Work Plan
Enhanced Biotic and Abiotic Trichloroethene Degradation
Beckwith & Kuffel, Inc. Site
1313 South 96th Street
Seattle, Washington

January 29, 2020

Prepared for

Beckwith & Kuffel
Seattle, Washington

LANDAU ASSOCIATES

130 2nd Avenue South
Edmonds, WA 98020
(425) 778-0907

Work Plan
Enhanced Biotic and Abiotic Trichloroethene Degradation
Beckwith & Kuffel, Inc. Site
1313 South 96th Street
Seattle, Washington

This document was prepared by, or under the direct supervision of, the technical professionals noted below.

Document prepared by: Evelyn Ives Evelyn H. Ives, PE
Primary Author

Document reviewed by: Clint Jacob Clinton L. Jacob, PE
Quality Reviewer

Date: January 29, 2020
Project No.: 1645001.030
File path: P:\1645\001\R\Enhanced Biotic & Abiotic TCE Degradation WP
Project Coordinator: tam

This page intentionally left blank.

TABLE OF CONTENTS

Page

FIGURES

TABLE

APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

µg/L	micrograms per liter
B&K	Beckwith & Kuffel, Inc.
bgs	below ground surface
cDCE	*cis*-1,2-dichloroethene
CULs	cleanup levels
cVOC	chlorinated volatile organic compound
DO	dissolved oxygen
Ecology	Washington State Department of Ecology
ESA	environmental site assessment
FMH	FMH Material Handling Solutions
ft	feet/foot
H_2	hydrogen
HASP	Health and Safety Plan
LAI	Landau Associates, Inc.
lbs	pounds
MCL	maximum contaminant level
MS/MSD	matrix spike/matrix spike duplicate
MTCA	Model Toxics Control Act
psi	pounds per square inch
redox	reduction-oxidation
RI	remedial investigation
SDS	safety data sheet
Site	1313 South 96th Street, Seattle, Washington
SWI	Shannon and Wilson, Inc.
TCE	trichloroethene
TOC	total organic carbon
VC	vinyl chloride
VCP	Voluntary Cleanup Program
WB	Wooldridge Boats
ZVI	zero-valent iron

This page intentionally left blank.

1.0 INTRODUCTION

This document provides a work plan for additional remediation activities to be conducted at the Beckwith & Kuffel, Inc. (B&K) property located at 1313 South 96th Street in Seattle, Washington (Site; Figure 1). Remedial activities address treatment of chlorinated volatile organic compound (cVOC) contamination in Site groundwater. Activities will be performed as part of the Washington State Department of Ecology (Ecology) Voluntary Cleanup Program (VCP). The Site VCP project number is NW3119.

This work plan describes implementation of *in situ* treatment of the area of highest cVOCs concentrations in groundwater. Both biotic (biological) and abiotic (chemical) degradation of cVOCs will be stimulated through direct-push injection of a treatment reagent, EHC® (a proprietary product from Peroxychem). Groundwater monitoring will be used to evaluate the treatment performance. Activities described in this work plan will be conducted in accordance with the procedures set forth in the Site Health and Safety Plan (HASP), as provided in Appendix A.

1.1 Site Background

Prior to purchase of the Site in 2013, B&K contracted with Shannon & Wilson, Inc. (SWI) to complete a Phase I environmental site assessment (ESA) to identify potential environmental liabilities associated with the Site (Shannon & Wilson 2012). Based on research conducted for the Phase I ESA, the Site appears to have consisted of undeveloped land prior to 1977 and then of forklift maintenance companies (Clarklift of Washington and later FMH Material Handling Solutions [FMH]). In 2010, Industrial Materials Handling, which had previously purchased FMH, vacated the Site. The Site was vacant until B&K purchased it in 2013. B&K sells, distributes, and maintains pumps, blowers, and compressors.

Sampling conducted during Phase II ESA activities indicated that cVOCs including trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), and vinyl chloride (VC) were present in groundwater at the southeast end of the Site in the vicinity of an old concrete wash pad with a severely cracked surface (Shannon & Wilson 2014). Based on the sampling results and the Site's prior use, it was assumed that the source of the cVOCs contamination was TCE degreasing solvents used by the former Site occupants to clean forklift parts at the wash pad; cDCE and VC are biodegradation breakdown products of TCE.

1.2 Previous Remedial Activities

In November 2013, SWI conducted an interim remedial action to remove the wash pad and excavate the underlying contaminated soil. The excavation extended to approximately 18 feet (ft) below ground surface (bgs) within the approximate extents shown on Figure 2. The northern half of the excavation was backfilled with pea gravel and the southern half with sand and gravel fill. Approximately 1,100 pounds (lbs) of Regenesis' 3D Microemulsion® electron donor product was added to the excavation during backfilling to stimulate biodegradation of the cVOCs in groundwater at the Site post-excavation (Shannon & Wilson 2014). This quantity of electron donor substrate (less than 150 gallons) was quite limited relative to the size of the excavation and remaining cVOC concentrations.

Groundwater monitoring following the remedial excavation activities indicated a temporary reduction in cVOC concentrations in the immediate vicinity of the remedial excavation, followed by concentration rebound about 9 months after completion. Groundwater monitoring was suspended by SWI after the August 2014 groundwater monitoring event. Interim Action activities and investigation results are provided in the Site's Remedial Investigation (RI) Report (SWI 2014).

Since 2014, additional characterization of cVOCs in groundwater has been conducted both on and adjacent to the B&K property, as described below:

- In the spring of 2016, environmental explorations were conducted at the adjacent property to the east owned by Sea Mar Community Health Centers (Sea Mar). Explorations included installation and sampling of seven new monitoring wells in the vicinity of the cVOC plume (SM-MW-8, SM-MW-14, SM-MW-15, and SM-MW-17 through SM-MW-20), and sampling of four direct-push explorations. The groundwater samples collected during this investigation indicated that cVOCs were present in groundwater at the Sea Mar site within approximately 10 to 20 ft to the east of the property boundary with the B&K Site and up to 40 ft north of the remedial excavation at concentrations greater than the applicable Model Toxics Control Act (MTCA) Method A cleanup levels (CULs).
- Between November 2016 and March 2017, Landau Associates, Inc. (LAI) conducted additional RI activities on the B&K Site, Sea Mar property, and Wooldridge Boats (WB) property (located adjacent to the south of the B&K Site) to further evaluate the lateral and vertical extents of the cVOC groundwater plume. These investigation activities consisted of sampling selected B&K wells not previously sampled for cVOCs, and collecting groundwater samples from 21 direct-push explorations as documented in the supplemental RI report (LAI 2017a).
- Site monitoring wells were periodically sampled, with the most recent sampling occurring in August 2019.

LAI performed a bioremediation injection in 2018 to further enhance biodegradation of cVOCs in the vicinity of the wash pad excavation. Injection fluid 480 gallons (4,400 pounds) of the electron donor substrate LactOil™ was injected on January 25, 2018 to existing monitoring well MW-7, located within the backfilled excavation. The injection was challenging due to short-circuiting of injection fluid into a broken underground storm drain line on the adjacent property; fluid was intercepted at the downstream manhole and discharged to the sanitary sewer. Although infiltration to the storm drain interfered with the desired distribution of electron donor areas, August 2019 data indicate some localized treatment benefits of this injection. Results from 2019, shown with prior results on Figure 3, show significant decreases in TCE concentrations at the injection well, MW-7, and downgradient wells, MW-9 and SM-MW-21. Increases in the concentrations of degradation products, cDCE and VC, at these downgradient wells provided further evidence of biodegradation resulting from the 2018 injection. The 2018 injection was performed in general accordance with the work plan (LAI 2017b) and was documented in a 2019 status report (LAI 2019).

In August 2019, LAI performed tapwater injection testing at WB wells MW-11 and MW-12 to evaluate the feasibility of injecting donor substrates in the area of highest TCE concentrations. During the test, injection rates were low and water “daylighted” at the ground surface near the test injection wells after a relatively small volume was injected. These results confirmed that injections of liquid donor substrate were infeasible due to the high silt and clay content of the contaminated water-bearing zone that would be targeted for treatment, leading to the remedial approached described in this work plan.

1.3 Extent of Contamination

The results of the RIs have characterized the nature and extent of cVOC contamination. TCE and breakdown products cDCE and VC occur in the southeast corner of the B&K Site and extend onto the adjacent Sea Mar and WB properties. Depth-discrete sampling results indicate that the cVOCs contamination in groundwater is generally limited to the uppermost 20 ft in an interbedded sand/silt/clay unit that underlies fill material at the Site.

