinckrodt and Olin** shall not perform any remedial actions at the Site outside those remedial actions required by this Order, unless Ecology concurs, in writing, with such additional remedial actions.

D. Designated Project Coordinators

The project coordinator for Ecology is:

Guy Barrett, LHG
Department of Ecology
Southwest Regional Office
P.O. Box 47775
Olympia, WA 98504-7775
(360) 407-7115
Gbar461@ecy.wa.gov

The project coordinator for Mallinckrodt is:

Karen Burke
Director Environmental Remediation
Mallinckrodt US LLC
625 McDonnell Blvd
Hazelwood, MO 63042

The project coordinator for Olin is:

David M. Share
Director, Environmental Remediation Group

Olin Corporation
3855 N. Ocoee, Suite 200
Cleveland, TN 37312

Each project coordinator shall be responsible for overseeing the implementation of this Order. Ecology's project coordinator will be Ecology's designated representative for the Site. To the maximum extent possible, communications between Ecology and **Mallinckrodt and Olin**, and all documents, including reports, approvals, and other correspondence concerning the activities performed pursuant to the terms and conditions of this Order shall be directed through the project coordinators. The project coordinators may designate, in writing, working level staff contacts for all or portions of the implementation of the work to be performed required by this Order.

Any party may change its respective project coordinator. Written notification shall be given to the other parties at least ten (10) calendar days prior to the change.

E. Performance

All geologic and hydrogeologic work performed pursuant to this Order shall be under the supervision and direction of a geologist licensed in the State of Washington or under the direct supervision of an engineer registered in the State of Washington, except as otherwise provided for by RCW 18.220 and 18.43.

All engineering work performed pursuant to this Order shall be under the direct supervision of a professional engineer registered in the State of Washington, except as otherwise provided for by RCW 18.43.130.

All construction work performed pursuant to this Order shall be under the direct supervision of a professional engineer or a qualified technician under the direct supervision of a professional engineer. The professional engineer must be registered in the State of Washington, except as otherwise provided for by RCW 18.43.130.

Any documents submitted containing geologic, hydrologic or engineering work shall be under the seal of an appropriately licensed professional as required by RCW 18.220 or 18.43.130.

Mallinckrodt and Olin shall notify Ecology in writing of the identity of any engineer(s) and geologist(s), contractor(s) and subcontractor(s), and others to be used in carrying out the terms of this Order, in advance of their involvement at the Site.

F. Access

Ecology or any Ecology authorized representative shall have the full authority to enter and freely move about all property at the Site that **Mallinckrodt and Olin** either owns, controls, or has access rights to at all reasonable times for the purposes of, *inter alia*: inspecting records, operation logs, and contracts related to the work being performed pursuant to this Order; reviewing **Mallinckrodt and Olin**'s progress in carrying out the terms of this Order; conducting such tests or collecting such samples as Ecology may deem necessary; using a camera, sound recording, or other documentary type equipment to record work done pursuant to this Order; and verifying the data submitted to Ecology by **Mallinckrodt and Olin**. **Mallinckrodt and Olin** shall make all reasonable efforts to secure access rights for those properties within the Site not owned or controlled by **Mallinckrodt and Olin** where remedial activities or investigations will be performed pursuant to this Order. Ecology or any Ecology authorized representative shall give reasonable notice before entering any Site property owned or controlled by **Mallinckrodt and Olin** unless an emergency prevents such notice. All persons who access the Site pursuant to this Section shall comply with any applicable Health and Safety Plan(s). Ecology employees and their representatives shall not be required to sign any liability release or waiver as a condition of Site property access. Should Mallinckrodt and Olin be unable to gain the access needed to complete the work, Ecology will make reasonable efforts to facilitate access to real property for Mallinckrodt and Olin for the purposes of conduct remedial actions pursuant to this Order.

G. Sampling, Data Submittal, and Availability

With respect to the implementation of this Order, **Mallinckrodt and Olin** shall make the results of all sampling, laboratory reports, and/or test results generated by it or on its behalf available to Ecology. Pursuant to WAC 173-340-840(5), all sampling data shall be submitted to Ecology in both printed and electronic formats in accordance with Section (Work to be

Performed), Ecology's Toxics Cleanup Program Policy 840 (Data Submittal Requirements), and/or any subsequent procedures specified by Ecology for data submittal.

If requested by Ecology, **Mallinckrodt and Olin** shall allow Ecology and/or its authorized representative to take split or duplicate samples of any samples collected by **Mallinckrodt and Olin** pursuant to implementation of this Order. **Mallinckrodt and Olin** shall notify Ecology seven (7) days in advance of any sample collection or work activity at the Site. Ecology shall, upon request, allow **Mallinckrodt and Olin** and/or its authorized representative to take split or duplicate samples of any samples collected by Ecology pursuant to the implementation of this Order, provided that doing so does not interfere with Ecology's sampling. Without limitation on Ecology's rights under Section VIII.(Access), Ecology shall notify **Mallinckrodt and Olin** prior to any sample collection activity unless an emergency prevents such notice.

In accordance with WAC 173-340-830(2)(a), all hazardous substance analyses shall be conducted by a laboratory accredited under Chapter 173-50 WAC for the specific analyses to be conducted, unless otherwise approved by Ecology.

H. Public Participation

Ecology shall maintain the responsibility for public participation at the Site. However, **Mallinckrodt and Olin** shall cooperate with Ecology, and shall:

1. If agreed to by Ecology, develop appropriate mailing list, prepare drafts of public notices and fact sheets at important stages of the remedial action, such as the submission of work plans, remedial investigation/feasibility study reports, cleanup action plans, and engineering design reports. As appropriate, Ecology will edit, finalize, and distribute such fact sheets and prepare and distribute public notices of Ecology's presentations and meetings.

2. Notify Ecology's project coordinator prior to the preparation of all press releases and fact sheets, and before major meetings with the interested public and local governments. Likewise, Ecology shall notify **Mallinckrodt and Olin** prior to the issuance of all press releases and fact sheets, and before major meetings with the interested public and local governments and

provide an opportunity to review any drafts before distribution or presentation to the public. For all press releases, fact sheets, meetings, and other outreach efforts by **Mallinckrodt and Olin** that do not receive prior Ecology approval, **Mallinckrodt and Olin** shall clearly indicate to its audience that the press release, fact sheet, meeting, or other outreach effort was not sponsored or endorsed by Ecology.

3. When requested by Ecology, participate in public presentations on the progress of the remedial action at the Site. Participation may be through attendance at public meetings to assist in answering questions or as a presenter.

4. When requested by Ecology, arrange and/or continue information repositories to be located at the following locations:

a. South Hill Public Library
15420 Meridian Avenue East
Puyallup, WA 98375

b. Ecology's Southwest Regional Office
300 Desmond Drive
Lacey, WA 98503

At a minimum, copies of all public notices, fact sheets, and documents relating to public comment periods shall be promptly placed in these repositories. A copy of all documents related to this site shall be maintained in the repository at Ecology's **Southwest** Regional Office in **Lacey**, Washington.

I. Retention of Records

During the pendency of this Order, and for ten (10) years from the date of completion of work performed pursuant to this Order, **Mallinckrodt and Olin** shall preserve all records, reports, documents, and underlying data in its possession relevant to the implementation of this Order and shall insert a similar record retention requirement into all contracts with project contractors and subcontractors. Upon request of Ecology, **Mallinckrodt and Olin** shall make all records available to Ecology and allow access for review within a reasonable time.

J. Resolution of Disputes

1. In the event a dispute arises as to an approval, disapproval, proposed change, or other decision or action by Ecology's project coordinator, or an itemized billing statement under Section VIII. (Remedial Action Costs), the Parties shall utilize the dispute resolution procedure set forth below.

a. Upon receipt of Ecology's project coordinator's written decision or the itemized billing statement, **Mallinckrodt and Olin** has fourteen (14) days within which to notify Ecology's project coordinator in writing of its objection to the decision or itemized statement.

b. The Parties' project coordinators shall then confer in an effort to resolve the dispute. If the project coordinators cannot resolve the dispute within fourteen (14) days, Ecology's project coordinator shall issue a written decision.

c. **Mallinckrodt and Olin** may then request Ecology regional management review of the decision. This request shall be submitted in writing to the **Southwest** Region Toxics Cleanup Section Manager within seven (7) days of receipt of Ecology's project coordinator's written decision.

d. The Section Manager shall conduct a review of the dispute and shall endeavor to issue a written decision regarding the dispute within thirty (30) days of **Mallinckrodt and Olin**'s request for review. The Section Manager's decision shall be Ecology's final decision on the disputed matter.

2. The Parties agree to only utilize the dispute resolution process in good faith and agree to expedite, to the extent possible, the dispute resolution process whenever it is used.

3. Implementation of these dispute resolution procedures shall not provide a basis for delay of any activities required in this Order, unless Ecology agrees in writing to a schedule extension.

K. Extension of Schedule

1. An extension of schedule shall be granted only when a request for an extension is submitted in a timely fashion, generally at least thirty (30) days prior to expiration of the deadline for which the extension is requested, and good cause exists for granting the extension. All extensions shall be requested in writing. The request shall specify:

a. The deadline that is sought to be extended;

b. The length of the extension sought;

c. The reason(s) for the extension; and

d. Any related deadline or schedule that would be affected if the extension were granted.

2. The burden shall be on **Mallinckrodt and Olin** to demonstrate to the satisfaction of Ecology that the request for such extension has been submitted in a timely fashion and that good cause exists for granting the extension. Good cause may include, but may not be limited to:

a. Circumstances beyond the reasonable control and despite the due diligence of **Mallinckrodt and Olin** including delays caused by unrelated third parties or Ecology, such as (but not limited to) delays by Ecology in reviewing, approving, or modifying documents submitted by **Mallinckrodt and Olin**;

b. Acts of God, including fire, flood, blizzard, extreme temperatures, storm, or other unavoidable casualty; or

c. Endangerment as described in Section VIII. (Endangerment).

However, neither increased costs of performance of the terms of this Order nor changed economic circumstances shall be considered circumstances beyond the reasonable control of **Mallinckrodt and Olin**.

3. Ecology shall act upon any written request for extension in a timely fashion. Ecology shall give **Mallinckrodt and Olin** written notification of any extensions granted pursuant to this Order. A requested extension shall not be effective until approved by Ecology.

Unless the extension is a substantial change, it shall not be necessary to amend this Order pursuant to Section VIII. (Amendment of Order) when a schedule extension is granted.

4. An extension shall only be granted for such period of time as Ecology determines is reasonable under the circumstances. Ecology may grant schedule extensions exceeding ninety (90) days only as a result of:

a. Delays in the issuance of a necessary permit which was applied for in a timely manner;

b. Other circumstances deemed exceptional or extraordinary by Ecology; or

c. Endangerment as described in Section VIII. (Endangerment).

L. Amendment of Order

The project coordinators may verbally agree to minor changes to the work to be performed without formally amending this Order. Minor changes will be documented in writing by Ecology within seven (7) days of verbal agreement.

Except as provided in Section VIII. (Reservation of Rights), substantial changes to the work to be performed shall require formal amendment of this Order. This Order may only be formally amended by the written consent of both Ecology and **Mallinckrodt and Olin**. **Mallinckrodt and Olin** shall submit a written request for amendment to Ecology for approval. Ecology shall indicate its approval or disapproval in writing and in a timely manner after the written request for amendment is received. If the amendment to this Order represents a substantial change, Ecology will provide public notice and opportunity to comment. Reasons for the disapproval of a proposed amendment to this Order shall be stated in writing. If Ecology does not agree to a proposed amendment, the disagreement may be addressed through the dispute resolution procedures described in Section VIII. (Resolution of Disputes).

M. Endangerment

In the event Ecology determines that any activity being performed at the Site is creating or has the potential to create a danger to human health or the environment on or surrounding the Site, Ecology may direct **Mallinckrodt and Olin** to cease such activities for such period of time as it deems necessary to abate the danger. **Mallinckrodt and Olin** shall immediately comply with such direction.

In the event **Mallinckrodt and Olin** determines that any activity being performed at the Site is creating or has the potential to create a danger to human health or the environment, **Mallinckrodt and Olin** may cease such activities. **Mallinckrodt and Olin** shall notify Ecology's project coordinator as soon as possible, but no later than twenty-four (24) hours after making such determination or ceasing such activities. Upon Ecology's direction **Mallinckrodt and Olin** shall provide Ecology with documentation of the basis for the determination or cessation of such activities. If Ecology disagrees with **Mallinckrodt and Olin**'s cessation of activities, it may direct **Mallinckrodt and Olin** to resume such activities.

If Ecology concurs with or orders a work stoppage pursuant to Section VIII. (Endangerment), **Mallinckrodt and Olin**'s obligations with respect to the ceased activities shall be suspended until Ecology determines the danger is abated, and the time for performance of such activities, as well as the time for any other work dependent upon such activities, shall be extended in accordance with Section VIII. (Extension of Schedule) for such period of time as Ecology determines is reasonable under the circumstances.

Nothing in this Order shall limit the authority of Ecology, its employees, agents, or contractors to take or require appropriate action in the event of an emergency.

N. Reservation of Rights

This Order is not a settlement under Chapter 70.105D RCW. Ecology's signature on this Order in no way constitutes a covenant not to sue or a compromise of any of Ecology's rights or authority. Ecology will not, however, bring an action against **Mallinckrodt and Olin** to recover remedial action costs paid to and received by Ecology under this Order. In addition, Ecology will not take additional enforcement actions against **Mallinckrodt and Olin** regarding remedial actions required by this Order, provided **Mallinckrodt and Olin** complies with this Order.

Ecology nevertheless reserves its rights under Chapter 70.105D RCW, including the right to require additional or different remedial actions at the Site should it deem such actions necessary to protect human health and the environment, and to issue orders requiring such remedial actions. Ecology also reserves all rights regarding the injury to, destruction of, or loss of natural resources resulting from the release or threatened release of hazardous substances at the Site.

O. Transfer of Interest in Property

Mallinckrodt and Olin have no ownership interest in the Site. Accordingly, this Order shall not be deemed to impose any duty on Mallinckrodt and/or Olin that is inconsistent with the absence of any ownership interest in the Site on the part of Mallinckrodt and/or Olin.

P. Compliance with Applicable Laws

1. All actions carried out by **Mallinckrodt and Olin** pursuant to this Order shall be done in accordance with all applicable federal, state, and local requirements, including requirements to obtain necessary permits, except as provided in RCW 70.105D.090. At this time, no federal, state or local requirements have been identified as being applicable to the actions required by this Order**.**

2. Pursuant to RCW 70.105D.090(1), **Mallinckrodt and Olin** are exempt from the procedural requirements of Chapters 70.94, 70.95, 70.105, 77.55, 90.48, and 90.58 RCW and of any laws requiring or authorizing local government permits or approvals. However, **Mallinckrodt and Olin** shall comply with the substantive requirements of such permits or approvals. At this time, no state or local permits or approvals have been identified as being applicable but procedurally exempt under this Section**.**

Mallinckrodt and Olin have a continuing obligation to determine whether additional permits or approvals addressed in RCW 70.105D.090(1) would otherwise be required for the remedial action under this Order. In the event either Ecology or **Mallinckrodt and Olin** determines that additional permits or approvals addressed in RCW 70.105D.090(1) would otherwise be required for the remedial action under this Order, it shall promptly notify the other parties of its determination. Ecology shall determine whether Ecology or **Mallinckrodt and Olin** shall be responsible to contact the appropriate state and/or local agencies. If Ecology so requires, **Mallinckrodt and Olin** shall promptly consult with the appropriate state and/or local agencies and provide Ecology with written documentation from those agencies of the substantive requirements those agencies believe are applicable to the remedial action. Ecology shall make the final determination on the additional substantive requirements that must be met by **Mallinckrodt and Olin** and on how **Mallinckrodt and Olin** must meet those requirements. Ecology shall inform **Mallinckrodt and Olin** in writing of these requirements. Once established by Ecology, the additional requirements shall be enforceable requirements of this Order. **Mallinckrodt and Olin** shall not begin or continue the remedial action potentially subject to the additional requirements until Ecology makes its final determination.

3. Pursuant to RCW 70.105D.090(2), in the event Ecology determines that the exemption from complying with the procedural requirements of the laws referenced in RCW 70.105D.090(1) would result in the loss of approval from a federal agency that is necessary for the State to administer any federal law, the exemption shall not apply and **Mallinckrodt and Olin** shall comply with both the procedural and substantive requirements of the laws referenced in RCW 70.105D.090(1), including any requirements to obtain permits.

Q. Periodic Review

As remedial action, including groundwater monitoring, continues at the Site, the Parties agree to review the progress of remedial action at the Site, and to review the data accumulated as a result of monitoring the Site as often as is necessary and appropriate under the circumstances. At least every five (5) years after the initiation of cleanup action at the Site the Parties shall meet to discuss the status of the Site and the need, if any, for further remedial action at the Site. At least ninety (90) days prior to each periodic review, **Mallinckrodt and Olin** shall submit a report to Ecology that documents whether human health and the environment are being protected based on the factors set forth in WAC 173-340-420(4). Ecology reserves the right to require further remedial action at the Site under appropriate circumstances. This provision shall remain in effect for the duration of this Order.

R. Indemnification

Mallinckrodt and Olin agrees to indemnify and save and hold the State of Washington, its employees, and agents harmless from any and all claims or causes of action for death or injuries to persons or for loss or damage to property to the extent arising from or on account of acts or omissions of **Mallinckrodt and Olin**, its officers, employees, agents, or contractors in entering into and implementing this Order. However, **Mallinckrodt and Olin** shall not indemnify the State of Washington nor save nor hold its employees and agents harmless from any claims or causes of action to the extent arising out of the negligent acts or omissions of the State of Washington, or the employees or agents of the State, in entering into or implementing this Order.

IX. SATISFACTION OF ORDER

The provisions of this Order shall be deemed satisfied upon **Mallinckrodt and Olin**'s receipt of written notification from Ecology that **Mallinckrodt and Olin** have completed the remedial activity required by this Order, as amended by any modifications, and that **Mallinckrodt and Olin** have complied with all other provisions of this Agreed Order.

X. ENFORCEMENT

Pursuant to RCW 70.105D.050, this Order may be enforced as follows:

A. The Attorney General may bring an action to enforce this Order in a state or federal court.

B. The Attorney General may seek, by filing an action, if necessary, to recover amounts spent by Ecology for investigative and remedial actions and orders related to the Site.

C. In the event **Mallinckrodt and Olin** refuses, without sufficient cause, to comply with any term of this Order, **Mallinckrodt and Olin** will be liable for:

a. Up to three (3) times the amount of any costs incurred by the State of Washington as a result of its refusal to comply; and

b. Civil penalties of up to twenty-five thousand dollars ($25,000) per day for each day it refuses to comply.

D. This Order is not appealable to the Washington Pollution Control Hearings Board. This Order may be reviewed only as provided under RCW 70.105D.060.