LAI investigations in 2016 and 2017 determined that the highest concentration of TCE currently exists offsite on the WB property. The highest concentrations of TCE (1,100 micrograms per liter [µg/L]) were detected at direct-push boring LB-10 and MW-11, located just south of the B&K Site boundary and the former wash pad. TCE was also detected above the 5 µg/L Maximum Contaminant Level (MCL) for drinking water at three other direct-push borings (LB-15, LB-16, and LB-18) and at well MW-12 on the WB property. An isoconcentration contour map of the cVOCs plume map, based on groundwater data from 2017 through 2019, is presented on Figure 3.TCE contamination extends beneath the northeast corner of the WB building, but is bounded to the north, east, and west by borings and a well where TCE is not detected.

Comparable concentrations of TCE have been detected both to the north (MW-5) and south (MW-11) of the former wash pad. Prior to the 2013 wash-pad excavation, the highest concentration of TCE in groundwater (1,320 µg/L) was detected in former monitoring well MW-5, within the footprint of the excavation. The elevated concentration of TCE at MW-11 on the WB property suggests a current and/or historical groundwater mound or divide near the B&K and WB property boundary that resulted in cVOCs distribution to both the north and south of the former wash pad source.

2.0 *IN SITU* BIOTIC AND ABIOTIC TREATMENT APPROACH

To overcome the difficulty of injecting liquid amendments at this Site, *in situ* treatment will be stimulated through high pressure injection of a powder substrate that will stimulate both biotic and abiotic degradation of TCE and breakdown products. The powdered substrate will be mixed with water to form a slurry, which will be injected under high pressure to distribute the slurry into fractures created in the interbedded sand/silt/clay. Treatment will be performed on the WB property where the highest remaining TCE concentrations in groundwater occur. This section describes the injection substrate and resulting degradation processes. Implementation is described in Section 3.

2.1 Injection Substrate

The substrate selected for the Site is EHC (PeroxyChem, Philadelphia, Pennsylvania). EHC contains micro-scale zero-valent iron (ZVI), controlled-release food grade organic carbon, nutrients, and a food-grade binding agent. The organic carbon and ZVI stimulate concurrent and complementary biotic and abiotic degradation of TCE and breakdown products to non-toxic end products. EHC is commonly used to treat cVOCs in groundwater and soil. In addition to EHC, the injection substrate will also contain 4 percent by weight of LactOil®. LactOil is an emulsified vegetable oil product that can easily mix with water and provides a longer-lasting source of organic carbon than EHC, which will further enhance biological degradation of TCE.

2.2 Required Aquifer Conditions

Anaerobic aquifer conditions are generally required for biotic and abiotic degradation of TCE and breakdown products. The presence of dissolved oxygen (DO) is an indicator of aerobic, or oxidative, aquifer conditions. In the absence of DO, conditions are anaerobic, or reducing.

Aerobic and anaerobic conditions are characterized by sequential reduction-oxidation (redox) reactions of naturally occurring compounds, whereby aquifer micro-organisms (including bacteria) obtain energy. These redox reactions require an electron donor (i.e., a source of organic carbon, which ferments to volatile fatty acids and hydrogen) and an electron acceptor (e.g., oxygen, nitrate, iron, sulfate, carbon dioxide, chlorinated ethene compounds). These redox reactions can be compared to the process whereby humans obtain energy through consumption of food (electron donor) and oxygen (electron acceptor).

Micro-organisms obtain the greatest energy yield by using oxygen as an acceptor, which is highly oxidized and, therefore, can be easily reduced. Less oxidized acceptors provide sequentially less energy to aquifer micro-organisms and are used only after available oxygen has been consumed. When oxygen is largely depleted, micro-organisms use the less oxidized electron acceptors present in the aquifer in the following order: nitrate, manganese (IV), iron (III), sulfate, and carbon dioxide. The redox state of the aquifer (e.g., sulfate-reducing) is defined by which natural electron acceptors (e.g., sulfate) are being used (i.e., reduced) at a given time.

Understanding the redox state of the aquifer is important, as specific redox conditions are required for complete reductive dechlorination of TCE. TCE is relatively oxidized and can be transformed by dechlorinating bacteria under mild, iron-reducing, and sulfate-reducing conditions (Chapelle 1997). cDCE and VC require more reducing aquifer conditions; cDCE can be transformed under sulfate-reducing or methanogenic conditions (Chapelle 1997; Vogel et al. 1987) and VC can be transformed under methanogenic conditions (Ballapragada et al. 1997; Freedman and Gossett 1989; Maymó-Gatell et al. 1995; Vogel and McCarty 1985).

2.3 Biodegradation of Trichloroethene

The most significant biodegradation process for the treatment of TCE is reductive dechlorination. Reductive dechlorination occurs as bacteria gain energy from mediating (redox) reactions involving the chlorinated compounds as electron acceptors. Dechlorinating bacteria use chlorinated compounds like TCE as electron acceptors and use hydrogen (H_2) as the electron donor. The fermentation of the organic carbon in EHC and LactOil releases a variety of volatile fatty acids that further degrade to H_2, providing the needed electron donor for the dechlorinating bacteria to carry out redox reactions and gain energy for growth, reproduction, and other cellular processes.

In the process of reductive dechlorination, chlorine atoms on the TCE molecule are replaced by a hydrogen atom, resulting in the formation of successively less chlorinated molecules and, ultimately, in non-toxic end products ethene and ethane. This sequential dechlorination is as follows:

Reductive dechlorination: TCE → cDCE → VC → Ethene + Ethane

TCE and breakdown products require different redox conditions for reductive dechlorination to occur. The consumption of the organic carbon and natural electron acceptors like oxygen by other organisms helps create the necessary redox conditions for each step of the reductive dechlorination process. TCE is relatively oxidized and can be transformed by dechlorinating bacteria under mild, iron-reducing conditions (Chapelle 1997). cDCE and VC require more reducing aquifer conditions; cDCE can be transformed under sulfate-reducing or methanogenic conditions (Chapelle 1997; Vogel et al. 1987) and VC can be transformed under methanogenic conditions (Ballapragada et al. 1997; Freedman and Gossett 1989; Maymó-Gatell et al. 1995; Vogel and McCarty 1985).

2.4 Abiotic Degradation of Trichloroethene

The ZVI in EHC promotes the abiotic (e.g., chemical) degradation of TCE as a reactive surface for direct chemical dechlorination. The abiotic degradation of TCE involves both the β-elimination and hydrogenolysis pathways. In the β-elimination pathway, electrons are transferred to the TCE molecule when it comes into contact with the reactive iron surface of the ZVI particles. This pathway removes two chlorines at a time and produces acetylene compounds, which are transformed into ethene and ethane by the hydrogenolysis pathway (Brown et al. 2009):

β-elimination: TCE → Chloroacetylene
cDCE → Acetylene
Hydrogenolysis: Acetylene → Ethene + Ethane

The acetylene compounds are highly reactive and short-lived in the subsurface and are commonly not detected even when β-elimination is occurring. Any detections of acetylene (non-chlorinated) are clear evidence that abiotic degradation of this compound is occurring (Shen and Wilson 2007).

ZVI also aids in creating the redox conditions necessary for the biotic degradation. ZVI scavenges oxygen as its surface is oxidized (i.e., as it transfers electrons to TCE, oxygen, and other electron acceptors), creating a more reducing environment that dechlorinating bacteria need to perform their transformation processes. Corrosion of ZVI in water produces hydrogen that can be used by bacteria for biodegradation.

3.0 IMPLEMENTATION OF TREATMENT

This section describes the implementation of treatment in the vicinity of monitoring well MW-11 on the WB property, where the highest TCE concentrations are detected. The EHC mixture will be injected as a slurry using direct-push drilling methods. The slurry composition and injection procedures are summarized below.

3.1 Treatment Area

The treatment will occur in an area, 40-foot by 40-foot, that includes investigation locations MW-11, LB-10, and LB-15; and an adjacent area targeting LB-9 on the Sea Mar property and downgradient MW-6 (Figure 3). Injection points will be spaced approximately 8 ft apart in offset rows, resulting in 34 injection points total in the treatment area (Figure 4). The offset grid pattern increases the likelihood that emplaced EHC will overlap between borings in adjacent rows. Injection at these 34 points will target the contaminated interval from the water table (approximately 8 ft bgs) to 25 ft bgs. The location and number of injection points may be adjusted in the field based on the location of existing underground utilities. The spacing of injection points in the vicinity of MW-11, specifically, may be adjusted in the field in order to preserve this well as a monitoring location (i.e., prevent EHC slurry from clogging or otherwise damaging the well screen).

3.2 Slurry Design

Powdered EHC will be mixed with water and LactOil to create a thick slurry similar to loose cement and injected under high pressures (Section 4.2). The solid particles of EHC will not be widely dispersed by groundwater flow; instead, EHC slurry must be injected in a grid pattern that covers the desired treatment area.

The injection slurry will be prepared using 13,400 lbs of EHC powder, 3,500 gallons of potable water, and 250 gallons of LactOil resulting in 4,800 gallons of slurry with a manufacturer’s recommended solids concentration of 30 percent by weight. This slurry design results in the application of approximately 23 lbs of EHC powder per vertical foot of treatment interval. This injection design approximates the manufacturer’s recommendation of 20 lbs of EHC per vertical foot of boring for very tight (clayey) formations (PeroxyChem 2017); the slightly higher application rate of 23 lbs per vertical foot reflects the layered sand/silt/clay at the Site.