Effective date of this Order: February 27, 2014

Mallinckrodt

Eric Berry

Eric Berry
Vice President

Olin Corporation

Curtis M Richards

Curtis M. Richards
Vice President Environmental, Health and Safety

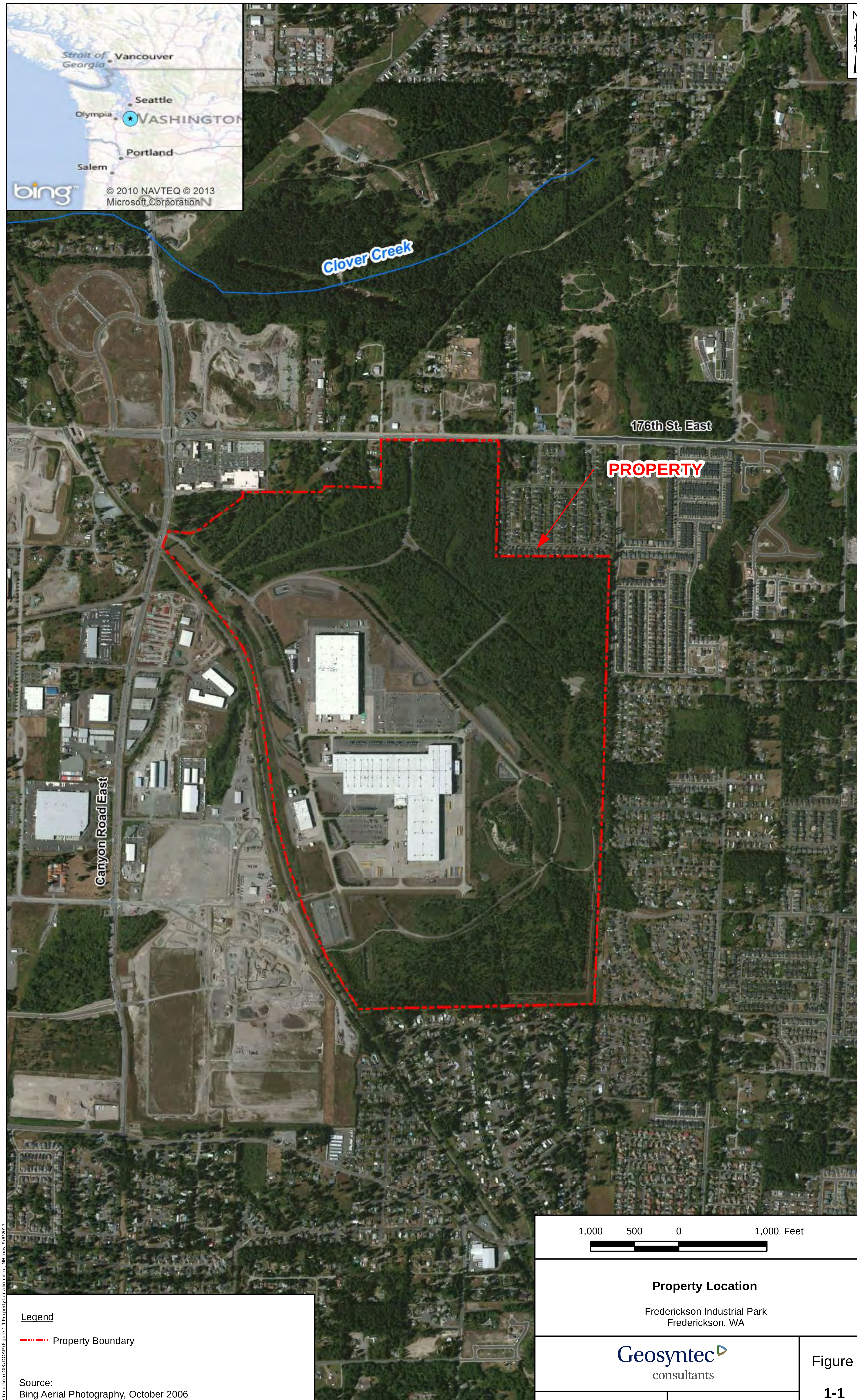
SKR
1/3/14

STATE OF WASHINGTON, DEPARTMENT OF ECOLOGY

Rebecca S. Lawson

Rebecca S. Lawson, P.E., L.H.G.
Southwest Regional Office
Telephone: (360) 407-6241

EXHIBIT A



Property Location

Frederickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Kennesaw, GA | 06-Sep-2013

Figure 1-1

N:\Frederickson\GIS\DCAP\Figure 1-1 Property Location.mxd; NHirons; 9/6/2013

EXHIBIT B

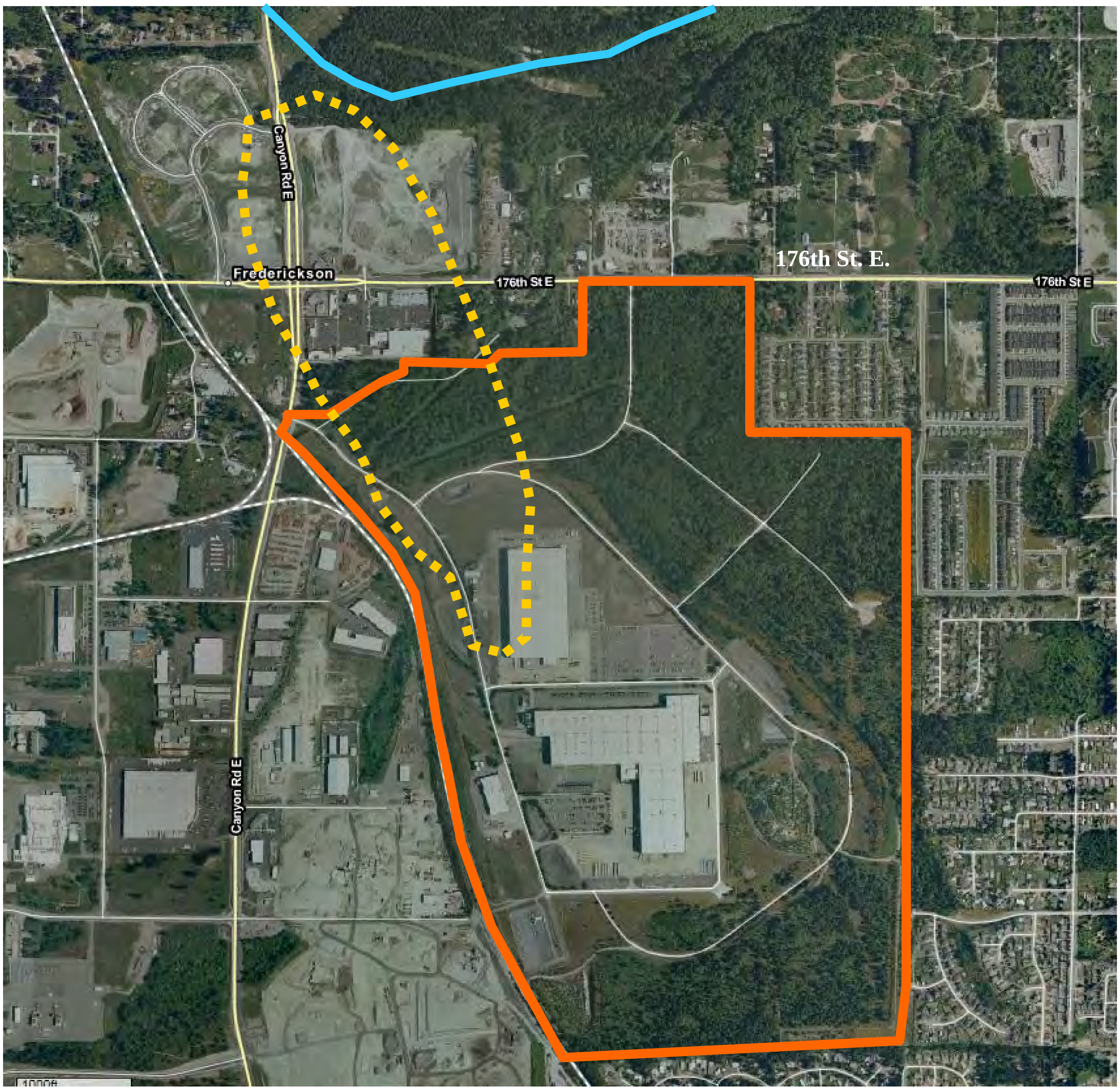


Exhibit B. Frederickson Industrial Park Site Diagram (2013)

Frederickson Industrial Park Property

Approximate plume of carbon tetrachloride (CTC)-contaminated groundwater

Clover Creek

Exhibit C

Issued by

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

Prepared for

Olin Corporation

and

Mallinckrodt US, LLC

CLEANUP ACTION PLAN

FREDERICKSON INDUSTRIAL PARK
FREDERICKSON, WASHINGTON

Prepared by

Geosyntec consultants

engineers | scientists | innovators

1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144

Project Number GR4631

February 2014

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*.

Purpose

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:

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[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 Site Conditions

The Site is located within the Clover Creek Subbasin, which occupies the southeastern portion of the Clover/Chambers Creek (CCC) Basin **(Figure 1-1)**. Detailed descriptions of the regional and site-specific conditions have been presented previously (Brown & Caldwell, 1985; CRA, 1998; CRA, 1999; CRA, 2000; CRA, 2001; CRA, 2002; CRA, 2003; Geosyntec, 2010; and, Geosyntec, 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 Nature and Extent of Contamination

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 Site Risk & Exposure Pathway Evaluation

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 Process Overview & Conclusion

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.

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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

Analyte	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)	
	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

Fredericksen Industrial Park
Fredericksen, WA

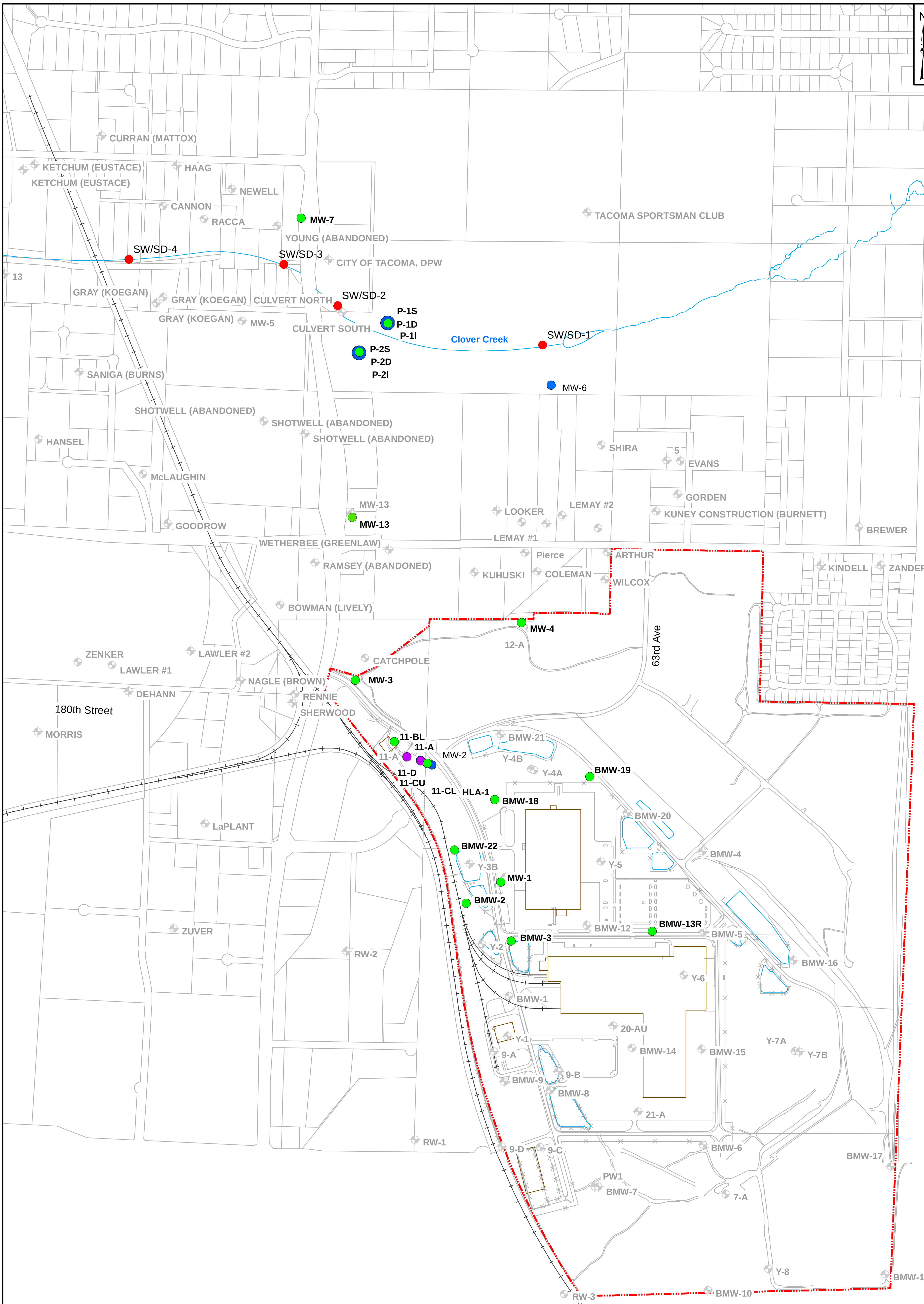
Geosyntec consultants

Kennesaw, GA

06-Sep-2013

Figure
1-1

N:\Frederickson\GIS\DCAP\Figure 1-1 Property Location.mxd; NHirons; 9/6/2013



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

1,000 500 0 1,000 Feet

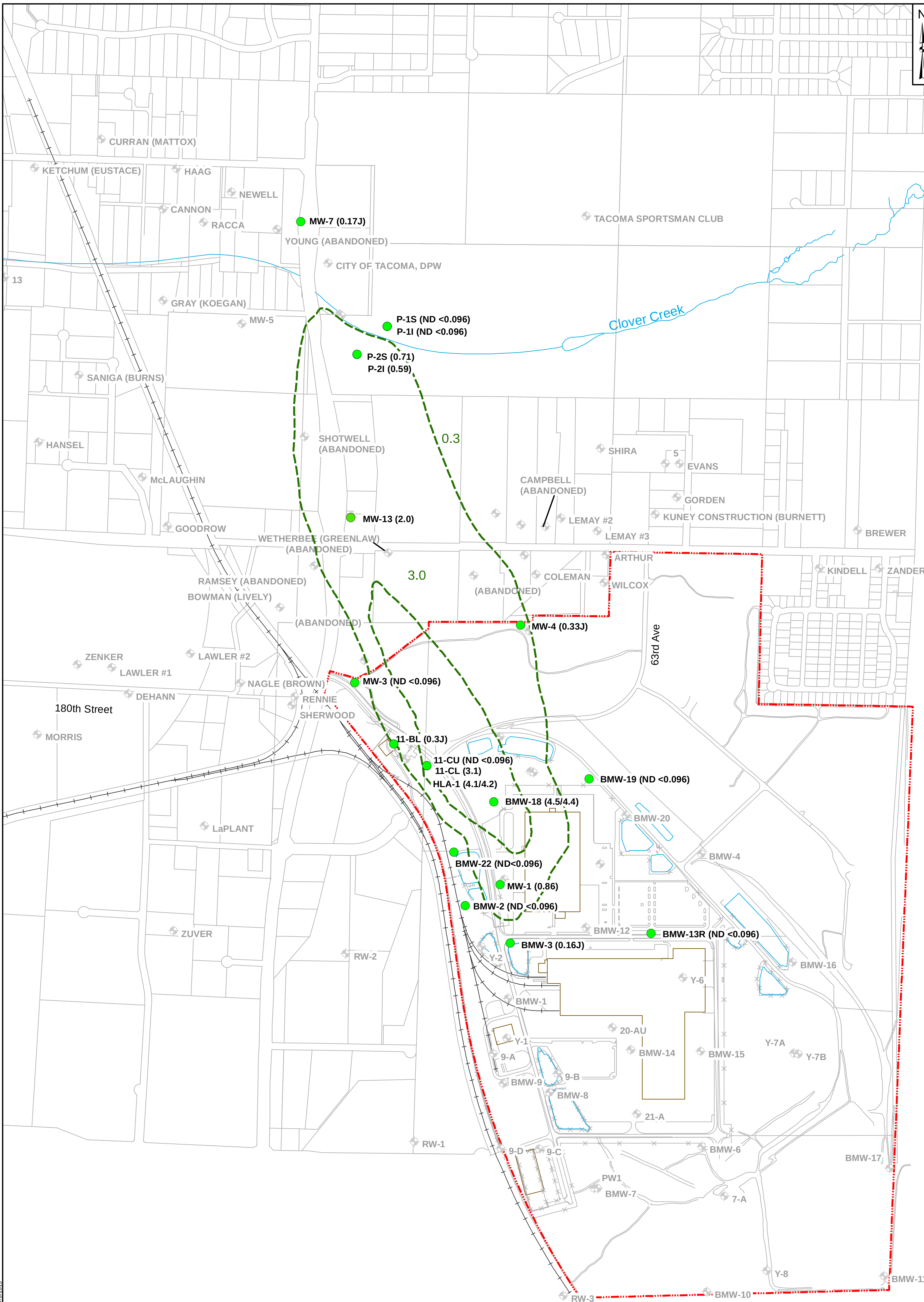
Site Plan

Frederickson Industrial Park
Fredericksen, WA

Geosyntec consultants

Figure **2-1**

Kennesaw, GA | 06-Sep-2013



N:\Fredrickson GIS\DCAP\MXD\Figure 2-2a Olin CTC Conc Feb 2011.mxd Nelson 9/6/2013

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)