3.3 Method of Injection

The slurry will be injected into borings drilled using a direct-push drilling rig equipped with special tooling for injecting the slurry under high pressure (e.g., 100 to 200 lbs per square inch [psi]). In contrast to liquid injections, where fluid is pushed through the pore space of the soil formation, high pressure slurry injection creates fractures in the soil formation that are filled with EHC. Contaminated groundwater is treated as it comes into contact with the EHC emplaced in these hydro fractures. Radial injection of EHC slurry occurs as the injection tooling is pulled up a few feet at a time from the bottom depth. This results in radial fans of hydro fractures filled with EHC over the vertical treatment interval.

Both treatment areas are paved with asphalt. Following drilling and injection, the surface at each boring location will be repaired by the driller with cold patch asphalt.

3.4 Health and Safety

All work will be performed in accordance with the revised HASP (Appendix A). The EHC Reagent SDS (Appendix B) has been reviewed in preparation of the HASP and appropriate procedures for safety, handling, storage, and disposal will be followed. Any vessel that contains water and EHC must be allowed to vent due to the potential buildup of pressures due to gases that are produced from the mixed slurry (PeroxyChem 2017). The SDS will be kept on the Site at all times during work.

4.0 PERFORMANCE MONITORING

This section describes the groundwater sampling that will be performed to monitor treatment progress following injection of EHC and LactOil. Analytical methods and sampling procedures are summarized below.

4.1 Groundwater Sampling

Groundwater monitoring will be conducted on a semiannual basis for the first 4 years following injection. One sampling event will be performed during the wet season (October to April) and one event will be performed during the dry season (May to September). It is anticipated that semiannual monitoring will transition into annual monitoring after 4 years.

Sampling will be performed at 12 monitoring wells within or near the extent of cVOCs contamination, as shown on Figure 5. Monitoring parameters include the laboratory analyses and field parameters presented in the following table. The groundwater sampling matrix presented in Table 1 details the laboratory analyses and field measurements performed at each monitoring well. Analytes include target contaminants, degradation end products, indicators of electron donor distribution and persistence, and aquifer redox parameters. Field quality control samples will include one duplicate and one matrix spike/matrix spike duplicate (MS/MSD) for data quality assurance purposes.

Water levels will be measured at each of the 12 sampled wells and at an additional 5 monitoring wells at the beginning of each sampling, as indicated in Table 1. Measurements will be used to develop groundwater elevation contour maps to monitor Site groundwater flow direction.

4.2 Sampling Procedures

Low-flow sampling techniques will be used to collect groundwater samples from Site monitoring wells. In general, the procedure is as follows:

1. Remove well monument cover. Inspect monument cover, monument, well head, and casing for damage, leaking, and staining.
2. Measure depth to water from north side of top of well casing.
3. Purge well using a peristaltic pump and dedicated sample collection tubing. Wells will be purged at less than 0.5 liters per minute and with drawdown of less than 4 inches during purging. Purging will continue until field parameters reach stabilization.
4. Collect samples and measure field parameters after field parameters stabilize. Field parameters will be recorded during purging and immediately before sampling. Any significant problems or observations will also be recorded.
5. Store samples on ice until they are delivered to the lab or picked up by the lab.

Non-dedicated sampling equipment (i.e., equipment used at multiple wells during sampling) will be decontaminated between sampling locations according to the procedures provided in the HASP

(Appendix A). Groundwater collected in buckets during the purging and sampling process will be transferred to a designated 55-gallon drum and stored at the Site for disposal at an appropriate facility.

5.0 DATA EVALUATION AND REPORTING

This section summarizes the data evaluation that will be performed to monitor treatment progress and the reporting schedule.

5.1 Evaluation of Treatment Effectiveness and Longevity

The effectiveness of treatment will be evaluated in multiple ways, including concentrations of electron donor over time, evidence of appropriate redox conditions for TCE breakdown, and trends in concentrations of TCE and its breakdown products.

Primary indicators or treatment effectiveness are:

- Total organic carbon (TOC) concentrations above baseline (indicates distribution and longevity of the organic carbon in the injected EHC and LactOil).
- Decreasing TCE concentrations with sequentially increasing concentrations of cDCE and VC breakdown products (indicates that biodegradation is occurring).
- Increasing or persistent reduction of ethene and ethane end products (indicates that complete biodegradation and abiotic degradation is occurring).
- Possible detections of acetylene (short-lived intermediary indicates abiotic degradation).

Changes in aquifer redox parameters provide secondary indicators of the extent of treatment.

Treatment longevity of EHC is site-specific, but PeroxyChem reports that effects of EHC generally last for 3 to 5 years (PeroxyChem 2014). Indicators of slowing or incomplete treatment may include:

- Low TOC concentrations.
- Increasing cDCE and VC concentrations with no subsequent ethene and/or ethane production (indicates that there is not enough electron donor present for complete biodegradation).
- Very low methane or elevated sulfate concentrations (indicates that redox conditions are not reducing enough to support biodegradation).

After EHC treatment capacity is exhausted, it is anticipated that cVOCs concentrations will continue to slowing decline through natural attenuation.

5.2 Reporting Schedule

Annual reports will be prepared to document Site activities and present performance monitoring data for the previous calendar year. The first annual report will also include details of the direct-push injection of EHC. All annual reports will present groundwater monitoring results and an evaluation of the data. Recommendations for additional treatment or changes to the monitoring schedule will be presented, as necessary, based on these evaluations. To document cleanup progress with Ecology, annual reports will be submitted to the VCP Site Manager.

6.0 USE OF THIS REPORT

This report has been prepared for the exclusive use of Beckwith & Kuffel, Inc. and applicable regulatory agencies for specific application to the B&K Site. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of LAI. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by LAI, shall be at the user's sole risk. LAI warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. We make no other warranty, either express or implied.

7.0 REFERENCES

Ballapragada, B.S., H.D. Stensel, J.A. Puhakka, and J.F. Ferguson. 1997. "Effect of Hydrogen on Reductive Dechlorination of Chlorinated Ethenes." Environmental Science & Technology. 31:1728-1734.

Brown, R.A., J.G. Mueller, A.G. Seech, J.K. Henderson, and J.T. Wilson. 2009. "Interaction between Biological and Abiotic Pathways in the Reduction of Chlorinated Solvents." Remediation Journal. 20(1):9-20.

Chapelle, F.H. 1997. "Identifying Redox Conditions that Favor the Natural Attenuation of Chlorinated Ethenes in Contaminated Ground-Water Systems." Proceedings of the Symposium on Natural Attenuation of Chlorinated Organics in Ground Water, Dallas, TX, May.

Freedman, D.L., and J.M. Gossett. 1989. "Biological Reductive Dechlorination of Tetrachloroethylene and Trichloroethylene to Ethylene under Methanogenic Conditions." Applied and Environmental Microbiology. 55 (9):2144-2151.

LAI. 2017a. Supplemental Remedial Investigation Report, Beckwith & Kuffel Site, 1313 South 96th Street, Seattle, Washington. Landau Associates, Inc. June 5.

LAI. 2017b. Trichloroethene Source Zone Bioremediation Work Plan, Beckwith & Kuffel, Inc. Site, 1313 South 96th Street, Seattle, Washington. Landau Associates, Inc. September 13.

LAI. 2019. 2017-2018 Bioremediation Injection and Groundwater Monitoring Status Report, Beckwith & Kuffel, Inc. Site, 1313 South 96th Street, Seattle, Washington. Landau Associates, Inc. June 20.

Maymó-Gatell, X., V. Tandoi, J.M. Gossett, and S.H. Zinder. 1995. "Characterization of an H2-utilizing Enrichment Culture that Reductively Dechlorinates Tetrachloroethene to Vinyl Chloride and Ethene in the Absence of Methanogenesis and Acetogenesis." Applied and Environmental Microbiology. 61 (11):3928-3933.

PeroxyChem. 2014. EHC® Reagent Product Sheet; EHC The Original ISCR Reagent.

PeroxyChem. 2017. EHC® Reagent Production Application Guide.

Shannon & Wilson, Inc. 2012. Report: Phase I Environmental Site Assessment, 1313 South 96th Street, King County, Washington. January 11.

Shannon & Wilson, Inc. 2014. Remedial Investigation/Interim Remedial Action Report, Beckwith & Kuffel Site, Seattle, Washington. October 21.

Shen, H., and J.T. Wilson. 2007. "Trichloroethylene Removal from Groundwater in Flow-Through Columns Simulating a Permeable Reactive Barrier Constructed with Plant Mulch." Environmental Science & Technology. 41 (11):4077-4083. doi: 10.1021/es0626180. May 4.

Vogel, Timothy M., Craig S. Criddle, and Perry L. McCarty. 1987. "Transformations of Halogenated Aliphatic Compounds." Environmental Science & Technology. 21 (8):722-736.

Vogel, Timothy M., and Perry L. McCarty. 1985. "Biotransformation of Tetrachloroethylene to Trichloroethylene, Dichloroethylene, Vinyl Chloride, and Carbon Dioxide under Methanogenic Conditions." Applied and Environmental Microbiology. 49 (5):1080-1083. May.

Data Source: Esri 2012

G:\Projects\1645\001\030\031\F01VicMap.mxd 11/19/2019

Landau Associates

Beckwith & Kuffel, Inc.
Seattle, Washington

Vicinity Map

Figure
1

G:\Projects\1645\001\030\031\F02SitePlan.mxd 12/13/2019

Legend

MW-12 ◐ Monitoring Well (LAI)

SM-MW-11 ◐ Monitoring Well (Sea Mar)

MW-4 ◐ Former Monitoring Well

LB-1 ⊙ Former Direct-Push Boring

▭ Parcels

0 50 100

Scale in Feet

Data Source: Sea Mar; Google Earth Imagery.

Note

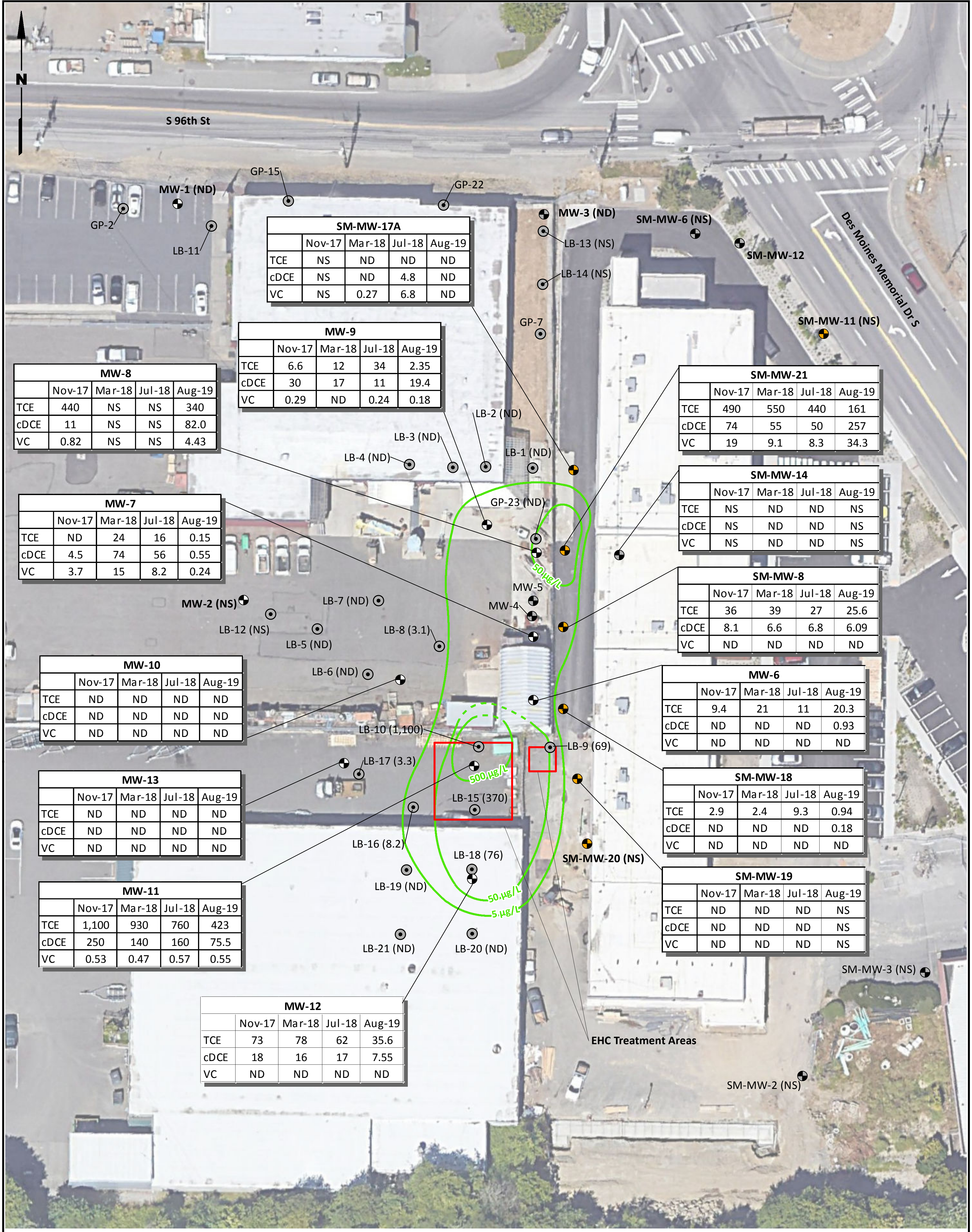
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

LANDAU ASSOCIATES

Beckwith & Kuffel, Inc.
Seattle, Washington

Site Plan

Figure
2



SM-MW-17A	Nov-17	Mar-18	Jul-18	Aug-19
TCE	NS	ND	ND	ND
cDCE	NS	ND	4.8	ND
VC	NS	0.27	6.8	ND

MW-9	Nov-17	Mar-18	Jul-18	Aug-19
TCE	6.6	12	34	2.35
cDCE	30	17	11	19.4
VC	0.29	ND	0.24	0.18

MW-8	Nov-17	Mar-18	Jul-18	Aug-19
TCE	440	NS	NS	340
cDCE	11	NS	NS	82.0
VC	0.82	NS	NS	4.43

MW-7	Nov-17	Mar-18	Jul-18	Aug-19
TCE	ND	24	16	0.15
cDCE	4.5	74	56	0.55
VC	3.7	15	8.2	0.24

MW-10	Nov-17	Mar-18	Jul-18	Aug-19
TCE	ND	ND	ND	ND
cDCE	ND	ND	ND	ND
VC	ND	ND	ND	ND

MW-13	Nov-17	Mar-18	Jul-18	Aug-19
TCE	ND	ND	ND	ND
cDCE	ND	ND	ND	ND
VC	ND	ND	ND	ND

MW-11	Nov-17	Mar-18	Jul-18	Aug-19
TCE	1,100	930	760	423
cDCE	250	140	160	75.5
VC	0.53	0.47	0.57	0.55

MW-12	Nov-17	Mar-18	Jul-18	Aug-19
TCE	73	78	62	35.6
cDCE	18	16	17	7.55
VC	ND	ND	ND	ND

SM-MW-21	Nov-17	Mar-18	Jul-18	Aug-19
TCE	490	550	440	161
cDCE	74	55	50	257
VC	19	9.1	8.3	34.3

SM-MW-14	Nov-17	Mar-18	Jul-18	Aug-19
TCE	NS	ND	ND	NS
cDCE	NS	ND	ND	NS
VC	NS	ND	ND	NS

SM-MW-8	Nov-17	Mar-18	Jul-18	Aug-19
TCE	36	39	27	25.6
cDCE	8.1	6.6	6.8	6.09
VC	ND	ND	ND	ND

MW-6	Nov-17	Mar-18	Jul-18	Aug-19
TCE	9.4	21	11	20.3
cDCE	ND	ND	ND	0.93
VC	ND	ND	ND	ND

SM-MW-18	Nov-17	Mar-18	Jul-18	Aug-19
TCE	2.9	2.4	9.3	0.94
cDCE	ND	ND	ND	0.18
VC	ND	ND	ND	ND

SM-MW-19	Nov-17	Mar-18	Jul-18	Aug-19
TCE	ND	ND	ND	NS
cDCE	ND	ND	ND	NS
VC	ND	ND	ND	NS

Legend

MW-12 ◐ Monitoring Well (LAI)
SM-MW-11 ◐ Monitoring Well (Sea Mar)
MW-4 ◐ Former Monitoring Well
LB-1 ⊙ Former Direct-Push Boring
- - - TCE Baseline Iso-Concentration Contour (Approx.)
— TCE Baseline Iso-Concentration Contour

Boring Name — LB-16 (8.2) — Maximum TCE concentration detected in groundwater grab sample collected at time of drilling (2016)

MW-12	Nov-17	Mar-18	Jul-18
TCE	73	78	62

- Monitoring Well Designation
- Sampling Date
- Detected Concentration (µg/L)

Detected Analyte

0 50 100
Scale in Feet

Data Source: Sea Mar; Google Earth Imagery.