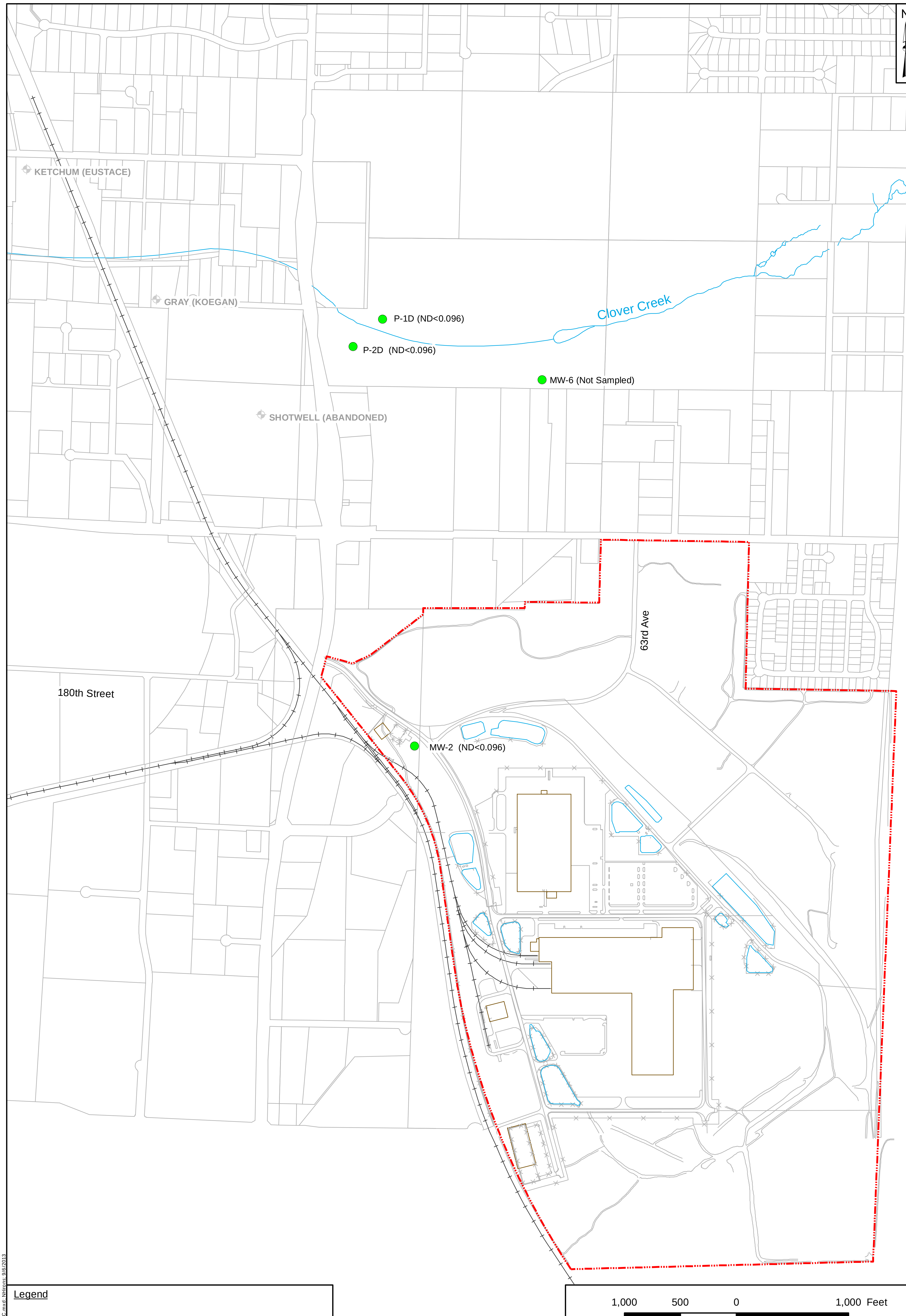
1,000 500 0 1,000 Feet

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

Geosyntec consultants

Kennesaw, GA | 06-Sep-2013

Figure
2-2a



Legend

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

Aquifer C Carbon Tetrachloride Groundwater Results February 2011

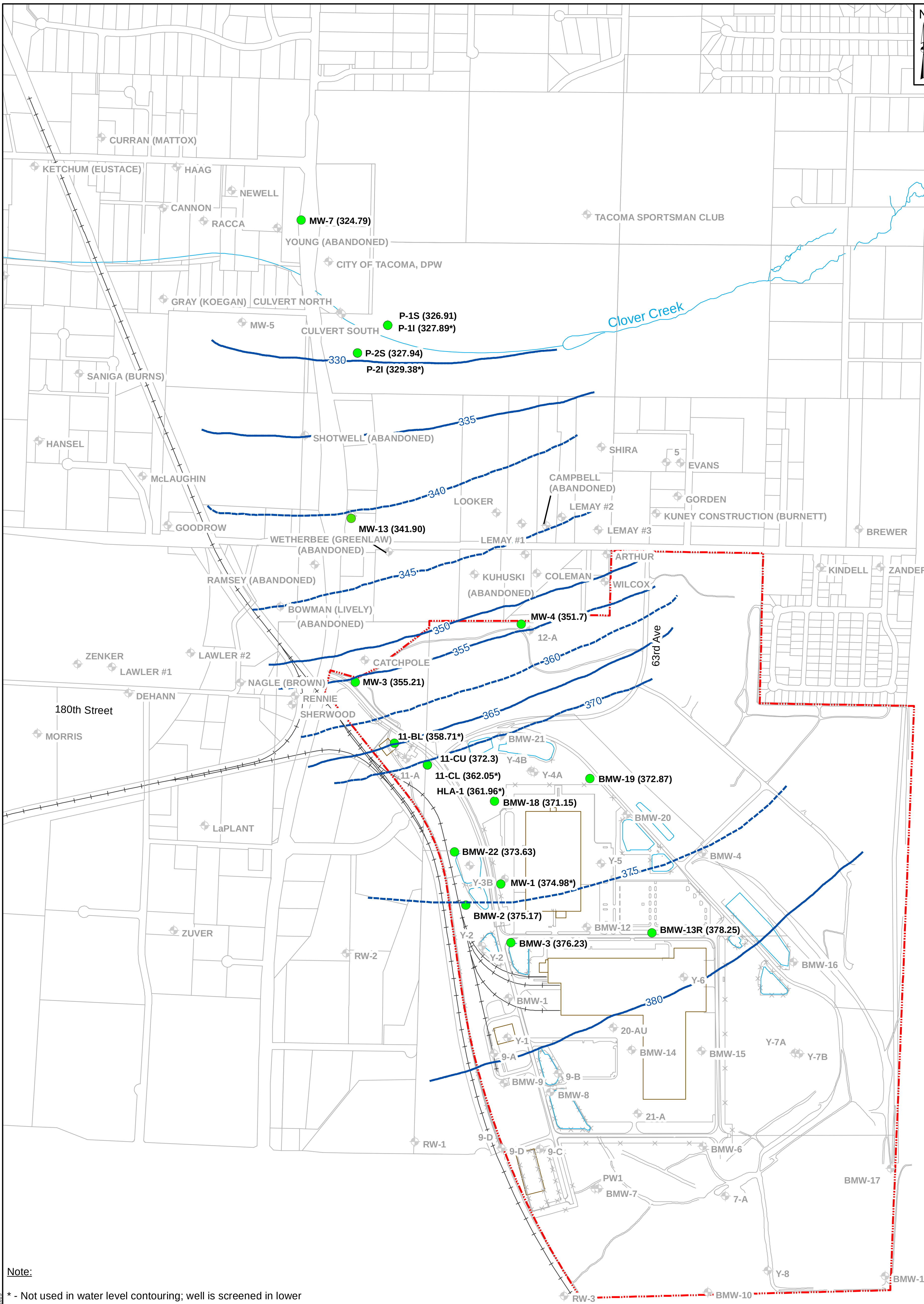
Fredericksson Industrial Park
Fredericksson, WA

Geosyntec consultants

Kennesaw, GA | 06-Sep-2013

Figure **2-2b**

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

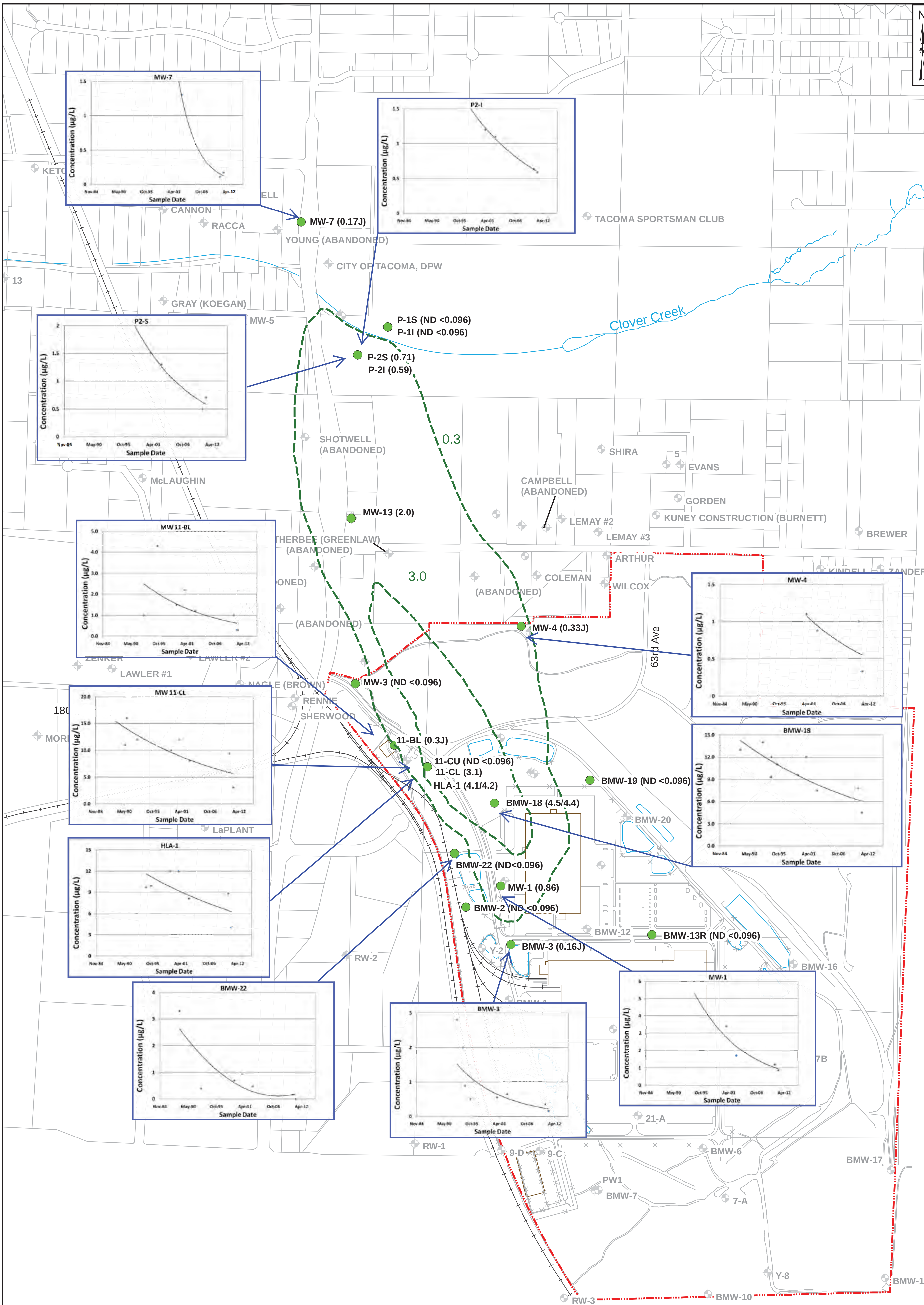
Aquifer A Groundwater Levels
February 2011

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

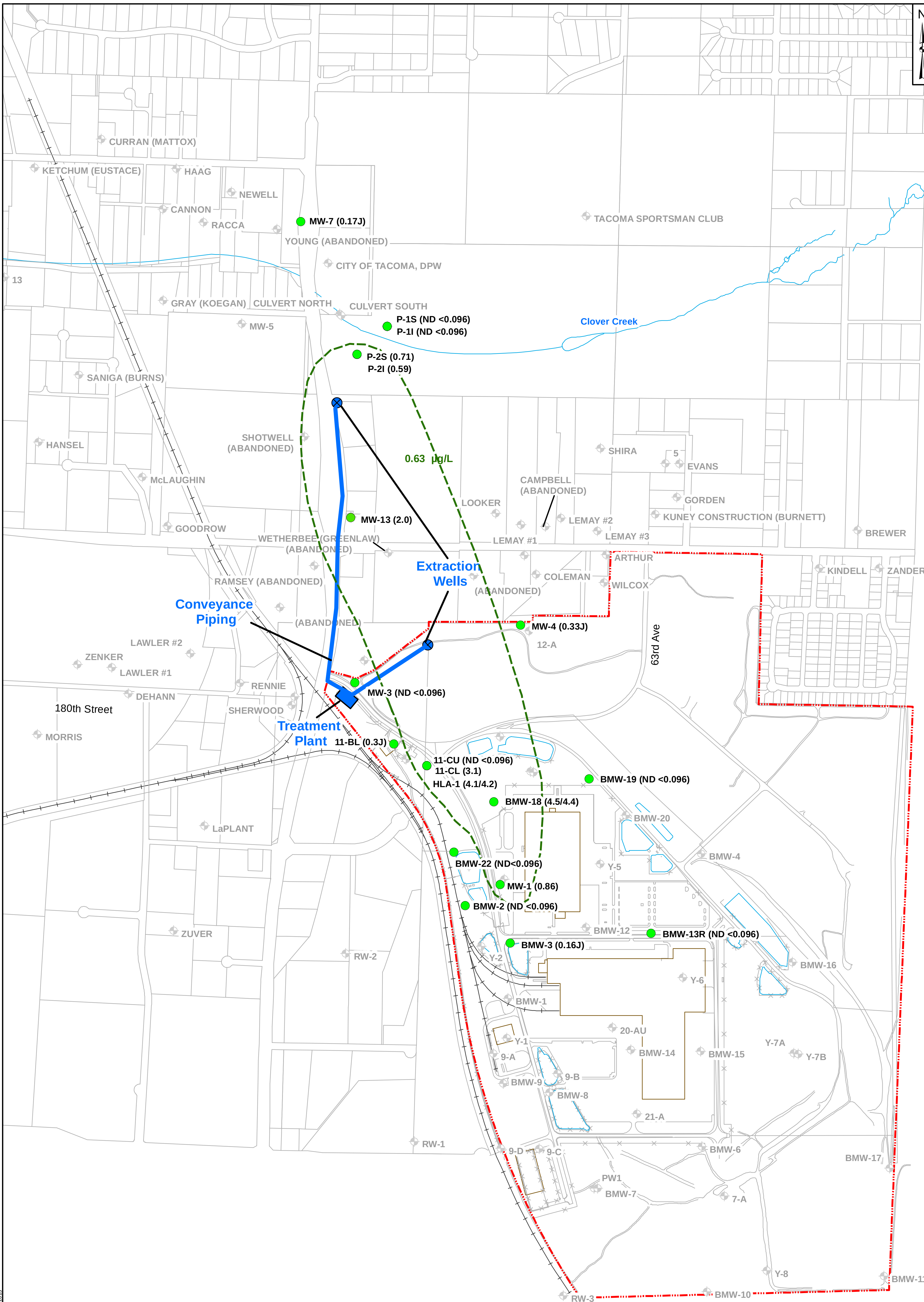
Concentration Trends for Carbon Tetrachloride February 2011

Fredrickson Industrial Park
Fredrickson, WA

Geosyntec consultants

Kennesaw, GA | 06-Sep-2013

Figure 2-4



Legend

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

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

1,000 500 0 1,000 Feet

Conceptual Layout for Alternative 2

Fredrickson Industrial Park
Fredrickson, WA

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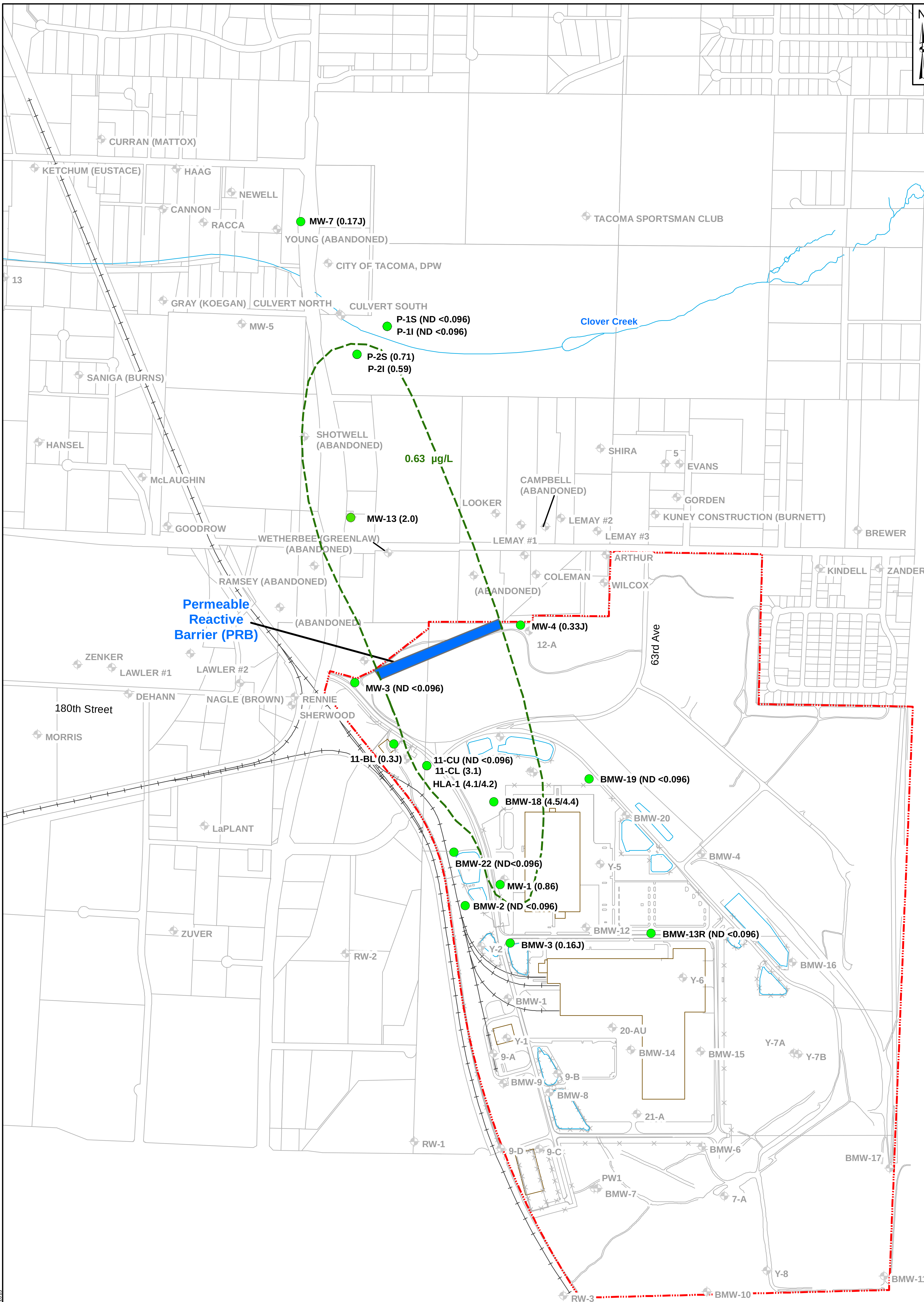
Figure 4-1

N:\Fredrickson GS\DCAP\MXD\Figure 4-1 Conceptual Layout Alt2.mxd NHirons 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

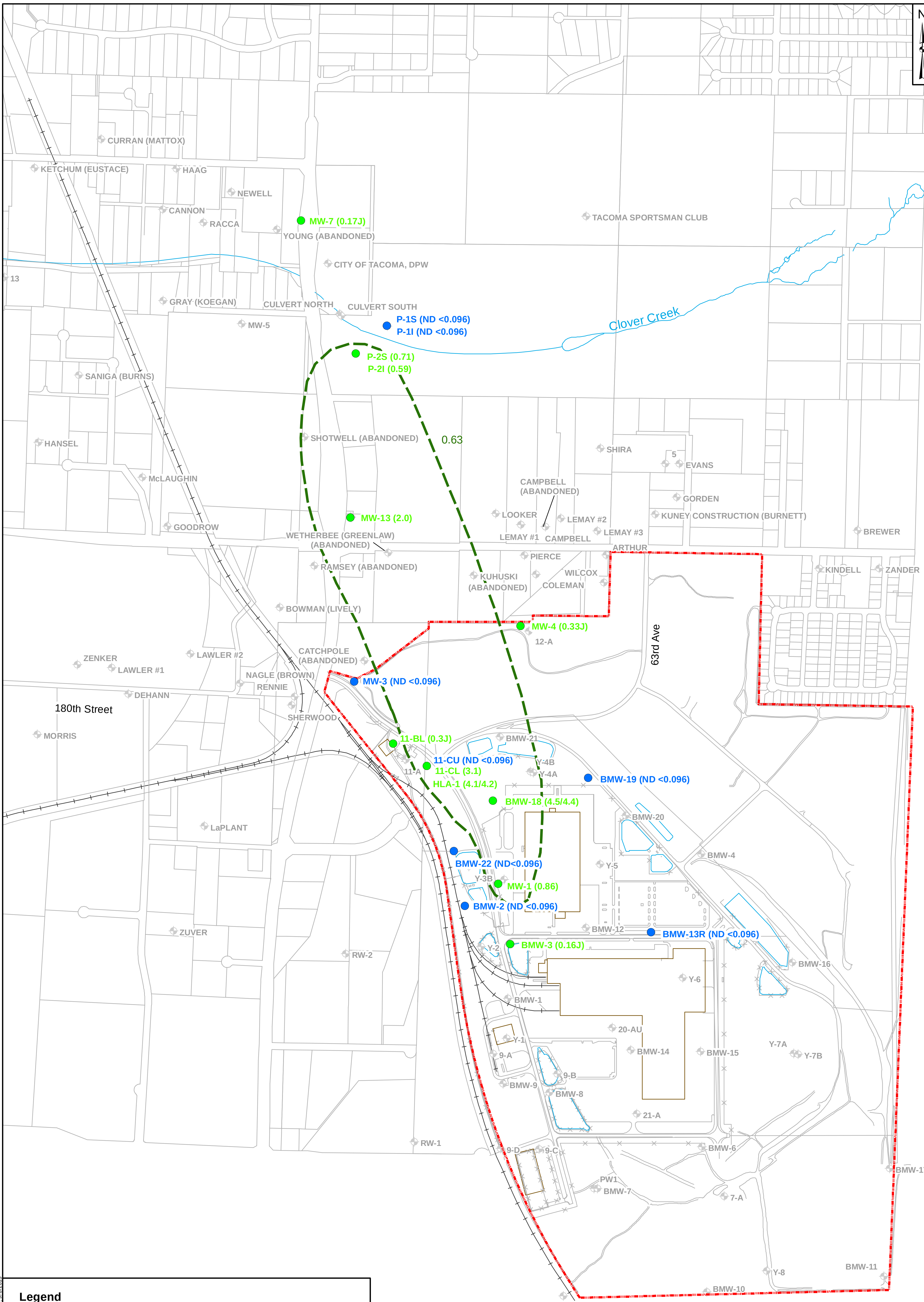
Conceptual Layout for Alternative 3

Fredrickson Industrial Park
Fredrickson, WA

Geosyntec
consultants

Figure
4-2

Kennesaw, GA | 06-Sep-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
Fredericksn, WA

Geosyntec consultants

Figure **5-1**

Kennesaw, GA | 06-Sep-2013

N:\Fredericksen GIS\DCAP\MXD\Figure 5-1 CTC Compliance Monitoring.mxd; NHirons; 9/6/2013

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 µg/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 μg/m^3 and 4.2 μg/m^3, respectively. These changes result in revised Method C Tier 1 soil gas SLs of 42 and 420 μg/m^3 (0.042 and 0.420 μg/L) for shallow (<15 ft bgs) and deep (≥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 μg/ m^3) slightly exceeds the SL for shallow soil gas (42 μg/ m^3) but the shallower sample (5 ft bgs) that is closer to the existing building foundation at this location (3.5 μg/ 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 μg/ m^3). The five shallow samples are: (i) 4.5 ft bgs at location E3 (122 μg/m^3); (ii) 5 ft bgs at location F2 (53.8 μg/m^3); and (iii) 5 ft bgs at location D4 (118.5 μg/m^3). None of the deep soil gas samples exceed the SL for deep soil gas (420 μg/m^3) but the 14.5 ft bgs sample at location D4 (186.3 μg/m^3) and the 14.5 ft bgs sample at location C7 (157.2 μg/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.

[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)
Frederickson Industrial Park
Frederickson, 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

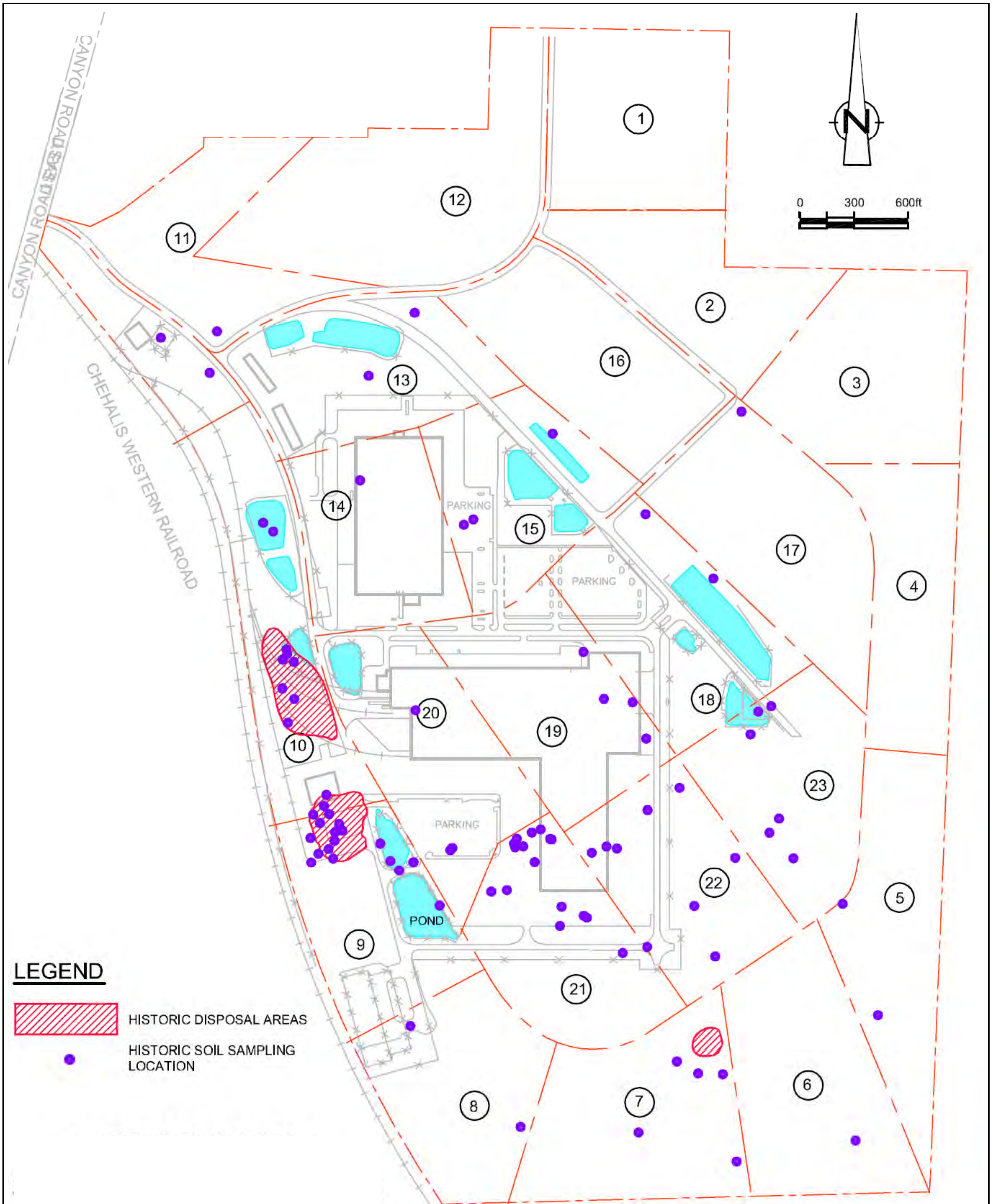


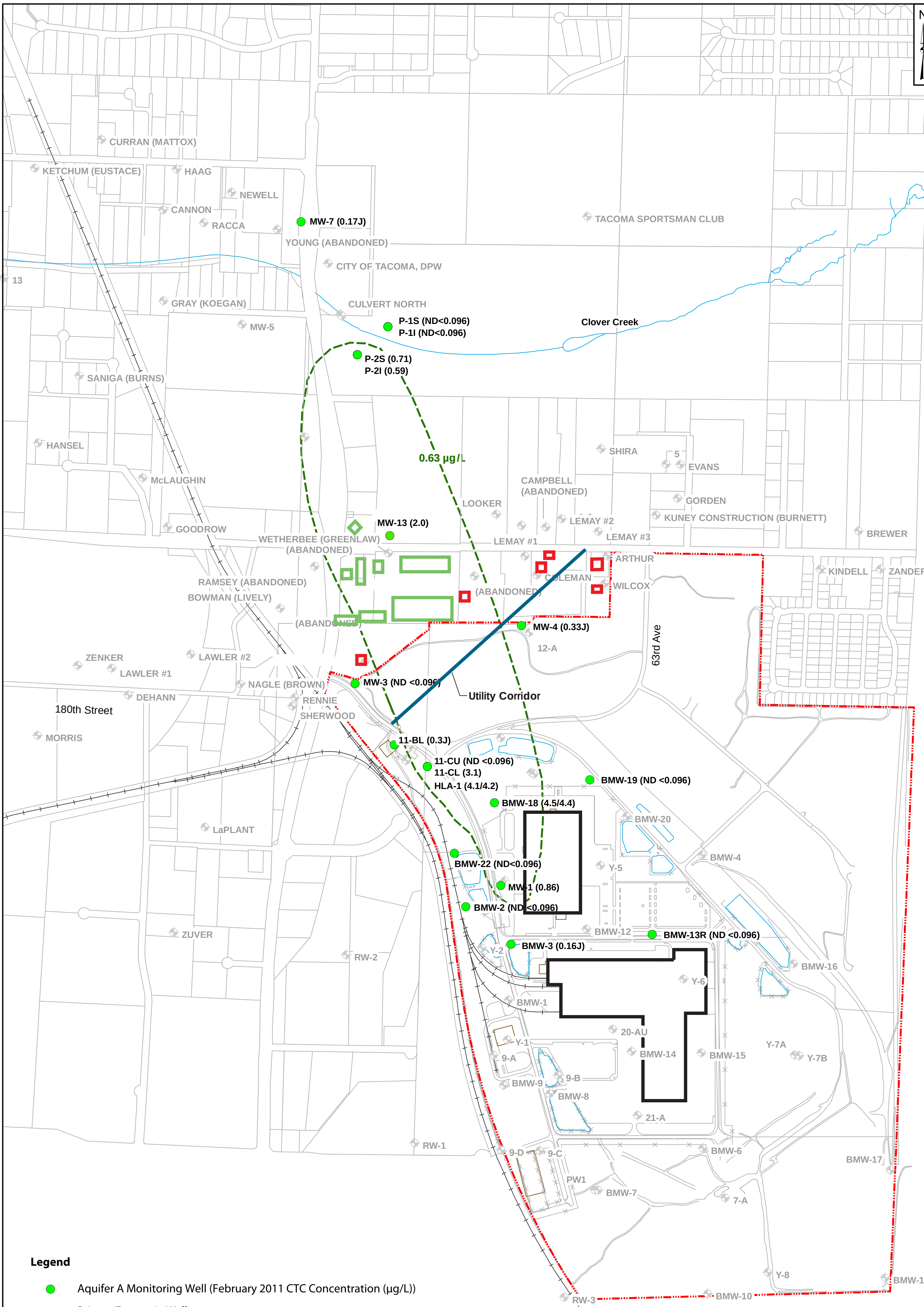
Figure Source is 24 February 2010 Presentation to Ecology

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)

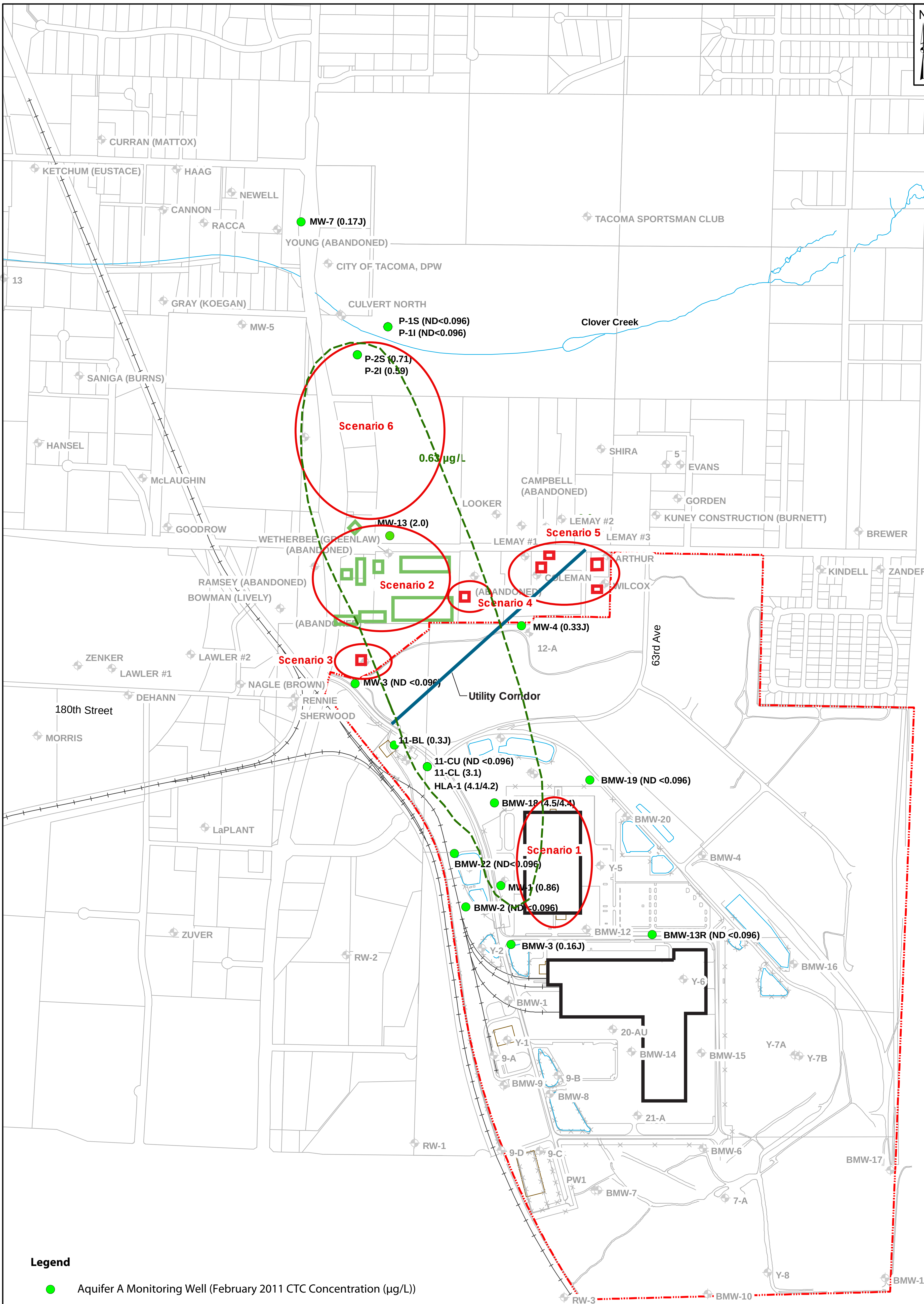
Building Locations Relative to CTC in Groundwater
Fredericksn Industrial Park
Fredericksn, WA

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)

Scenarios for Predictive Modeling
Frederickson Industrial Park
Frederickson, WA

Geosyntec consultants

Figure
A3

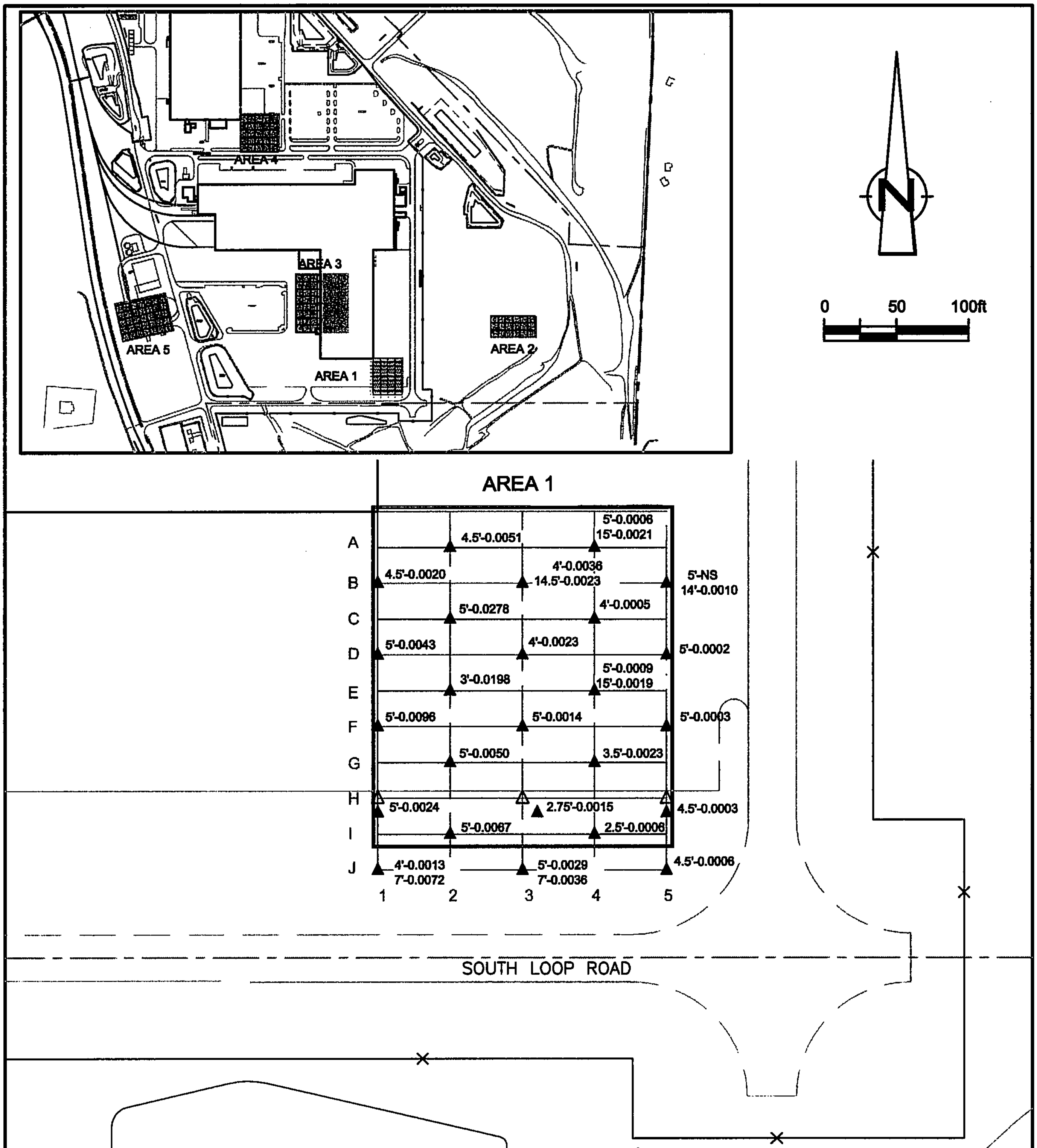
Kennesaw, GA

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)