Notes

1. Iso-concentration contours also informed by prior results from temporary groundwater borings not shown.
2. All detected concentrations are reported in micrograms per liter (µg/L).
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

cDCE = *cis*-1,2-dichloroethene
ND = not detected
NS = not sampled
TCE = trichoroethene
VC = vinyl chloride

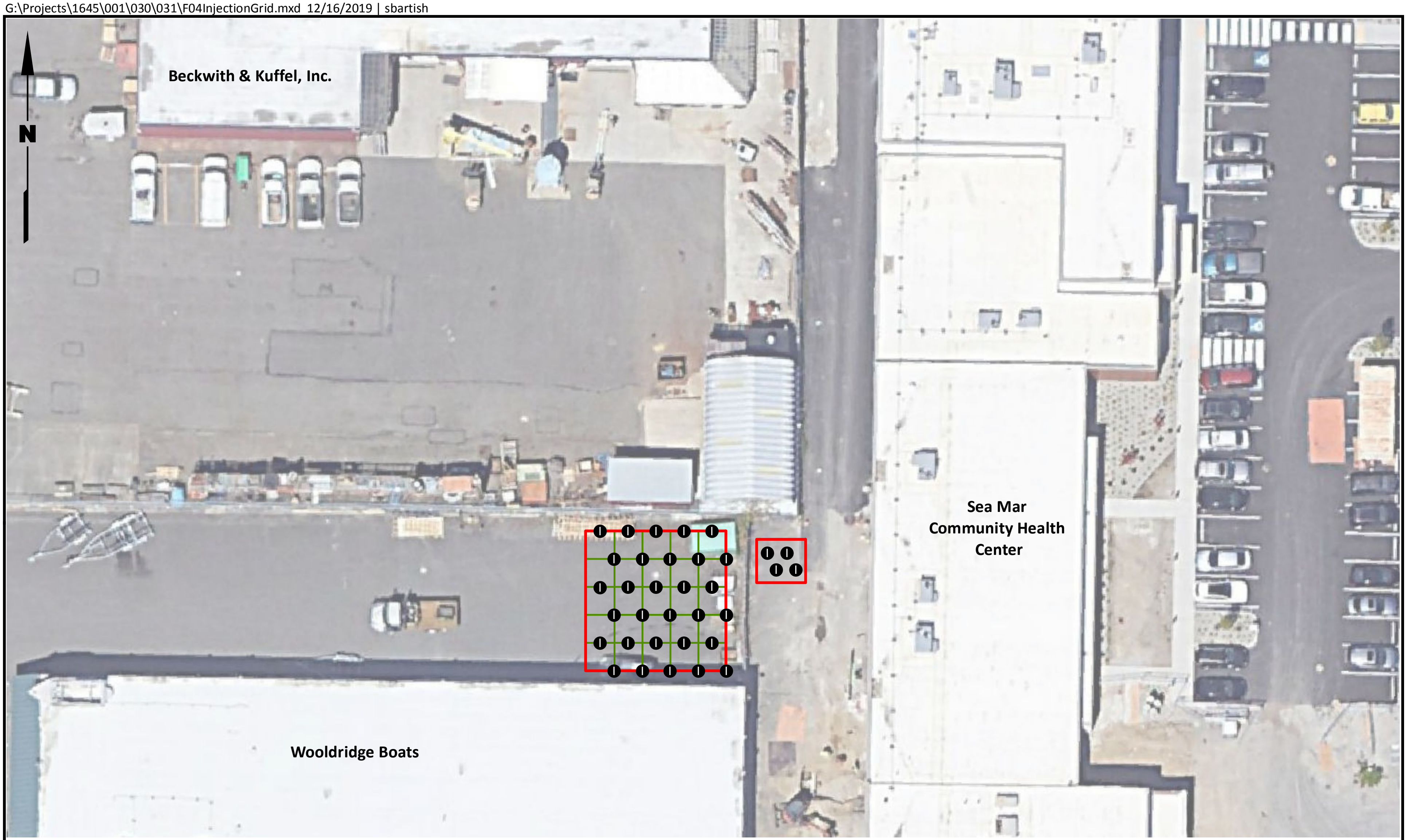
LANDAU ASSOCIATES

Beckwith & Kuffel, Inc.
Seattle, Washington

Halogenated Volatile Organic Compound Sampling Results

Figure
3

G:\Projects\1645\001\030\031\F04InjectionGrid.mxd 12/16/2019 | sbartish



Legend

● Injection Point (Approximate)

🟥 Treatment Area

Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Data Source: Sea Mar; Google Earth Imagery.

0 40 80

Scale in Feet

LANDAU ASSOCIATES

Beckwith & Kuffel, Inc.
Seattle, Washington

Injection Grid

Figure
4

G:\Projects\1645\001\030\031\F05SamplingLocations.mxd 12/17/2019

Legend

MW-12		Proposed Sampling Location
MW-12	●	Monitoring Well (LAI)
SM-MW-11	●	Monitoring Well (Sea Mar)
MW-4	●	Former Monitoring Well
LB-1	◉	Former Direct-Push Boring
	—	TCE Baseline Iso-Concentration Contour
	- -	TCE Baseline Iso-Concentration Contour (Approx.)

0 50 100

Scale in Feet

Data Source: Sea Mar; Google Earth Imagery.

Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

LANDAU ASSOCIATES

Beckwith & Kuffel, Inc.
Seattle, Washington

Sampling Locations

Figure
5

Table 1
Groundwater Sampling Matrix
Beckwith & Kuffel, Inc.
Seattle, Washington

Well ID	Analysis (a)						Notes
	TCE, cDCE, VC (8260)	Sulfate (300.0)	Nitrate (300.0)	TOC (SM5310)	AMEE (RSK-175)	DO, ORP, pH, Ferrous iron (b)	
Beckwith & Kuffel Property							
MW-1							(c)
MW-2							(c)
MW-6	x	x	x	x	x	x	
MW-7	x	x	x	x	x	x	
MW-8	x	x	x	x	x	x	
MW-9	x	x	x	x	x	x	
MW-10	x	x	x	x	x	x	
Wooldridge Property							
MW-11	x	x	x	x	x	x	
MW-12	x	x	x	x	x	x	
MW-13	x	x	x	x	x	x	
Sea Mar Property							
SM-MW-8	x				x	x	(d)
SM-MW-11							(c)
SM-MW-17A	x	x	x	x	x	x	
SM-MW-18	x	x	x	x	x	x	
SM-MW-19							(c)
SM-MW-20							(c)
SM-MW-21	x	x	x	x	x	x	

Notes:

(a) Field QC samples will include one duplicate and one MS/MSD. Locations of the field QC samples will be varied each event to reduce bias and confirm results.

(b) Field measurement; ferrous iron from Hach field test kit

(c) Water level measurement only. All wells listed are included in the groundwater elevation survey performed prior to sampling.

(d) Limited analytes due to very slow recharge. Well only produces enough water to purge and fill containers for the 8260 and RSK-175 analysis.

Abbreviations & Acronyms:

AMEE = acetylene, methane, ethene, ethane
cDCE = *cis* -1,2-dichloroethene
DO = dissolved oxygen
MS/MSD = matrix spike/matrix spike duplicate
ORP = oxidation reduction potential
QC = quality control
TCE = trichloroethene
TOC = total organic carbon
VC = vinyl chloride

APPENDIX A

Health and Safety Plan

WORK LOCATION PERSONNEL PROTECTION AND SAFETY EVALUATION FORM

Attach Pertinent Documents/Data
Fill in Blanks As Appropriate

Job No.:	1645001.010	Revised:	November 11, 2019
Prepared by:	Cody Johnson	Reviewed by:	Christine Kimmel
Date:	August 28, 2017	Date:	November 14, 2017

A. WORK LOCATIONS DESCRIPTION

1. **Project Name:** Beckwith & Kuffel
2. **Location:** 1313 South 96th Street, Seattle, Washington
3. **Anticipated Activities:** Activities covered under this plan include:
    - Groundwater sampling
    - Electron donor injection
    - Clear water injection testing
    - ISCR reagent direct-push injection
4. **Size:** Approximately 1 acre
5. **Surrounding Population:** Mixed industrial, commercial, and residential
6. **Buildings/Homes/Industry:** One industrial building, currently in use.
7. **Topography:** Mostly flat; gentle slope on west side.
8. **Anticipated Weather:** 30 to 75 degrees Fahrenheit
9. **Unusual Features:** None.
10. **Site History:** Site was previously occupied by a forklift maintenance facility. Chlorinated solvents were used at the southeast corner of the site resulting in release to soil and groundwater.

    Past remediation efforts have included excavation, backfilling with remediation amendments, and electron donor injection.

B. HAZARD DESCRIPTION

1. **Background Review:** ☒ Complete ☐ Partial

   If partial, why?

2. **Hazardous Level:** ☐ B ☐ C ☒ D ☐ Unknown

   Justification: Site monitoring results indicate contaminant concentrations in groundwater as high as 1,100 µg/L TCE; 200 µg/L cDCE; and 0.6 µg/L VC. There are no known hazards associated with the electron donor substrates (emulsified vegetable oil) or ISCR reagents (food-grade carbon and ZVI) to be used at the Site. There are minor health hazards associated with additives to be used for electron donor injection.

3. **Types of Hazards:** (Attach additional sheets as necessary)

   A. ☒ Chemical ☒ Inhalation ☐ Explosive
   ☐ Biological ☒ Ingestion ☐ O2 Def. ☒ Skin Contact

   Describe: Direct contact with contaminated soil or groundwater; accidental ingestion of contaminated soil or groundwater; or inhalation of vapors during drilling, sampling, and injection.

   B. ☒ Physical ☐ Cold Stress ☒ Noise ☐ Heat Stress ☐ Other

   Describe: Noise and physical hazards associated with working around pumps, hoses, drilling equipment, and other heavy equipment at the Site.

   C. ☐ Radiation

   Describe:

4. **Nature of Hazards:**

☒ Air	Describe: Potential for volatile constituents to be released from contaminated soil or groundwater.
☒ Soil	Describe: Potential for contact with or ingestion of contaminated soil.
☐ Surface Water	Describe:
☒ Groundwater	Describe: Potential for contact with or ingestion of contaminated groundwater.
☒ Other	Describe: Powdered ISCR reagents can present an inhalation hazard if not used in a well-ventilated area. If reagents are stored when wet or when combined with water, the vessel must remain open to the air (i.e., vented) to prevent buildup of fermentation gasses.

5. Chemical Contaminants of Concern ☐ N/A

The primary chemical contaminants of concern are volatile organic compounds (VOCs). The table below lists information for these primary compounds and other potential contaminants.

Contaminant	PEL (ppm)	I.D.L.H. (ppm)	Source/Quantity Characteristics	Route of Exposure	Symptoms of Acute Exposure	Instruments Used to Monitor Contaminant
Trichloroethene	50 ppm	1,000 ppm	Present in groundwater	Inhalation, ingestion, dermal contact	Eye, nose, and throat irritation; headache; nausea	PID
Vinyl Chloride	1 ppm	NV	Present in groundwater	Inhalation, ingestion, dermal contact	Weakness, abdominal pain. Known carcinogen	Colorimetric tubes
cis-1,2-Dichloroethene	200 ppm	1,000 ppm	Present in groundwater	Inhalation, ingestion, dermal contact	Dizziness, nausea, dermatitis, irritation of mucous membranes	PID
Yeast Extract	N/A	N/A	Mixed with injection fluid	Inhalation, ingestion, eye/dermal contact	Eye, nose, skin, and throat irritation	Visual, dust
EHC® ISCR Reagent	N/A	N/A	Mixed with water	Inhalation, ingestion, eye/dermal contact	Throat irritation	Visual, dust

Notes:

IDLH = Immediately Dangerous to Life and Health
ISCR = *in situ* chemical reduction
N/A = Not Applicable
NV = No Value
PEL = Personal Exposure Limit
PID = Photoionization Detector
ppm = parts per million

6. Physical Hazards of Concern ☐ N/A

Hazard	Description	Location	Procedures Used to Monitor Hazard
Injection Equipment	Mechanical and electrical hazards associated with pumps; trip/slip hazards associated with pressurized hoses and wet surfaces	Within the injection work area	• Alert observation of surroundings • Shut off pumps for disassemble, etc. • Maintain dry and tidy work space • Conduct lockout/tagout of mechanical and/or electrical equipment in the direct vicinity of work area • Maintain three points of contact when climbing ladder of injection tank • Monitor pressures in hoses and valves • Aware of pressurized hose
Drilling Equipment	Mechanical and electrical hazards associated with drill rig; physical hazards associated with moving parts on drill rig	Within work area	• Alert observation of surroundings • Establish eye contact with drill rig operator before moving in front of or near rig • Wear hard hat and hearing protection at all times when in the vicinity of the drill rig • Maintain tidy work space
Slips, Trips, and Falls	Uneven terrain and drilling equipment	Around work area	• Visual observations of terrain and hazards • Keep work area clear of tools and debris
Travel to and from site	Operating motor vehicle in traffic on highways and rural roads	Route to and from site from Landau Associates office	• Operate motor vehicle while well rested, physically able to drive safely • Conduct pre-trip vehicle inspection, all vehicles to be maintained and in good working order • Obey all traffic laws (no cell phone use while driving) • Secure all cargo properly to avoid shifting • Allow sufficient time for travel to site at safe speeds • Engage emergency brake when parking vehicles • Establish a planned route prior to departure

7. Work Location Instrument Readings ☒ N/A

Location: Date/Time:
Percent O_2: Percent LEL:
Colorimetric tube VC (PPM): PID:
Colorimetric tube PCE (PPM) Other:

Location: Date/Time:
Percent O_2: Percent LEL:
Colorimetric tube VC (PPM): PID:
Colorimetric tube PCE (PPM) Other:

Location: Date/Time:
Percent O_2: Percent LEL:
Colorimetric tube VC (PPM): PID:
Colorimetric tube PCE (PPM) Other:

Location: Date/Time:
Percent O_2: Percent LEL:
Colorimetric tube VC (PPM): PID:
Colorimetric tube PCE (PPM) Other:

Location: Date/Time:
Percent O_2: Percent LEL:
Colorimetric tube VC (PPM): PID:
Colorimetric tube PCE (PPM) Other:

Location: Date/Time:
Percent O_2: Percent LEL:
Colorimetric tube VC (PPM): PID:
Colorimetric tube PCE (PPM) Other:

Location: Date/Time:
Percent O_2: Percent LEL:
Colorimetric tube VC (PPM): PID:
Colorimetric tube PCE (PPM) Other:

8. Hazards Expected In Preparation For Work Assignment ☒ N/A

Describe:

C. PERSONAL PROTECTIVE EQUIPMENT

1. Level of Protection

☐ A ☐ B ☐ C ☒ D

Location/Activity: All

☐ A ☐ B ☒ C ☐ D

Location/Activity:

- All Locations – Upgrade to Level C personal protective equipment (PPE) if ambient air conditions meet target monitoring level in Attachment A.
- Injection fluid mixing stations – All activities requiring handling/mixing of dry chemical additives will require wearing of safety glasses. If visual dust remains despite efforts to control dust, a half-face respirator with HEPA filter will be worn.
- ISCR reagent slurry mixing stations – All activities requiring handling/mixing of dry reagents will require wearing of safety glasses. A half-face respirator with HEPA filter will also be required if other control measures cannot adequately suppress dust created during handling/mixing.

2. Protective Equipment (specify probable quantity required)

Respirator ☐ N/A

☐ SCBA, Airline
☐ Full-Face Respirator
☒ Half-Face Respirator (Cart. organic vapor) (Only if upgrade to Level C)
☐ Escape mask
☐ None
☐ Other:
☐ Other:

Clothing ☐ N/A

☐ Fully Encapsulating Suit
☐ Chemically Resistant Splash Suit
☒ Safety Vests
☒ Tyvek Coverall (Only if upgrade to Level C)
☐ Saranex Coverall
☐ Coverall, Specify
☐ Other:

Head & Eye ☐ N/A

☒ Hard Hat
☒ Goggles (dry chemical handling and/or mixing
☐ Face Shield
☒ Safety Eyeglasses
☒ Other: Hearing protection

Hand Protection ☐ N/A

☐ Undergloves; Type:
☒ Gloves; Type: Nitrile
☐ Overgloves; Type:
☐ None
☐ Other:

Foot Protection ☐ N/A

☐ Neoprene Safety Boots with Steel Toe/Shank

☐ Disposable Overboots

☒ Other: Steel-toed work boots

3. Monitoring Equipment ☐ N/A

☐ CGI
☐ O^2 Meter
☐ Rad Survey
☒ Detector Tubes (Attachment A)
☒ PID
☐ FID
☐ Other

Type: Colorimetric tubes

D. DECONTAMINATION (ATTACH DIAGRAM)

☒ Required ☐ Not Required

Avoid hand to mouth contact, no eating/drinking in exclusion zone. Wash hands and face after work shift and prior to breaks. Change disposable PPE frequently during work.

EQUIPMENT DECONTAMINATION (ATTACH DIAGRAM)

☒ Required ☐ Not Required

Groundwater sampling: Dedicated sampling equipment will be used when possible (e.g., tubing). Any equipment in contact with contaminated media that will be used at multiple locations (e.g., water level meters) must be decontaminated using a three-step procedure after each use:

- Alconox (or similar) rinse
- Tap water rinse
- Dionized water rinse.

ISCR reagent direct-push injection: Equipment used to measure downhole distances (e.g., tape measures, water level meters) that comes into contact with contaminated media must be decontaminated after each use following the three-step process described above. Downhole drilling equipment (e.g., rods, screens, other injection tools) must be pressure washed after each boring.