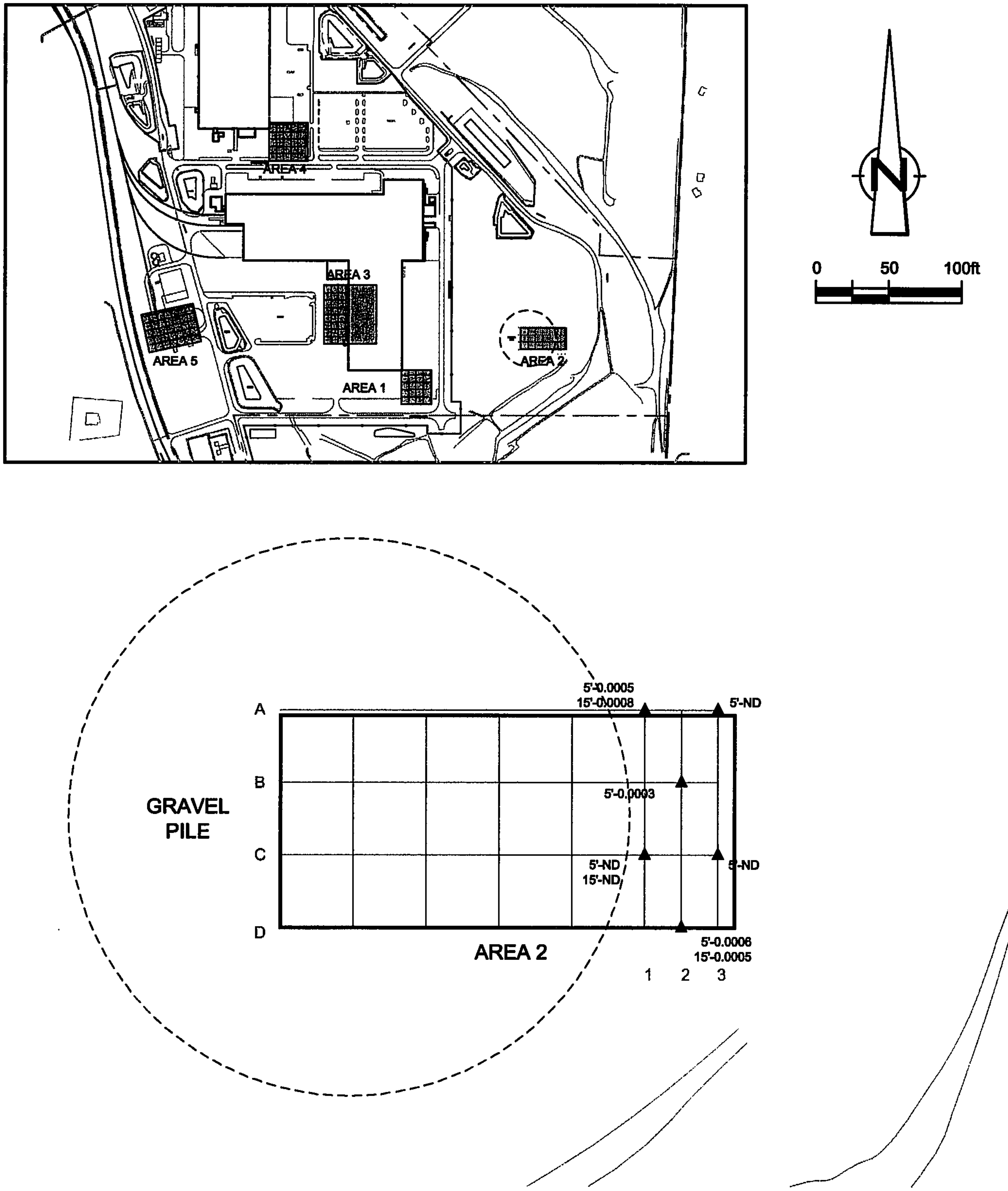
NS NOT SAMPLED

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

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

▲ SOIL GAS SAMPLE LOCATION

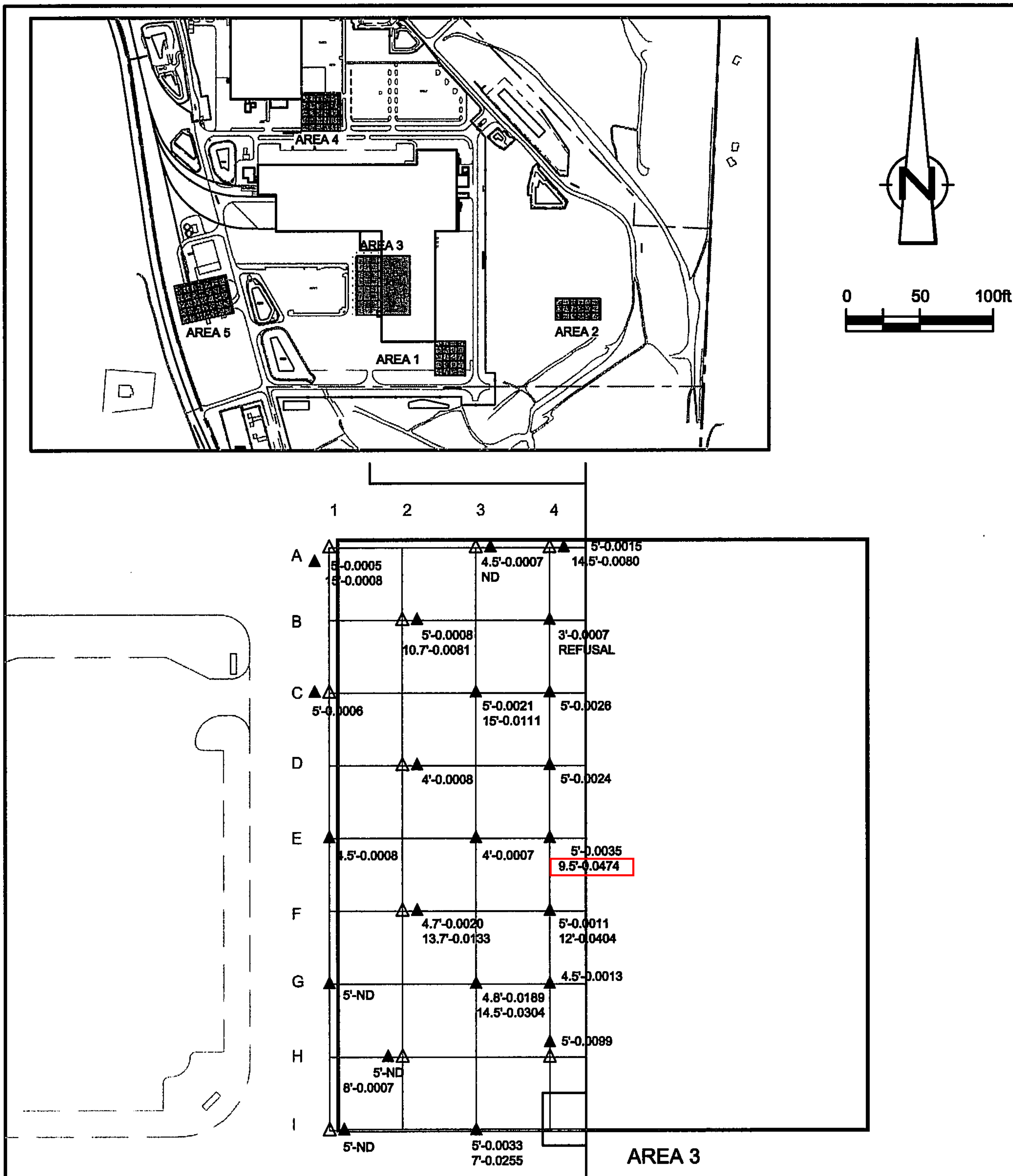
ND NOT DETECTED (MDL=0.0001 ug/L)

figure 5.2

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

CRA

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



LEGEND

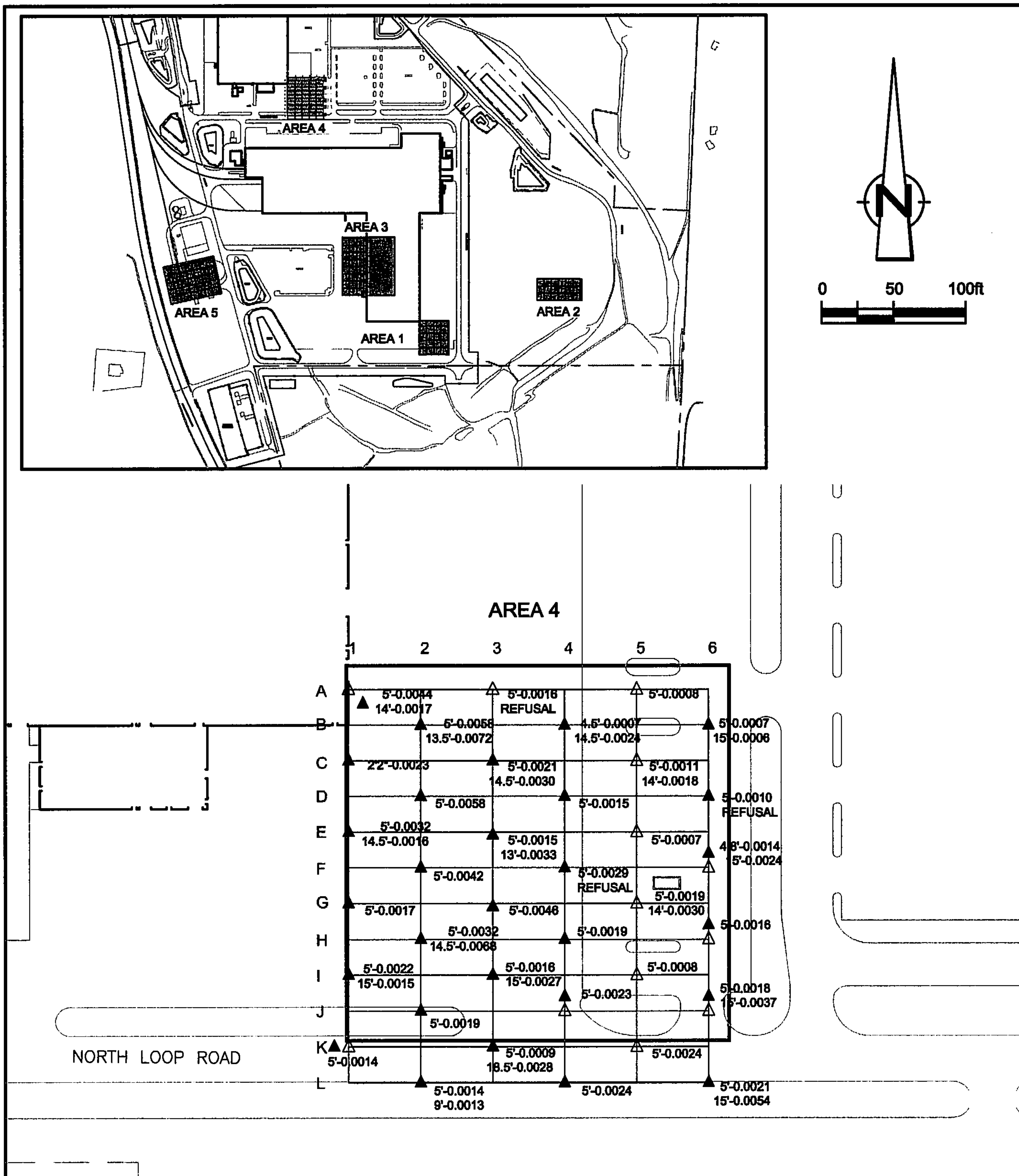
- POTENTIAL HISTORIC CTC SOURCE AREA
- FEET BELOW GROUND SURFACE
- 4'-0.0036 — CTC SOIL GAS CONCENTRATION (ug/L)
- △ INITIAL SOIL GAS SAMPLING ATTEMPT/LOCATION
- ▲ SOIL GAS SAMPLE LOCATION
- ND NOT DETECTED (MDL = 0.0001ug/L)

figure 5.3

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

CRA

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



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

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

△ INITIAL SOIL GAS SAMPLING ATTEMPT/LOCATION

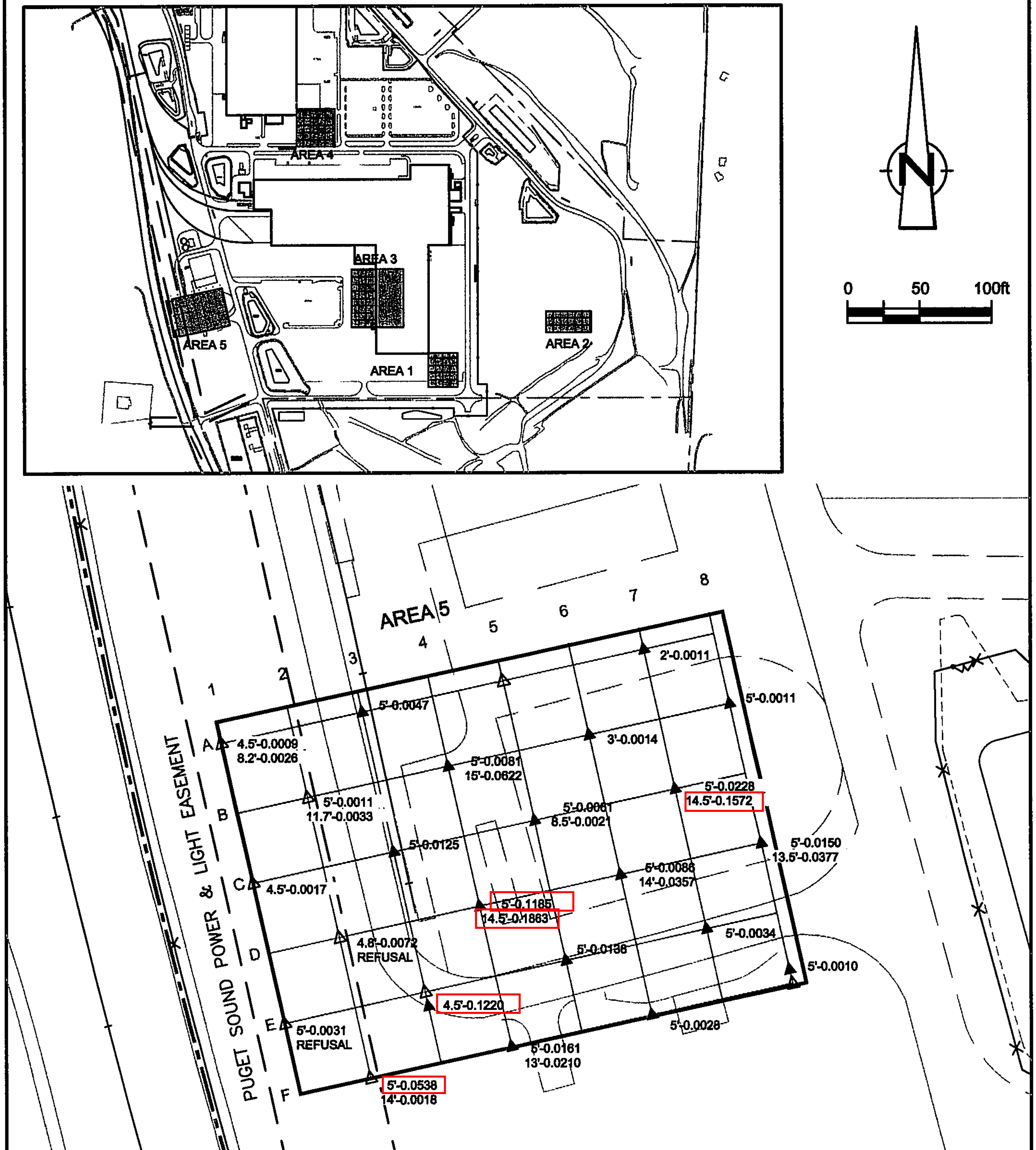
▲ SOIL GAS SAMPLE LOCATION

CRA

figure 5.4

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

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



LEGEND

POTENTIAL HISTORIC CTC SOURCE AREA

FEET BELOW GROUND SURFACE
4'-0.0036 — 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

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 ($\mu g/m^3$)	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	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 (^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)
15	289.56	11	289.56			S		

Totals must add up to value of Ls (cell F24)

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

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 ($\mu g/m^3$)	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, $\rho_b{}^A$ (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, $\theta_w{}^A$ (cm^3/cm^3)	ENTER Stratum B SCS soil type	ENTER Stratum B soil dry bulk density, $\rho_b{}^B$ (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, $\theta_w{}^B$ (cm^3/cm^3)	ENTER Stratum C SCS soil type	ENTER Stratum C soil dry bulk density, $\rho_b{}^C$ (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, $\theta_w{}^C$ (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 ($\mu g/m^3$)	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	1.22E+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 (°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	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 ($g/cm\text{-}s^2$)	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

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-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 ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
56235	1.86E+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 (°C)	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	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	0.25	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} ($atm\text{-}m^3/mol$)	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	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 (^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	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/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type (Lookup Soil Parameters)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type (Lookup Soil Parameters)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054		1.5	0.43	0.215		1.5	0.43	0.215

MORE ↓

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

MORE ↓

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

Used to calculate risk-based groundwater concentration.

END

INTERMEDIATE CALCULATIONS SHEET

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

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-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 (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
11	15	1158	1158	0	0	A	S	S		1.00E-08

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

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		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

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

Reset to Defaults

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

YES [ ]

OR

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

YES [X]

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

MORE ↓

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	457	457	0	0	A	S	S		1.00E-08

MORE ↓

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

MORE ↓

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

MORE ↓

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

Used to calculate risk-based groundwater concentration.

END

SCENARIO 3

INTERMEDIATE CALCULATIONS SHEET

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

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

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

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

Reset to Defaults

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

YES [ ]

OR

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

YES [X]

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

MORE ↓

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

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	0.25	5

MORE ↓

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

Used to calculate risk-based groundwater concentration.

END

SCENARIO 5

INTERMEDIATE CALCULATIONS SHEET

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

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

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

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

Reset to Defaults

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

YES [ ]

OR

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

YES [X]

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

MORE ↓

ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER 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 ($^{\circ}$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)
			Totals must add up to value of L_{WT} (cell G28)							
11	15	914	914	0	0	A	S	S		1.00E-08

MORE ↓

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

MORE ↓

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

MORE ↓

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

Used to calculate risk-based groundwater concentration.