E. PERSONNEL

	Name	Work Location Title/Task	Medical Current	Fit Test Current
1.	**Jenny Green**	**Field Engineer**	☒	☒
2.	**Jeovani Huerta-Avila**	**Field Scientist**	☒	☒
3.	**Katie Gauglitz**	**Field Geologist**	☒	☒
4.			☐	☐
5.			☐	☐
6.			☐	☐
7.			☐	☐
8.			☐	☐
9.			☐	☐
10.			☐	☐

Site Safety Coordinator: **Jenny Green**

F. ACTIVITIES COVERED UNDER THIS PLAN

Task No.	Description	Preliminary Schedule
1	Well installation, development, groundwater sampling, initial donor injection	Fall 2017 – Early 2018
2	Groundwater Sampling	Fall 2017 – TBD
3	Clear water injection testing	Summer 2019
4	EHC reagent direct-push injection	Early 2020

SUBCONTACTOR EVALUATION ☐ N/A

Name and Address of Subcontractor:
Anderson Environmental Contracting, LLC
705 Colorado Street
Kelso, WA 98626

EVALUATION CRITERIA

Item	Adequate	Inadequate	Comments
Medical Surveillance Program	☐	☐	
Personal Protective Equipment Availability	☐	☐	
Onsite Monitoring Equipment Availability	☐	☐	
Safe Working Procedures Specification	☐	☐	
Training Protocols	☐	☐	
Ancillary Support Procedures (if any)	☐	☐	
Emergency Procedures	☐	☐	
Evacuation Procedures Contingency Plan	☐	☐	
Decontamination Procedures Equipment	☐	☐	
Decontamination Procedures Personnel	☐	☐	

GENERAL HEALTH AND SAFETY PROGRAM EVALUATION: ☒ Adequate ☐ Inadequate

Additional Comments: Adequate based on Basic Agreement between Landau Associates and Anderson Environmental Contracting, LLC

Evaluation Conducted By: Christine Kimmel

Date: 11/11/19

G. EMERGENCY FACILITIES AND NUMBERS

Nearest hospital: 7.3 miles (~22 minutes)

Swedish Emergency Room – Cherry Hill
540 16th Avenue
Seattle, WA 98122
206-320-2000

Emergency Contacts:

Name	Title	Phone Numbers
Evelyn Ives	Landau Associates Project Manager	425-778-0907 office 360-213-6478 cell
Christine Kimmel	Landau Associates Health and Safety Manager	425-778-0907 office 206-786-3801 cell

In the event of an emergency, do the following:

1. Call for help as soon as possible. Call 911. Give the following information:
   - WHERE the emergency is – use cross streets or landmarks
   - PHONE NUMBER you are calling from
   - WHAT HAPPENED – type of injury
   - WHAT is being done for the victim(s)
   - YOU HANG UP LAST – let the person you called hang up first.

2. If the victim can be moved, paramedics will transport to the hospital. If the injury or exposure is not life threatening, decontaminate the individual first. If decontamination is not feasible, wrap the individual in a blanket or sheet of plastic prior to transport.

3. Notify the Project Manager (Evelyn Ives 360-213-6478).

Emergency Routes – Map – See last page

HEALTH AND SAFETY PLAN
APPROVAL/SIGN OFF FORMAT

I have read, understood, and agreed with the information set forth in this Health and Safety Plan (and attachments) and discussed in the Personnel Health and Safety briefing.

Name	Signature	Date
Name	Signature	Date
Katie Gauglitz		
Name	Signature	Date
Jeovani Huerta-Avila		
Name	Signature	Date
Jenny Green		
Name	Signature	Date
Site Safety Coordinator	Signature	Date
Christine Kimmel	Christine Kimmel	11/11/19
Landau Health and Safety Manager	Signature	Date
Evelyn Ives	Evelyn Ives	12/18/2019
Project Manager	Signature	Date

Personnel Health and Safety Briefing Conducted By:

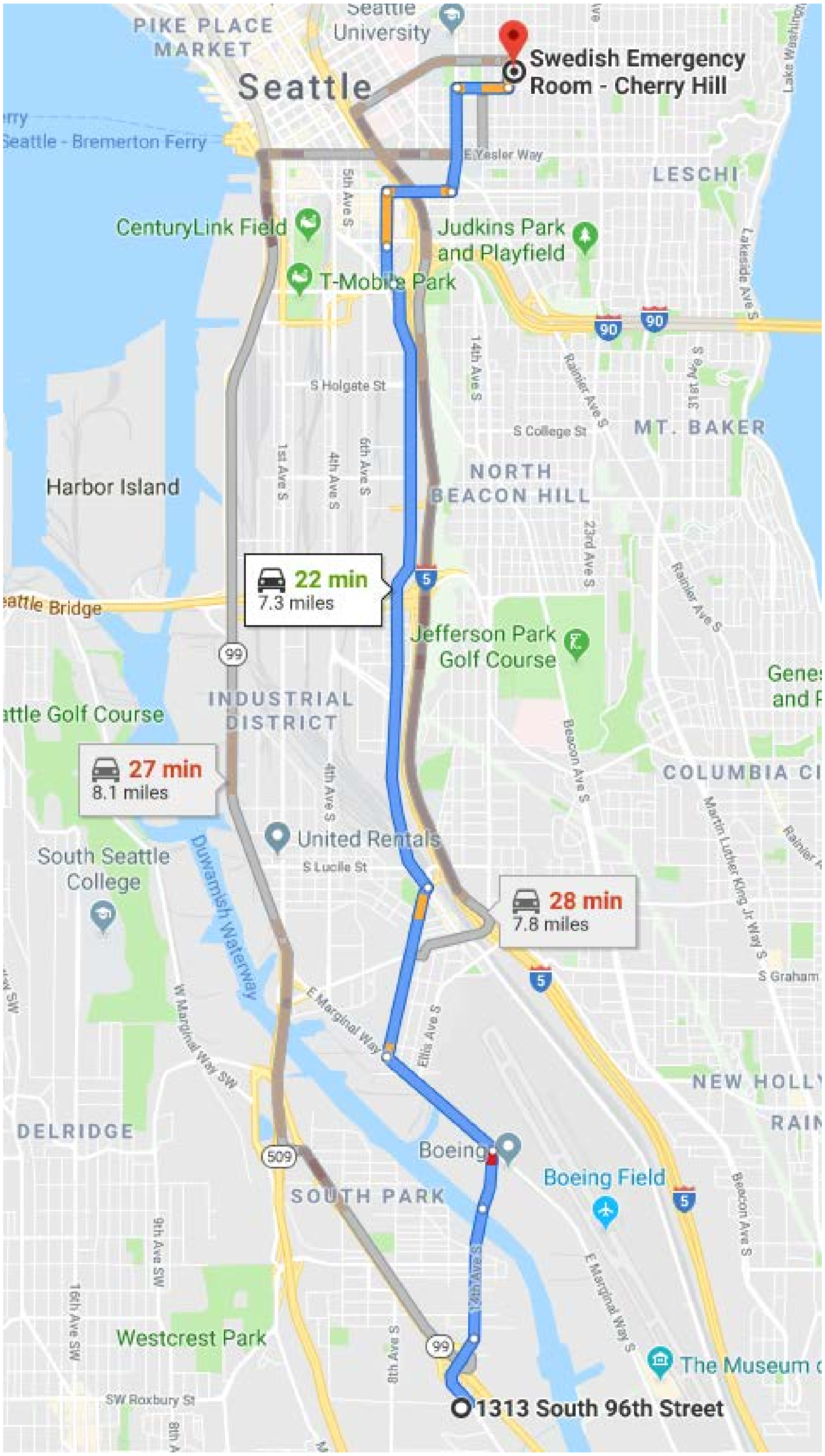
Name	Signature	Date

ATTACHMENT A

ACTION LEVELS FOR RESPIRATORY PROTECTION

Monitoring Parameter	Reading	Level of Protection
VOCs	PID reading >2 ppm, check ambient air with VC colorimetric tube	Upgrade to Level C is colorimetric tube reading above 1 ppm
	PID reading >10 ppm in breathing zone for more than 5 minutes or >20 ppm for momentary peak.	Evacuate the area or upgrade to Level C - half-face respirator with organic vapor / HEPA cartridge.
	>10 ppm and <50 ppm	Temporarily stop work to allow vapors to return to baseline- proceed with upgrade to Level C
	>50 ppm	Stop Work, contact H&S Manager

Emergency Routes – Map



APPENDIX B

Safety Data Sheets

SAFETY DATA SHEET
EHC® Reagent

SDS # : EHC-C
Revision date: 2016-02-18
Format: NA
Version 2

1. PRODUCT AND COMPANY IDENTIFICATION

Product Identifier

Product Name EHC® Reagent

Other means of identification

Alternate Commercial Name EHC Fine, EHC Granular, EHC 50%

Recommended use of the chemical and restrictions on use

Recommended Use: For the remediation of contaminated groundwater

Restrictions on Use No uses to be advised against were identified.