END

Exhibit D

Prepared for

Olin Corporation

and

Mallinckrodt US, LLC

COMPLIANCE MONITORING WORK PLAN

FREDERICKSON INDUSTRIAL PARK FREDERICKSON, WASHINGTON

Prepared by

Geosyntec consultants

engineers | scientists | innovators

1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144

Project Number GR4631

September 2013

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LIST OF APPENDICES

LIST OF ACRONYMS

CAP	Cleanup Action Plan
CMWP	Compliance Monitoring Work Plan
CTC	Carbon Tetrachloride
Ecology	Washington Department of Ecology
MNA	Monitored Natural Attenuation
MTCA	Model Toxics Control Act
RI/FS	Remedial Investigation and Feasibility Study
USEPA	United States Environmental Protection Agency
WAC	Washington Administrative Code

1. INTRODUCTION

This draft *Compliance Monitoring Work Plan* (CMWP) has been prepared by Geosyntec Consultants on behalf of Olin Corporation and Mallinckrodt US LLC (the Companies), and is being submitted concurrently with the draft *Cleanup Action Plan* (CAP) to the Washington Department of Ecology (Ecology), for the Frederickson Industrial Park (the Property) in Frederickson, Washington (Figure 1-1). The draft CAP is based upon the Ecology-approved remedy of monitored natural attenuation (MNA) to address carbon tetrachloride (CTC) in groundwater. The rationale for the selection of MNA to remediate CTC was presented in the *Remedial Investigation/Feasibility Study (RI/FS) Report* (RI/FS Report) [Geosyntec, 2012] submitted to Ecology by the Companies on 28 March 2012. Ecology's issuance of Agreed Order No. DE 97TC-S121 (Order) based on the final RI/FS Report confirmed the selection of MNA as the approved cleanup action for the Site[1].

1.1 Purpose

The purpose of the draft CMWP in the Model Toxics Control Act (MTCA) process is to fulfill requirements of Compliance Monitoring per Washington Administrative Code (WAC) 173-340-410. Compliance monitoring under WAC 173-340-410 consists of three elements, which are: 1) Protection Monitoring; 2) Performance Monitoring; and 3) Confirmational Monitoring.

Because the selected remedy is MNA and the monitoring well network already exists, there will be no need for Protection Monitoring, which is used to confirm that human health and the environment are protected during construction, operation and maintenance of the selected remedy. Thus, the draft CMP will include:

- 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).

[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.

As described in the RI/FS Report (Geosyntec, 2012), 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 Report Organization

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

- Section 2 – Compliance Monitoring Well Network;
- Section 3 – Performance & Confirmational Monitoring;
- Section 4 – Data Evaluation and Management; and
- Section 5 – References.

2. COMPLIANCE MONITORING WELL NETWORK

2.1 Existing Monitoring Well Network

Twenty-two (22) monitoring wells were sampled and analyzed for CTC during the most recent groundwater sampling event, which was conducted in February 2011. Of the wells sampled, nineteen (19) are screened in Aquifer A and three (3) are screened in Aquifer C. The locations of the monitoring wells are shown in Figure 2-1. Well construction details are provided in Table 2-1. Historical CTC data for the monitoring wells are provided in Table 2-2.

2.2 Compliance Monitoring Well Network

The CTC data from the existing monitoring well network were evaluated to identify wells to be included in the compliance monitoring network. Based on the evaluation, the compliance monitoring network consists of 11 monitoring wells discussed below, and shown on Figure 2-2. As discussed in more detail in Section 4, Confirmational Monitoring will use a subset of this monitoring well network. The monitoring wells considered for Performance Monitoring are listed here and 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 2-2).

- 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 2-2).

- 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 2-2), but not in subsequent events. During the first round of Performance 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 (i.e., dropped from the Performance Monitoring and Confirmational Monitoring programs).

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.

A subset of the above wells will be selected for Confirmational Monitoring, as detailed in Section 3.

3. PERFORMANCE & CONFIRMATIONAL MONITORING

Performance Monitoring will be implemented at the Site to: (i) evaluate whether MNA processes are effectively reducing CTC concentrations in groundwater, and (ii) determine when individual monitoring wells have achieved the cleanup standard for the Site and can be removed from the Performance Monitoring sampling program. Confirmational Monitoring will be implemented once the network of compliance monitoring wells has achieved the cleanup standard for the Site. The objective of Confirmational Monitoring is to demonstrate the long-term effectiveness of the cleanup action once cleanup standards have been attained site-wide. The Companies will submit a request for final site closure once Confirmational Monitoring is complete. Upon final closure of the Site, the monitoring well network will be appropriately decommissioned with Ecology approval.

3.1 Performance Monitoring Schedule

Performance Monitoring is anticipated to begin during 2013. The initial sampling frequency for the compliance monitoring well network will be semi-annual for the first two years of Compliance Monitoring and then will be changed to annual sampling[2]. The proposed semi-annual sampling frequency for the monitoring wells is considered to be appropriate for the following reasons:

- As indicated in Figure 2-8 of the RI/FS Report (Geosyntec, 2012), each of the wells included in the compliance monitoring network has exhibited a consistent, decreasing CTC concentration trend over the past 10 to 20 years. An increased sampling frequency would not improve the level of understanding of CTC fate at the Site;

- The remedial timeframes for the individual monitoring wells to achieve the cleanup standard were estimated in the RI/FS Report (Geosyntec, 2012) to range from 3 years (i.e., P2-S) to 28 years (i.e., BMW-18). The proposed sampling frequency is appropriate for the anticipated timescale of the MNA remedy; and

[2] As noted in Section 2.2, MW-7 and BMW-3 will be removed from the compliance monitoring well network if their CTC concentrations from the first round of Performance Monitoring are below the cleanup level.

- Concentrations of CTC in groundwater, especially off-Property, are very low. An increased sampling frequency is not warranted given the low CTC concentrations.

The sampling frequency will be evaluated yearly. For certain wells, it may be appropriate to reduce the sampling frequency to bi-annually (every second year) in the future if concentration trends remain stable.

The criteria for removing individual compliance monitoring wells from the Performance Monitoring program will be the following, whichever occurs first: (i) CTC concentrations from three consecutive sampling events are below the MTCA cleanup level (which is currently 0.63 µg/L); or (ii) the 3-point moving average of the CTC concentration drops below the MTCA cleanup level.

3.2 Confirmational Monitoring Schedule

Confirmational Monitoring will be initiated one year after successful completion of Performance Monitoring. The Confirmational Monitoring well network will be identified at that time. Conceptually, it is anticipated that five monitoring wells will be selected for Confirmational Monitoring, likely to include one well within the upgradient portion of the current CTC plume (e.g., BMW-3), two wells within the current plume core (e.g., HLA-1 and BMW-18), and two off-Property wells (e.g., MW-13 and P2-S).

The timing of the Confirmational Monitoring sampling event will be determined in consultation with Ecology. The proposed criteria for Site closure are likely to be the following: (i) the average of the five well samples is less than the MTCA cleanup level (which is currently 0.63 µg/L), and (ii) no more than one of the five wells exceeds the 0.63 µg/L cleanup level. If the criteria are not met, a second Confirmational Monitoring event will be performed one year later and the results compared to the criteria. Following the successful completion of Confirmational Monitoring, the Site will be proposed to Ecology for regulatory closure.

A contingency plan will be developed, and provided to Ecology for review and approval, if, during Confirmational Monitoring, the criteria are not achieved after the second sampling event. Development of the contingency plan will use the monitoring data collected to evaluate MNA processes, and propose a path forward. Following successful implementation of the contingency plan, Confirmational Monitoring will be conducted.

3.3 Reporting

Performance Monitoring results will be reported to Ecology on an annual basis. The MNA Performance Monitoring Reports will provide monitoring results, analytical reports, and an evaluation of groundwater monitoring results and MNA trends. A discussion and proposal for approval by Ecology of any changes in the monitoring well network (reducing the monitoring frequency, transitioning a well from Performance Monitoring to Confirmational Monitoring, etc.) will be included.

A Confirmational Monitoring Report will be submitted to Ecology for review and comment within 60 days of the Confirmational Monitoring sampling event. If the data conform to Site closure criteria, a request will be made to Ecology to discontinue monitoring at the Site.

3.4 Monitoring Procedures

3.4.1 Field Measurements

Water levels and field parameters will be measured during well purging. Field parameters will include:

- pH;
- Dissolved Oxygen (DO);
- Temperature;
- Conductivity;
- Oxidation/Reduction Potential (ORP); and
- Turbidity.

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, given the steady CTC concentration declines observed at the Site over the past 10 to 20 years, 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.

3.4.2 Sampling Methods

Water level measurements will be collected prior to and during groundwater sampling (to maintain stable water levels during sampling). Sampling will be conducted using low-flow sampling procedures, as described in the Sampling and Analysis Plan (SAP) in Appendix A. The amount of purging at each well will be based on stabilization of pH, temperature, turbidity and specific conductivity field parameters. DO and ORP will also be measured, but will not be used as stabilization criteria since they tend to fluctuate. A Quality Assurance Project Plan (QAPP) is provided in Appendix B.

3.4.3 Sampling Parameters

Groundwater samples will be collected in VOA vials for laboratory analysis of CTC by EPA Method 8260C. Details on the analytical testing methodology are provided in Appendices A and B.

4. DATA EVALUATION AND MANAGEMENT

4.1 Data Validation

Monitoring reports provided to Ecology will contain a review of the data (Level 1 review) for consistency, quality control, and laboratory protocols, and laboratory data reports as attachments. Data packages from the laboratory will be sufficient to provide a Level 2 data validation, if necessary, based on USEPA Functional Guidelines (USEPA, 2008).

4.2 Data Evaluation

Performance and Confirmational laboratory data will be subjected to data review and evaluation, as described above, and the complete monitoring event data set compiled and evaluated with respect to existing monitoring data for field parameters, groundwater elevations, and laboratory analytical results.

Monitoring reports will evaluate collected data for indication that MNA is progressing, and if anomalies are encountered, these will be summarized and recommendations for contingencies provided.

5. REFERENCES

Geosyntec, 2012. *Remedial Investigation/Feasibility Study (RI/FS) Report, Frederickson Industrial Park, Frederickson, Washington*. March 2012

USEPA, 2008. *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*, EPA 540/R-08-01.

TABLES

Table 2-1
Compliance Monitoring Well Network with Water Level Data
Frederickson Industrial Park, Frederickson, Washington

Well	Ground Elevation (ft MSL)	Top of Casing Elevation (MSL)	Top of Screen (MSL)	Bottom of Screen (MSL)	Aquifer	Sample Date	Depth to Water (ft)	Water Level (MSL)
11-BL	395.5	396.08	331.5	321.5	Lower - Aquifer A	02/10/11	37.37	358.71
11-CL	403.69	404.55	329.7	319.7	Lower - Aquifer A	02/10/11	42.50	362.05
11-CU	403.69	404.67	363.7	353.7	Upper - Aquifer A	02/10/11	32.37	372.30
BMW-13R	416.48	416.48	381	351	Upper - Aquifer A	02/11/11	38.23	378.25
BMW-18	409.74	412.09	375.7	345.7	Upper - Aquifer A	02/11/11	40.94	371.15
BMW-19	413.12	415.66	373.6	343.6	Upper - Aquifer A	02/11/11	42.79	372.87
BMW-2	406.88	408.98	381.9	351.9	Upper - Aquifer A	02/11/11	33.81	375.17
BMW-22	409.53	412.13	376	346	Upper - Aquifer A	02/11/11	38.50	373.63
BMW-3	414.74	416.76	381.7	351.7	Upper - Aquifer A	02/11/11	40.53	376.23
HLA-1	403.86	405.81	320.9	310.9	Lower - Aquifer A	02/10/11	43.85	361.96
MW-1	413.27	415.79	324.8	314.8	Lower - Aquifer A	02/10/11	40.81	374.98
MW-2	402.77	405.18	255.8	245.8	Aquifer C	02/10/11	33.91	371.27
MW-3	389.2	391.41	299.2	289.2	Aquifer A	02/10/11	36.20	355.21
MW-4	465.5	467.72	317.9	307.9	Aquifer A	02/10/11	116.02	351.70
MW-7	350.7	350.12	310.2	300.2	Upper - Aquifer A	02/11/11	25.33	324.79
P1-D	334.6	336.87	235	225	Aquifer C	02/10/11	9.12	327.75
P1-I	335.67	337.44	272.7	267.7	Lower - Aquifer A	02/10/11	9.55	327.89
P1-S	335.01	337.84	320	310	Upper - Aquifer A	02/10/11	10.93	326.91
P2-D	340.23	342.78	231.2	221.2	Aquifer C	02/11/11	14.55	328.23
P2-I	340.65	343.23	270.7	265.7	Lower - Aquifer A	02/11/11	13.85	329.38
P2-S	340.55	343.6	320.6	310.6	Upper - Aquifer A	02/11/11	15.66	327.94
MW-13	394.5	394.1	284.5	274.05	Aquifer A	02/10/11	52.60	341.90

Table 2-2
Historical Carbon Tetrachloride Groundwater Data
Frederickson Industrial Park, Frederickson, Washington

Wells	11-BL	11-CU	11-CL	HLA-1	BMW-2	BMW-3	BMW-13R	BMW-18	BMW-19	BMW-22	MW1	MW2	MW3	MW4	MW6	MW7	P1S	P1I	P1D	P2S	P2I	P2D	MW-13
Ground Elevation (MSL)	395.5	403.69	403.69	403.86	406.88	414.74	416.48	409.74	413.12	409.53	413.27	402.77	389.2	465.5	353.58	350.7	335.01	335.67	334.6	340.55	340.65	340.23	394.5
Top of Screen (MSL)	331.5	329.7	363.7	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	319.7	353.7	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																							
Jun-85	ND(1.0)	ND(1.0)	15.7																				
Jul-85	ND(1.0)	ND(1.0)	51.3																				
Aug-85			25.0																				
Dec-85	0.3		9.7																				
Jan-86	15.7		19.8																				
Feb-86	28.7		53.1																				
Apr-86	1.7		6.9																				
Jun-86	0.5		10.4																				
Jul-90	ND(1.0)	ND(1.0)	11.0																				
Aug-90																							
Nov-90	1.1	ND(1.0)	16.0																				
Sep-88								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

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

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

FIGURES

Legend

Property Boundary

Source:
Bing Aerial Photography, October 2006

Property Location

Fredericksen Industrial Park
Frederickson, WA

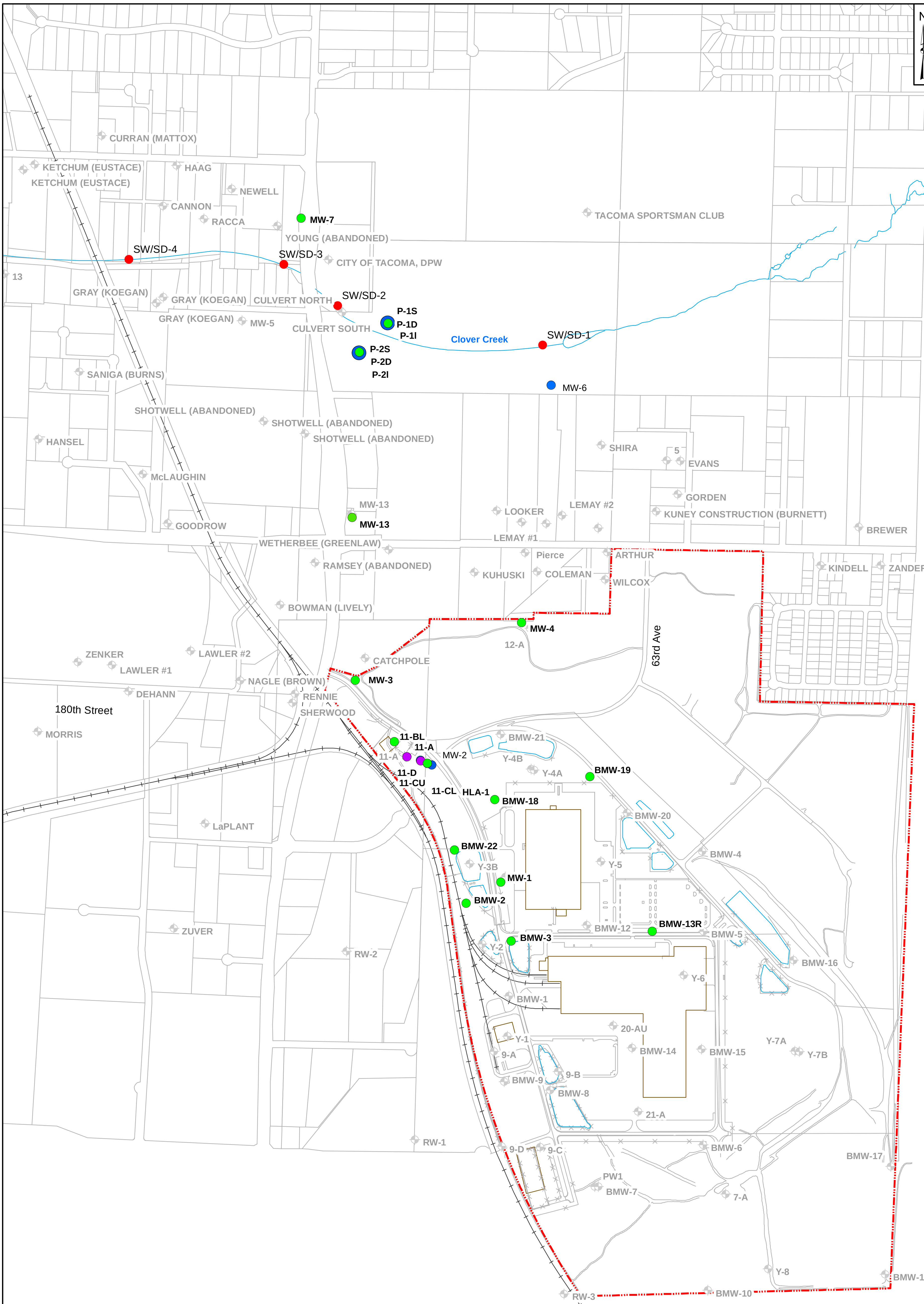
Geosyntec consultants

Kennesaw, GA

06-Sep-2013

Figure
1-1

N:\Frederickson\GIS\CMWP\MXD\Figure 1-1 Property Location.mxd; NHirons; 9/6/2013



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\CMWP\MXD\Figure 2-1.mxd NHirons; 9/6/2013

1,000 500 0 1,000 Feet

Site Plan

Fredericksen Industrial Park
Frederickson, WA

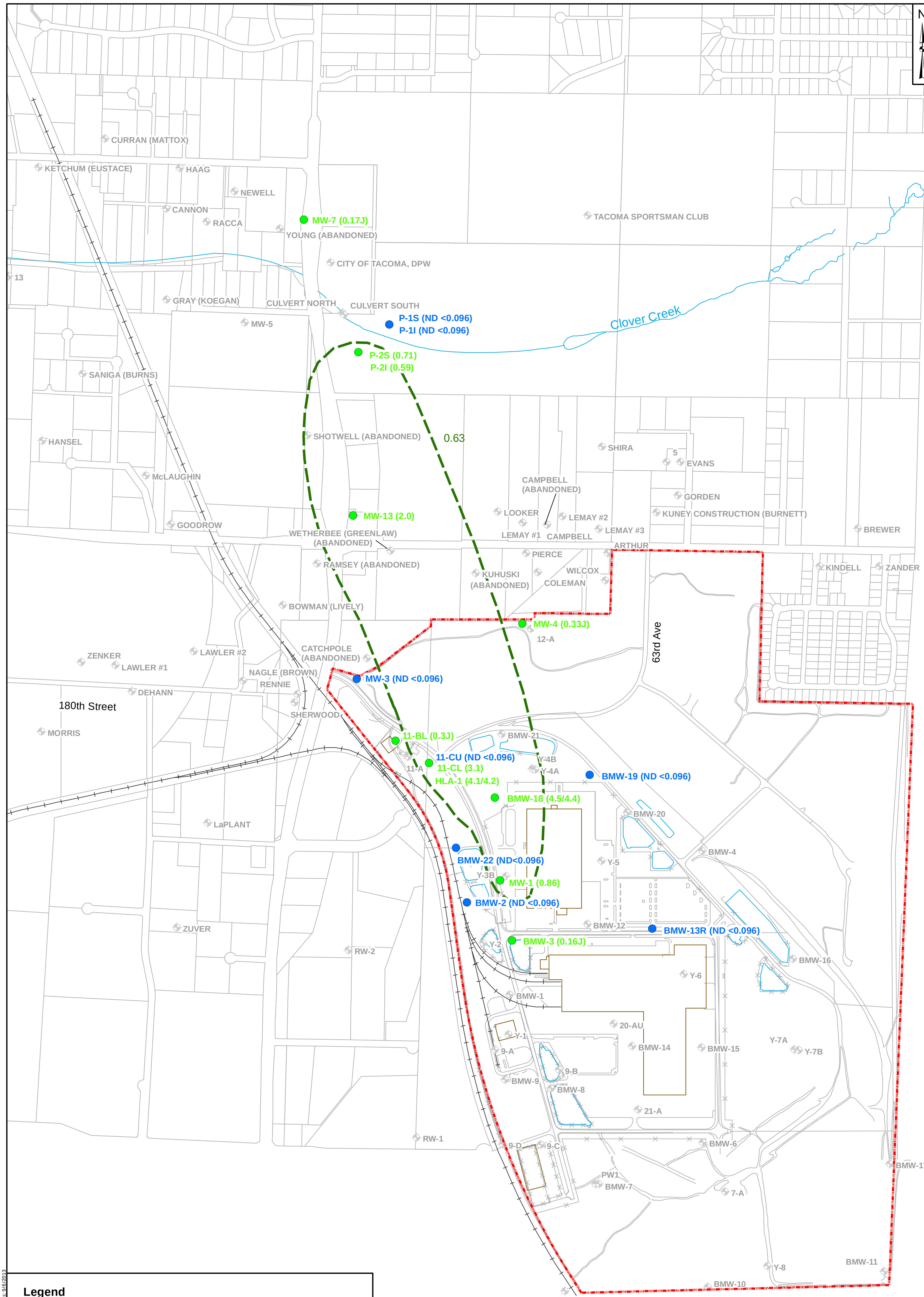
Geosyntec consultants

Kennesaw, GA

06-Sep-2013

Figure

2-1



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 Well Network

Fredericksbon Industrial Park
Fredericksbon, WA

Geosyntec consultants

Figure **2-2**

Kennesaw, GA | 06-Sep-2013

N:\Fredericskon\GIS\CMWP\MXD\Figure 2-2 CTC Compliance Monitoring.mxd; NHirons; 9/6/2013

APPENDIX A

Sampling Analysis Plan

APPENDIX A SAMPLING AND ANALYSIS PLAN
for the
COMPLIANCE MONITORING WORK PLAN
FREDERICKSON INDUSTRIAL PARK
PIERCE COUNTY, WASHINGTON

1.0 Introduction

This Sampling and Analysis Plan (SAP) to the Fredrickson Industrial Park Compliance Monitoring Work Plan (CMWP) was prepared by Geosyntec Consultants (Geosyntec) at the request of Olin Corporation and Mallinckrodt US, LLC (the Companies). This SAP describes procedures and protocols to be adhered to during groundwater compliance monitoring. The groundwater compliance monitoring includes Performance Monitoring of up to ten existing monitoring wells. Upon successful completion of the Performance Monitoring, Confirmational Monitoring will occur in a subset of five of the ten monitoring wells. Carbon tetrachloride (CTC) is the analytical constituent of concern.

Procedures and protocols outlined in this SAP will be performed in conjunction with those presented in the Quality Assurance Project Plan (QAPP), in particular discussion of parameters to be analyzed, detection and quantitation limits, analytical techniques and procedures, and quality assurance and quality control procedures. Discussion of project schedule, organization and responsibilities are discussed in the CMWP and QAPP.

Groundwater monitoring includes the following activities:

- Hydraulic monitoring (water level measurements) in monitoring wells designated as part of the compliance monitoring network; and
- Groundwater sampling of wells in monitoring network.

Sampling procedures and protocols for the above referenced sampling activities are presented in the following sections. The purposes of the specific details of the groundwater monitoring are presented in the CMWP.

2.0 General Sampling Protocols

The following general sampling protocols will be employed during sampling throughout this program:

1) Sampling instruments and equipment will be cleaned in accordance with the protocol presented in Section 6.0 prior to sampling at each monitoring well location.

2) Where applicable and practical, the field activities will proceed from "clean" monitoring wells (i.e. low CTC concentration wells upgradient and downgradient) to relatively "impacted" monitoring wells.
3) A new pair of disposable gloves will be used at each monitoring well location. Additional glove changes will be undertaken as conditions warrant.
4) Sampling generated waste such as gloves, paper towels, etc., will be collected and contained for proper disposal.
5) Samples collected for off-Site chemical analysis will be iced to 4°C in laboratory supplied coolers after collection and labeling. The sample bottles will be surrounded by bags of ice to ensure proper temperature is achieved and maintained during transport. The temperature blank in each cooler will be treated the same way. Any remaining space in the coolers will be filled with packing to cushion the containers within the shipment coolers. The cooler will then be sealed with packing tape.
6) Samples will remain under control of the Companies' Site Representative until relinquished to the laboratory or commercial courier under a chain-of-custody (see QAPP, Attachment A).

Additional protocols specific to the sampling methods are presented in the following sections.

3.0 Hydraulic Monitoring

Hydraulic monitoring in the monitoring wells will be conducted with an electronic battery-operated water level indicator. The equipment used during the hydraulic monitoring activities will be cleaned between monitoring well locations in accordance with protocols outlined in Section 6.0. The hydraulic monitoring activities will be performed in accordance with the CMWP and QAPP, and will be conducted according to the following protocol:

- The water level in monitoring wells will be measured with respect to the reference point (top of north side of inner riser pipe) to the nearest 0.01 ft using an electronic battery-operated water level indicator.
- Water level monitoring will occur during low-flow purging for analytical sampling and measured at 3-5 minute intervals, as with other field parameters.
- Final water level measurement will occur after the analytical sample has been collected and labeled.
- Sounding of the bottom of the monitoring well will occur as the last item in order to avoid stirring up of sediment in the well prior to collecting the analytical sample.

Hydraulic monitoring data will be recorded on a standard field sheet and field notebook.

4.0 Monitoring Well Sampling

4.1 General

Each monitoring well will be sampled using the following low flow protocol (LFP). Equipment used during the groundwater sampling/purging activities will be cleaned between monitoring well locations in accordance with the protocols outlined in Section 6.0. The groundwater purging/sampling activities will be conducted in accordance with the Health and Safety Plan dated October 1, 2010.

4.2 Well Purging

1. The groundwater level in the monitoring well will be measured to the nearest 0.01 foot using a pre-cleaned electric water level tape.

2. Purging will be conducted using the existing submersible pumps. At locations where a pump has not already been dedicated to the well, a pre-cleaned submersible pump will be rented.

3. The pumps will be positioned and secured such that the pump intake corresponds to the mid-point of the well screen, or a minimum of 2 feet above the well bottom or sediment level if present. The required nylon rope will be pre-measured before lowering the pump into the monitoring well to ensure accurate positioning of the pump intake.

4. Static groundwater level conditions in the monitoring well will be allowed to re-establish after lowering the pump into position. The groundwater level in the monitoring well will be measured (to nearest 0.01 foot) with the pump in place prior to beginning purging.

5. Purging of the monitoring well will be conducted using a pumping rate between 100 to 500 milliliters per minute (mL/min). Initial purging will begin using a pumping rate within the lower end of this range. The groundwater level will be measured while purging to ensure that less than 0.3 feet of drawdown occurs. The pumping rate may be gradually increased depending upon the amount of drawdown and the behavior of the stabilization parameters (see Item 6 below). Any pumping rate adjustments will generally be made within 15 minutes from the start of purging. While purging, the pumping rate and groundwater level will be measured and recorded every 10 minutes (or as appropriate). If it is apparent that stabilization of the purged groundwater (see item 6 below) will not be achieved rapidly, these measurements may be made at longer time intervals to allow field staff to perform other sampling activities.

6. The field parameters (temperature, pH, conductivity, dissolved oxygen (DO), and turbidity) will be monitored while purging to evaluate the stabilization of the

purged groundwater. As stabilization approaches, the field parameters will be measured and recorded every 5 minutes (or as appropriate). Stabilization will be considered to be achieved when 3 consecutive readings for each parameter, taken at 5 minute intervals, are within the following limits:

- pH ± 0.1 pH units;
- Dissolved Oxygen ± 10 percent of reading or 0.2 mg/L (optional);
- Temperature ± 5 percent of range;
- Conductivity ± 5 percent of range;
- Oxidation/Reduction Potential (ORP) ± 10 mV (optional);
- Turbidity ± the greater of 10 percent of range or 1 NTU; and
- Water level drawdown ± <0.1 meter (~0.33 feet).

The field parameters will be measured using a flow-through-cell apparatus. At the start of purging, the purge water will be visually inspected for water clarity prior to connecting the flow-through-cell. If the purge water appears turbid, purging will be continued until the purge water becomes visually less turbid before connecting the flow-through-cell.

In the event that the groundwater recharge to the monitoring well is insufficient to conduct LFP protocol, purging will be discontinued before the water level in the monitoring well drops below the top of the pump. Samples will be collected as soon as the volume of groundwater in the well has recovered sufficiently to allow sample collection. Wells in which recovery is insufficient to conduct the LFP protocol will not be subject to the above purging stabilization criteria.

7. Wells will be sampled within the same day as purging.

8. Water extraction equipment will be cleaned in accordance with the protocols presented in Section 6.0.

9. Purge water will be containerized, and placed in a designated storage area for proper disposal following the return of sample results from the laboratory. Of note, the purge water from monitoring wells did not exceed their applicable federal or state Maximum Contaminant Levels (MCLs) for CTC during the most recent groundwater sampling event (February 2011).

4.4 Well Sampling

Following well purging, monitoring well sampling will be carried out according to the following protocol.

1. The monitoring wells will be sampled in the order of lowest concentrations to highest concentrations.

2. Monitoring wells will be sampled, using the existing equipment in each well. These pumps will be operated in a continuous manner to that they do not produce pulsating samples that are aerated in the return tube or upon discharge. The sampling flow rate will not exceed the flow rate used during the purging activities. Prior to use in the initial and subsequent monitoring wells, where pumps have not been dedicated to the well, well sampling equipment will be cleaned as specified in Section 6.0.

3. The flow-through-cell will be disconnected prior to sample collection. The sample bottle will be filled by positioning the discharge line at the base of the sample bottle and the sample bottle will be filled with a meniscus of water above the rim of the bottle before sealing. After sealing the bottles will be turned upside down and inspected for bubbles.

4. Sufficient groundwater will be collected for chemical analysis. Groundwater samples will be collected in containers as specified in the QAPP. Sample containers will be shipped to the Site in sealed coolers.

5. Field measurements of pH, conductivity, temperature, dissolved oxygen, and turbidity will be taken during well development and purging. Calibration of field instruments will be undertaken as described in the QAPP.

6. Field duplicate, field rinsate, trip blanks and MS/MSD samples will be collected concurrently with field samples at the frequency specified in the QAPP.

7. Field rinsate blanks will be collected by pouring demonstrated analyte-free water over the pump saving the water into the appropriate sample bottle.

5.0 Sample Containers Preservation Packaging and Shipping

Required sample containers, sample preservation methods and maximum sample holding times are summarized in Table 5-1 of the QAPP.

6.0 Equipment Cleaning Protocols

6.1 Groundwater Sampling Equipment

Sampling apparatus will be properly decontaminated prior to its use in the field to prevent cross-contamination. Also to avoid cross-contamination, disposable gloves will be worn by the sampling team and changed between sampling points.

6.2 Decontamination Procedures

The required decontamination procedure for groundwater equipment is:

- Wash and scrub with low phosphate detergent;

- Deionized water rinse;
- Rinse with methanol; and
- Rinse thoroughly with deionized demonstrated analyte-free water (use at least five times the volume of solvent used in previous step).

Tubing, piping, and bailer cord or pump cord, evacuation equipment such as submersible pumps, and other equipment which are put into the borehole will be rinsed with soapy water and deionized water before use. Tubing will be Teflon. Tubing will be dedicated to individual wells (i.e., tubing will not be reused). Probes, such as for pH and conductivity measurements will be rinsed with deionized water before use.

Cleaned equipment will be placed on clean plastic sheeting or aluminum foil in order to avoid contacting contaminated surfaces before use.

The groundwater purging/sampling activities will be conducted in accordance with the Updated Health & Safety Plan.

APPENDIX B

Quality Assurance Project Plan

APPENDIX B QUALITY ASSURANCE PROJECT PLAN
for the
COMPLIANCE MONITORING WORK PLAN
FREDERICKSON INDUSTRIAL PARK
PIERCE COUNTY, WASHINGTON

1.0 Introduction

This Quality Assurance Project Plan (QAPP) was prepared by Geosyntec Consultants (Geosyntec) at the request of Olin Corporation and Mallinckrodt US, LLC. (the Companies). This QAPP covers groundwater monitoring as described in the Compliance Monitoring Work Plan (CMWP).

The objective of this QAPP is to describe the procedures which will be used during compliance monitoring to ensure that the Carbon Tetrachloride (CTC) data generated will be of a known and acceptable level of precision and accuracy. This QAPP is consistent with the requirements of the Model Toxics Control Act (MTCA) and the Agreed Order between Ecology and the Companies.

This QAPP provides information regarding the project personnel responsibilities, and sets forth specific procedures to be used during the sampling and analysis of groundwater.

The following quality assurance (QA) topics are addressed in this plan:

- Data quality objectives (DQOs) for measurement of data, including precision, accuracy, completeness, representativeness, and comparability;
- Project organization and responsibility;
- Sampling procedures;
- Sample custody;
- Analytical procedures;
- Calibration procedures, references and frequency;
- Internal quality control (QC) checks and frequency;
- QA performance audits, system audits, and frequency;
- QA reports to management;
- Preventative maintenance procedures and scheduling;
- Specific procedures routinely used to assess data precision, representativeness, comparability, accuracy, and completeness;
- Data validation;
- Corrective action.

2.0 Project Description

This QAPP provides QA/QC criteria for the work efforts associated with groundwater samples collected and analyzed as part of the CMWP which is being submitted concurrently with the Cleanup Action Plan (CAP). Compliance monitoring is being performed to monitor the progress of the monitored natural attenuation (MNA) cleanup action and to confirm groundwater has met the cleanup levels for CTC established in the CAP.

3.0 Project Organization and Responsibility

3.1 Project Organization

The Companies have selected Geosyntec to implement the CAP and associated CMWP. ALS Environmental Laboratory of Kelso, Washington will perform the analyses for samples collected during compliance monitoring. However, the companies and personnel currently selected to implement the CMWP and analyze the samples may change in the future. If this occurs, the Companies will notify Ecology and append the Companies' representative list below. Currently, key project personnel under the direction of the Companies include the following:

- Project Manager – Evan Cox (Geosyntec)
- Project Coordinator – James Deitsch (Geosyntec)
- Quality Assurance/Quality Control Manager – Dave Parkinson (Geosyntec)
- Field Quality Assurance Manager – Christa Tyrell (Geosyntec)
- Laboratory Project Manager – Greg Salata (ALS)
- Laboratory Operations Manager – Jeff Christian (ALS)
- Laboratory QA Officer – Julie Gish (ALS)
- Sample Custodian – Lynda Huckerstein (ALS)

The responsibilities for the project titles are:

Project Manager

- General overview of project to ensure that the objectives are met; and
- Participation in key negotiations.

Project Coordinator

- Overview of field activities;
- Overview of laboratory activities;
- Data assessment;
- Preparation and review of reports; and
- Technical representation of project activities;

Quality Assurance/Quality Control Manager

- Laboratory systems audit;
- Overview and review of field QA/QC;
- Coordinate supply of performance evaluation samples;
- Review laboratory QA/QC;
- Data validation and assessment;
- Advise on data corrective action procedures;
- Preparation and review of QA reports; and
- QA/QC representation of project activities;

Field Quality Assurance Manager

- Management of field activities and field QA/QC;
- Data assessment;
- Technical representation of field activities;
- Preparation of SOPs for field activities; and
- Preparation of reports.

Laboratory Project Manager

- Coordinate laboratory analyses;
- Supervise in-house chain-of-custody;
- Schedule sample analyses;
- Oversee data review;
- Oversee preparation of analytical reports; and
- Approve final analytical reports prior to submission to the Companies.

Laboratory Operations Manager

- Ensures the necessary resources of the laboratory are available on an as-required basis; and
- Overview of final analytical reports.

Laboratory Quality Assurance Officer

- Overview of laboratory quality assurance;
- Overview QA/QC documentation;
- Conduct detailed data review;
- Decide laboratory corrective actions, if required;
- Technical representation of laboratory QA procedures; and
- Oversee preparation of laboratory SOPs.

Sample Custodian

- Receive and inspect the incoming sample containers;
- Record the condition of the incoming sample containers;
- Sign appropriate documents
- Verify chain-of-custody documents and their correctness;
- Notify laboratory manager and laboratory supervisor of sample receipt and inspection;

- Assign unique identification number and customer number and enter each into the sample receiving log;
- With the help of the operations manager, initiate transfer of the samples to appropriate lab sections; and
- Control monitor access/storage of sample and extracts.

4.0 Quality Assurance Objectives for Measurement Data

The overall QA objective is to develop and implement procedures for field sampling, sample preparation and handling, sample chain-of-custody, and laboratory analyses and reporting which will provide accurate and precise data.

The purpose of this section is to define the precision, accuracy, representativeness, comparability, and completeness goals for the project. In addition, QA objectives for field measurements are defined.

4.1 Level of QA Effort

4.1.1 Field QC Sampling

To assess the quality of data resulting from the field sampling program, field duplicate samples, rinse blank samples, trip blanks and samples for matrix spike analyses will be collected (where appropriate) and submitted to the analytical laboratory. A summary of the field QC sampling and analysis requirements for CTC is provided in Table 4-1.

Rinse and trip blanks will be analyzed to check for procedural contamination emanating from sampling device cleaning procedures, ambient conditions at the Site, and contamination from sample shipment or storage. Field duplicate samples will be analyzed to assess the aggregate sampling and analytical reproducibility. MS/MSD and samples will be analyzed to evaluate analytical accuracy and precision relative to the sample matrix. Trip blank samples will be shipped by the laboratory to the Site and back to the laboratory without being opened in the field. Trip blank analyses will provide a measure of potential cross-contamination of samples during shipment, storage, handling, and ambient conditions at the Site.

4.1.2 Laboratory QC Sampling

4.1.2.1 Accuracy, Precision and Sensitivity of Analysis

The fundamental QA objective with respect to the accuracy, precision, and sensitivity of analytical data is to achieve the QC acceptance criteria of the analytical method. The purpose of the analytical work performed during the investigation is to generate data for use in monitoring Site wide groundwater contamination by CTC, and the evaluation of when cleanup standards have been met.

The targeted quantitation limit for this investigation of CTC is 0.5 µg/L.

The method accuracy will be determined by spiking selected samples (matrix spikes) with selected compounds of interest. Accuracy will be reported as the percent recovery of the spiking compound(s) and will be compared to the laboratory's control limits.

The method precision (reproducibility between duplicate analyses) will be determined from the duplicate analysis of matrix spike samples for groundwater samples and by the use of laboratory duplicates. A minimum of one MS/MSD sample and one laboratory duplicate sample set per sampling event for less than twenty samples, and per twenty samples for greater than twenty samples will be analyzed. Precision will be evaluated based on laboratory control limits for relative percent differences (RPDs) calculated from the MS and MSD and/or duplicate sample results.

Overall sampling and analytical precision will be evaluated using the data from field duplicate samples.

4.1.2.2 Completeness, Representativeness and Comparability

It is expected that the analyses conducted in accordance with the analytical methods for CTC will provide data meeting QC acceptance criteria for 85 percent of the samples tested. Any reasons for variances will be investigated by the laboratory and documented.

The analytical method used for the groundwater analyses is an updated version of the method used for previous studies to assure comparability of the data. Standard reference materials used by the laboratory will be traceable to National Institute of Standards and Technology (NIST) sources, if available.

4.2 Field Measurements

Measurement data will be generated in field activities. These include, but are not limited to, the following:

- Documenting time and weather conditions;
- Determining pH, dissolved oxygen, specific conductivity, oxidation/reduction potential, turbidity, and temperature of water samples;
- Determining sampling flow rate from groundwater wells;
- Observation of sample appearance and other conditions; and
- Measuring groundwater elevations in wells.

The general QA objective for measurement data is to obtain reproducible and comparable measurements to a degree of accuracy consistent with the use of standardized procedures.

Purge water will be discharged through a flow cell for field parameter measurements. Discharge will be into a 5-gallon bucket, and flow rate measured using a graduated container of sufficient size. Field measurements will be collected at 3-5 minute intervals until parameters have stabilized for three consecutive measurements. Stabilization criteria are:

- pH ± 0.1 pH units;
- Dissolved Oxygen ± 10 percent of reading or 0.2 mg/L (optional);
- Temperature ± 5 percent of range;
- Conductivity ± 5 percent of range;
- Oxidation/Reduction Potential (ORP) ± 10 mV (optional);
- Turbidity ± the greater of 10 percent of range or 1 NTU; and
- Water level drawdown ± <0.1 meter (~0.33 feet).

Purging and measurement of the above parameters will continue until stabilization is obtained.

5.0 Sampling Procedures

The sample container, preservative, shipping and packaging requirements for CTC are identified in Table 5-1.

6.0 Sample Custody and Document Control

The following documentation procedures will be used during sampling and analysis to document the chain-of-custody during transfer of samples from collection through laboratory receipt and log-in. Recordkeeping documentation will include use of the following:

- Field log book (bound with numbered pages);
- Labels to identify individual samples; and
- Chain-of-custody record to document analyses to be performed; and
- Laboratory sample custody log book.

6.1 Field Log Book

In the field, the sampler will record the following information in the field log book for each sample collected:

- Project number;
- Sample matrix;
- Name of sampler;
- Sample source;

- Time and date;
- Pertinent data (i.e. depth to water, pumping method);
- Analysis to be conducted;
- Sampling method (i.e. pump type);
- Appearance of each sample;
- Preservatives added;
- Number of sample bottles collected;
- Analyses performed in the field (temperature, pH, specific conductivity, etc.); and
- Pertinent weather data.

Each field log book page will be signed by the sampler. A unique sample numbering system will be used to identify each collected sample. This system will provide a tracking number to allow retrieval and cross-referencing of sample information. The sample numbering system to be used is as follows:

Example GW-110512-AA-123
where: GW = Designates sample type (GW – Groundwater)
110512 = Date of collection (mmddyy)
AA = Sampler initials
123 = Unique sample number

Field duplicates and field blank samples will also be numbered with a unique sample number and submitted to the laboratory blind (i.e. without designation as duplicate or blank). Samples designated for MS/MSD analysis will be identified on the chain-of-custody.

6.2 Chain-Of-Custody Records

Chain-of-custody forms will be completed for each sample collected to document the transfer of sample containers. Custody seals will be placed over the lids of each cooler. Samples will be shipped with bagged ice and delivered to the analytical laboratory by a commercial courier or will be hand delivered. Samples requiring refrigeration will be maintained at 4°C (±2°C) by the laboratory.

The chain-of-custody record, completed at the time of sampling, will contain, but not be limited to, the sample number, date, and time of sampling, and the name of the sampler. The chain-of-custody document will be signed by the sampler noting the date and time when the samples are transferred.

Each sample container being shipped to the laboratory will contain a chain-of-custody form. The chain-of-custody form consists of four copies that are distributed to the sampler, to the shipper, to the laboratory, and to the office file. The sampler and shipper will maintain their copies while the other two copies are enclosed in a waterproof enclosure within the shipping container. The laboratory, upon receiving the samples, will complete the remaining copies. The laboratory will maintain one copy for its records. The executed original will be returned with the data deliverables package.

6.3 Sample Documentation in the Laboratory

Each sample or group of samples shipped to the laboratory for analysis will be given a unique identification number. The laboratory Sample Custodian will record the client name, number of samples and date of sample receipt in the sample receiving log. Samples removed from storage for analysis will be recorded by the laboratory using internal chain-of-custody.

The laboratory will be responsible for maintaining analytical log books and laboratory data for submittal to the Companies on an “as required” basis. Raw laboratory data produced from the analysis of samples submitted for this program will be inventoried and maintained by the laboratory for a period of five years at which time the Companies will advise the laboratory regarding the need for additional storage.

6.4 Storage of Samples

After the Sample Custodian has completed the chain-of-custody forms and the incoming sample receiving log, samples will be stored in the appropriate locations. Samples will be stored within an access-controlled custody room or refrigerator. Samples will be maintained at 4°C (±2°C) until analytical work is complete.

6.5 Final Evidence Files

Evidentiary files for the entire project will be maintained and will consist of the following:

- Project related plans;
- Project log books;
- Field data records;
- Sample identification documents;
- Chain-of-custody documents;
- Report notes, calculations, etc.;
- References, copies of pertinent literature;
- Miscellaneous – photos, maps, drawings, etc.; and
- Copies of final reports pertaining to the project.

The evidentiary file materials shall be the responsibility of the project manager with respect to maintenance and document removal.

6.6 Document Control System

A document control system ensures that documents are accounted for when the project is complete. The project number assigned to this project is GR4631. This number will appear on sample labels, log books, data sheets, project memos, analytical reports, document control logs, corrective action forms and logs, QA plans, and other project-related records.

7.0 Calibration Procedures and Frequency

7.1 Instrument Calibration and Tuning

Calibration of instrumentation is required to ensure that the analytical system is operation correctly and functioning at the proper sensitivity to meet established reporting limits. Each instrument is calibrated with certified standard solutions and the linear range established for the analytical method. The frequency of calibration and the concentration of calibration standards are determined by the analytical method in Section 8.0.

7.1.1 Instrument Tuning Verification

It is necessary to establish that a given gas chromatograph/mass spectrometer (GC/MS) meets the standard mass spectral abundance criteria prior to initiating calibration or sample analysis. This is accomplished through the analyses of tuning compounds as specified in the analytical methods.

7.1.2 GC/MS Calibration

The initial calibration should be verified according to method protocol once every 12 hours prior to sample analysis as detailed in the method. . Calibration will be performed using procedures specified in the method.

8.0 Analytical Procedures

Samples collected for laboratory analysis will be analyzed for CTC using EPA Method 8260C (Table 4-1).

9.0 Data Reduction, Validation, Assessment, and Reporting

9.1 General

The laboratory will perform analytical data reduction and validation in-house under the direction of the laboratory QA Officer. The laboratory's QA Officer and/or area supervisor will be responsible for assessing data quality and advising of any data which were rated preliminary or unacceptable or other qualifications based on the QC criteria outlined in the relevant methods, which would caution the data user of possible unreliability. Data reduction, validation, and reporting by the laboratory typically will be conducted as detailed below:

- Raw data produced and checked by the responsible analysts will be turned over for independent review by another analyst;
- The area supervisor will review the data for attainment of the QC criteria presented in the referenced analytical methods and determine whether any sample reanalysis is required;
- Upon completion of required reviews and acceptance of the raw data, a report will be generated and sent to the laboratory QA Officer or Laboratory Project Manager;
- The Laboratory QA Officer or Laboratory Project Manager will complete a thorough inspection of the required reports; and
- Upon acceptance of the preliminary reports, final reports will be generated and signed by the Laboratory Project Manager.

The QA/QC Manager will conduct an evaluation of data reduction and reporting by the laboratory. These evaluations will consider the sample data, rinsate blank data, procedural and method blanks, field duplicate data, and the data from surrogate and matrix spikes. The final data will be checked for legibility, completeness, correctness, and the presence of requisite dates, initials, and signatures. The results of these checks will be assessed and reported to the Project Manager noting any discrepancies and their effect upon the usability of the data.

Validation of the analytical data will be performed by the QA/QC Manager. The data validation will be performed in accordance with the analytical method and the relevant review criteria in the guidance document “USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review” 2008, EPA 540/R-08-01.

Data assessment will include checks on data consistency through comparability of duplicate analyses, comparability to previous data from the same sampling location, adherence to accuracy and precision control criteria detailed in this QAPP, and anomalously high or low parameter values. The results of these data validations will be reported to the Project Manager, noting any discrepancies and their effect upon usability of the data.

9.2 Laboratory Data Deliverables and Final Report

Reporting and deliverables will include the following:

- A case narrative that includes a summary of analytical methods used and a description of any unusual action or conditions;
- Dates of sample receipt, preparation, and analysis;

- Laboratory and field sample identification numbers;
- Sample results in tabular format;
- Method blank sample data summaries;
- Surrogate compound percent recovery data and control limits;
- MS/MSD and percent recovery and RPD data and control limits; and
- Executed chain-of-custody forms.

Raw data and the corresponding QA/QC data will be maintained by the laboratory and will be accessible to the Companies in hard copy or electronic format as necessary.

The laboratory will submit a hard copy and electronic version of the final analytical report within 21 calendar days of their receipt of the samples from each sampling event, unless a more rapid turnaround time is requested.

10.0 Internal Quality Control Checks and Frequency

10.1 Field QC

Quality control procedures for field measurements will be limited to checking the reproducibility of the measurement in the field by obtaining multiple readings and by calibrating the instruments (where appropriate).

Quality control of the field sampling procedures will include collecting field duplicates, trip blanks, and rinsate blanks (where appropriate) in accordance with the applicable procedures and at the frequencies identified in Section 4.0.

10.2 Laboratory QC

Specific procedures related to internal laboratory QC samples are described in the following subsections.

10.2.1 Method Blanks

A method blank will be analyzed by the laboratory at a frequency of one blank per analytical batch of 20 or fewer samples. The method blank, an aliquot of analyte-free water will be carried through the entire analytical procedure.

10.2.2 MS/MSD Analyses

An MS/MSD sample will be analyzed at a minimum frequency of one per twenty groundwater samples, or a minimum of one per sampling event. A representative subset of the analytes of interest will be used as spiking compounds for VOC MS/MSD analyses. Percent spike recoveries will be used to evaluate analytical accuracy while RPD values will be used to assess analytical precision. Control limits will be established by the laboratory.

10.2.3 Surrogate Analyses

Surrogates are organic compounds which are similar to the analytes of interest, but which are not normally found in environmental samples. Surrogates are added to samples for VOC analysis to monitor the effect of the matrix on the accuracy of the analysis. Every blank, standard, and environmental sample will be spiked with surrogate compounds prior to sample analysis. The compounds that will be used as surrogates and the concentration levels recommended for spiking are identified in the analytical method. Percent recoveries of the surrogates will be reported for each Site sample and QC sample analyzed.

10.2.4 Laboratory Control Samples (LCS/LCSD)

QC checks samples (also known as laboratory control samples or laboratory performance solution) will be analyzed with every batch of 20 or fewer groundwater samples. QC check samples are prepared from standard reference materials that are from a different source than the standards used for calibration. As such, QC check sample data provide a check on the accuracy of the analyses, and with the duplicates, provide a measure of the precision.

11.0 Performance and System Audits

The laboratory routinely performs internal systems and performance audits under the guidance of the Laboratory QA Officer. The results of these audits are maintained by the Laboratory QA Officer. External systems and performance audits may be performed at the discretion of the State of Washington Department of Ecology for the groundwater and soil sample analyses.

The QA/QC manager may carry out performance and/or systems audits to ensure that the data of known and defensible quality are consistently produced during this program.

Systems audits are qualitative evaluations of the field and laboratory quality control measurement systems. They determine whether the measurement systems are being used appropriately. The audits may be carried out before systems are operational, during the program, or after completion of the program. Such audits typically involve a comparison of the activities specified in this QAPP with activities actually scheduled or performed.

Performance audits are quantitative evaluations of the measurement systems used for a monitoring program. It requires testing the measurement systems with samples of known composition or behavior to quantitatively evaluate precision and accuracy. A performance audit may be carried out by or under the auspices of the QA/QC manager without the knowledge of the laboratory during each sampling event for this program.

The Project Manager may schedule systems audits of the field activities to ensure that the QAPP and Sampling and Analysis Plan are being adhered to and/or that variances are justified and documented. These audits will be scheduled to allow oversight of as many different field activities as possible, and will be performed by the Project Manager or their designee.

12.0 Preventive Maintenance

12.1 Laboratory Preventive Maintenance

This section applies to both field and laboratory equipment. Specific preventive maintenance procedures for field equipment will be consistent with the manufacturers' guidelines. Specific preventive maintenance protocols for laboratory equipment will be consistent with the laboratory's standard operating procedures.

Analytical instruments used in this project will be serviced by laboratory personnel at regularly scheduled intervals in accordance with the manufacturers' recommendations. Instrument failure may result in unscheduled service or repairs. Requisite servicing beyond the abilities of laboratory personnel will be performed by the equipment manufacturer or a qualified service technician.

13.0 Data Precision, Accuracy, and Completeness

13.1 QA Measurement Quality Indicators

13.1.1 Precision

Precision will be assessed by comparing the analytical results between duplicate matrix spike analyses or duplicate sample analyses. Precision as relative percent difference will be calculated as follows:

$$\text{RPD} = \frac{|(D_1 - D_2|)}{(D_1 + D_2/2} \times 100$$

Where:

D_1 = value from first determination

D_2 = value from second determination

13.1.2 Accuracy

Accuracy will be assessed by comparing a set of analytical results to the accepted or "true" values that would be expected. In general, MS/MSD and check sample recoveries will be used to assess accuracy. Accuracy as percent recovery will be calculated as follows:

Percent Recovery = $\frac{A-B}{C} \times 100$

Where:

A = The analyte amount determined experimentally from the spike sample

B = The background amount determined by a separate analysis of the unspiked sample

C = The amount of spike added.

13.1.3 Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared with the amount that was expected to be obtained under normal conditions.

To be considered complete, the data set must contain QC check analyses verifying precision and accuracy for the analytical protocol. In addition, data are reviewed in terms of stated goals in order to determine if the data set is sufficient.

When possible, the percent completeness for each set of samples will be calculated as follows:

Percent Completeness = $\frac{(valid\ data\ obtained)}{(total\ data\ planned)} \times 100$

13.1.4 Outliers

Procedures discussed previously will be followed for documenting deviations. In the event that a result deviates significantly from method established control limits, this deviation will be noted and its effect on the quality of the remaining data assessed and documented.

14.0 Corrective Action

The need for corrective action may be identified by system or performance audits or by the QC procedures within the analytical methods. The essential steps in the corrective action system will be:

- Checking the predetermined limits for data acceptability beyond which corrective action is required;
- Identifying and defining problems;
- Assigning responsibility for investigating the problem;
- Investigating and determining the cause of the problem;

- Determining a corrective action to eliminate the problem (this may include reanalysis or resampling and analysis);
- Assigning and accepting responsibility for implementing the corrective action;
- Implementing the corrective action and evaluating the effectiveness;
- Verifying that the corrective action has eliminated the problem; and
- Documenting the corrective action taken.

For each measurement system, the need for corrective action may be identified by the analyst during sample analysis or by others during data review. The Laboratory Operations Manager, in consultation with the analyst and/or group leader, will initiate and implement the corrective action. The Laboratory QA Officer will document that the corrective action has been effective and the measurement system is functioning properly.

15.0 Quality Assurance Reports

Final reports will contain a discussion on QA/QC summarizing the quality of the data collected and/or used as appropriate for each phase of the project. The Project Coordinator, who has responsibility for these summaries, will rely on written reports/memoranda documenting the data assessment activities, performance and systems audits, and footnotes identifying qualifications of the data if any.

Each summary of sampling activities will include a tabulation of the data including:

- Investigative sample and field duplicate sample results;
- Maps showing well locations; and
- An explanation of any sampling conditions or QA problems and their effect on data quality.

QA reports will be prepared by the QA/QC manager following receipt of the analytical data. These reports will include discussions of QC sample data and their effects on the quality of investigative sample data reported. In addition, the QA reports will summarize any QA problems, and give a general assessment of QC results.

Table 4-1
Sample Container Preservation, Holding Time, Volume and Shipping Requirements
Compliance Monitoring Plan Quality Assurance Project Plan
Frederickson Industrial Park, Pierce County, Washington

Sample Matrix	Analytical Parameters	Analytical Method	Investigative Samples	Field Duplicates	Rinse Blanks	MS/MSD	Trip Blanks
Groundwater	Carbon Tetrachloride	EPA Method 8260C	10	1/10	1/10	1/10	1/Cooler

Table 5-1
Sample Container Preservation, Holding Time, Volume and Shipping Requirements
Compliance Monitoring Plan Quality Assurance Project Plan
Frederickson Industrial Park, Pierce County, Washington

Groundwater Analyses	Sample Containers	Preservation	Investigative Samples	Sample Volume	Shipping
Carbon Tetrachloride	3 40-mL teflon lined septum vials	HCl to pH <2 Cool to 4±2ºC	14 days	Fill completely, no headspace	Overnight Courier or Hand Delivery