Manufacturer/Supplier

PeroxyChem LLC
2005 Market Street
Suite 3200
Philadelphia, PA 19103
Phone: +1 267/ 422-2400 (General Information)
E-Mail: sdsinfo@peroxychem.com

Emergency telephone numbers

For leak, fire, spill or accident emergencies, call:
1 800 / 424 9300 (CHEMTREC - U.S.A.)
1 703 / 527 3887 (CHEMTREC - Collect - All Other Countries)
1 303/ 389-1409 (Medical - U.S. - Call Collect)

2. HAZARDS IDENTIFICATION

Classification

OSHA Regulatory Status
This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200)

Combustible dust

GHS Label elements, including precautionary statements

EMERGENCY OVERVIEW

Warning

Hazard Statements
May form combustible dust concentrations in air

Precautionary Statements - Prevention
Dry or powdered ingredients are combustible. Dispersal of finely divided dust from products into air may form mixtures that are ignitable or explosive. Minimize airborne dust generation and eliminate sources of ignition.

Hazards not otherwise classified (HNOC)
No hazards not otherwise classified were identified.

Other Information CONTAINMENT HAZARD: Any vessel that contains wet EHC must be vented due to potential pressure build up from fermentation gases

3. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical name	CAS-No	Weight %
Iron	7439-89-6	18-48
Organic amendment	Proprietary	52-82
Soybean oil	8001-22-7	2
Viscosity modifier	Proprietary	0-5

4. FIRST AID MEASURES

Eye Contact	In case of contact, immediately flush skin with plenty of water. Get medical attention if irritation develops and persists.
Skin Contact	Wash off with soap and water.
Inhalation	Remove person to fresh air. If signs/symptoms continue, get medical attention.
Ingestion	Rinse mouth with water and afterwards drink plenty of water or milk. Call a poison control center or doctor immediately for treatment advice. Never give anything by mouth to an unconscious person.
Most important symptoms and effects, both acute and delayed	Inhalation of dust in high concentration may cause irritation of respiratory system.
Indication of immediate medical attention and special treatment needed, if necessary	Treat symptomatically

5. FIRE-FIGHTING MEASURES

Suitable Extinguishing Media	Dry chemical, CO2, sand, earth, water spray or regular foam.
Unsuitable extinguishing media	Do not use a solid water stream as it may scatter and spread fire.
Specific Hazards Arising from the Chemical	Avoid generating dust; fine dust dispersed in air in sufficient concentrations, and in the presence of an ignition source is a potential dust explosion hazard.
Flammable properties	Combustible material

Explosion data

Sensitivity to Mechanical Impact	Not sensitive.
Sensitivity to Static Discharge	Not sensitive.

Protective equipment and	As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH

precautions for firefighters	(approved or equivalent) and full protective gear.

6. ACCIDENTAL RELEASE MEASURES

Personal Precautions	Avoid dust formation. Avoid dispersal of dust in the air (i.e., cleaning dust surfaces with compressed air.). For personal protection see Section 8.
Other	Eliminate all ignition sources (no smoking, flares, sparks or flames in immediate area). Use only non-sparking tools.
Environmental Precautions	Recover the product in solid form, if possible. Do not flush into surface water or sanitary sewer system.
Methods for Containment	Cover powder spill with plastic sheet or tarp to minimize spreading and keep powder dry.
Methods for cleaning up	Sweep or vacuum up spillage and return to container. The waste may be recovered and recycled.

7. HANDLING AND STORAGE

Handling	Minimize dust generation and accumulation. Use only non-sparking tools. Remove all sources of ignition. Refer to Section 8.
Storage	Keep tightly closed in a dry and cool place. Keep away from open flames, hot surfaces and sources of ignition. Any vessel that contains wet EHC must be vented due to potential pressure build up from fermentation gases.
Incompatible products	Oxidizing agents; Strong acids. Strong acids.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control parameters

Exposure Guidelines	This product, as supplied, does not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies. Local nuisance dust standards apply.

Appropriate engineering controls

Engineering measures	It is recommended that all dust control equipment such as local exhaust ventilation and material transport systems involved in the handling of this product contain explosion relief vents or an explosion suppression or an oxygen-deficient environment. Ensure that dust-handling systems (such as exhaust ducts, dust collectors, vessels, and processing equipment) are designed in a manner to prevent the escape of dust into the work area (i.e., there is no leakage from the equipment). Use only appropriately classified electrical equipment and powered industrial trucks.

Individual protection measures, such as personal protective equipment

Eye/Face Protection	Safety glasses with side-shields.
Skin and Body Protection	Wear suitable protective clothing. Protective shoes or boots.
Hand Protection	Use gloves if extended exposure is anticipated
Respiratory Protection	Whenever dust in the worker's breathing zone cannot be controlled with ventilation or other engineering means, workers should wear respirators or dust masks approved by NIOSH/MSHA, EU CEN or comparable organization to protect against airborne dust.
Hygiene measures	Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and immediately after handling the product.

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Appearance	Flakes
Physical State	Solid
Color	Brown, Tan
Odor	odorless
Odor threshold	Not applicable
pH	5.6 (as aqueous solution)
Melting point/freezing point	Decomposes
Boiling Point/Range	Not applicable
Flash point	Not applicable No information available
Evaporation Rate	No information available
Flammability (solid, gas)	Combustible material
Flammability Limit in Air	
Upper flammability limit:	No information available
Lower flammability limit:	No information available
Vapor pressure	No information available
Vapor density	No information available
Density	0.80 g/mL
Specific gravity	No information available
Water solubility	practically insoluble
Solubility in other solvents	No information available
Partition coefficient	No information available
Autoignition temperature	No information available
Decomposition temperature	No information available
Viscosity, kinematic	No information available (Solid)
Viscosity, dynamic	No information available
Explosive properties	Low level dust explosion hazard
K_{st}	19 bar-m/sec: St1 Class dust
Oxidizing properties	No information available
Molecular weight	No information available
Bulk density	No information available

10. STABILITY AND REACTIVITY

Reactivity	None under normal use conditions
Chemical Stability	Stable.
Possibility of Hazardous Reactions	May react with water to release flammable hydrogen gas.
Hazardous polymerization	Hazardous polymerization does not occur.
Conditions to avoid	Heat, flames and sparks.
Incompatible materials	Strong acids. Oxidizing agents; Strong acids.
Hazardous Decomposition Products	Burning produces obnoxious and toxic fumes.

11. TOXICOLOGICAL INFORMATION

Product Information

LD50 Oral	Iron: 98.6 g/kg (rat)
LD50 Dermal	No information available
LC50 Inhalation	Iron: > 100 mg/m^3 6 hr (rat)
Serious eye damage/eye irritation	Not expected to be irritating based on the components.
Skin corrosion/irritation	Not expected to be irritating based on the components.
Sensitization	As a precaution the product should be treated as a sensitizer.

Chemical name	LD50 Oral	LD50 Dermal	LC50 Inhalation	NOAEL Oral Value
Iron (7439-89-6)	98600 mg/kg (Rat)			
Viscosity modifier ()	6770 mg/kg (Rat)			

Information on toxicological effects

Symptoms	Inhalation of dust may cause shortness of breath, tightness of the chest, a sore throat and cough.

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Irritation	Not expected to be irritating based on the components.
corrosivity	Not applicable.
Chronic toxicity	No known chronic effects of components present at greater than 1%.
Carcinogenicity	Contains no ingredient listed as a carcinogen.
Mutagenicity	No known mutagenic or teratogenic effects.
Neurological effects	Contains no ingredient listed as a mutagen
Reproductive toxicity	This product does not contain any known or suspected reproductive hazards.
STOT - single exposure	No information available.
STOT - repeated exposure	No information available.
Aspiration hazard	No information available.

12. ECOLOGICAL INFORMATION

Ecotoxicity

Ecotoxicity effects	Contains no substances known to be hazardous to the environment or that are not degradable in waste water treatment plants

Chemical name	Toxicity to algae	Toxicity to fish	Toxicity to Microorganisms	Toxicity to daphnia and other aquatic invertebrates
Iron		96 h LC50: = 13.6 mg/L (Morone saxatilis) static		

Persistence and degradability	No data is available on the product itself. The organic components are biodegradable and can be expected to contribute to BOD.
Bioaccumulation	Does not bioaccumulate.
Mobility	Is not likely mobile in the environment due its low water solubility.
Other Adverse Effects	None known.

13. DISPOSAL CONSIDERATIONS

Waste disposal methods	Recovery/recycling recommended. Dispose of in accordance with local regulations.
Contaminated Packaging	Empty remaining contents. Dispose of in accordance with local regulations.

14. TRANSPORT INFORMATION

DOT NOT REGULATED

15. REGULATORY INFORMATION

U.S. Federal Regulations

SARA 313

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product does not contain any chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372

SARA 311/312 Hazard Categories

This product has the following hazards that are reportable under The Emergency Planning and Community Right-to-Know rule (EPCRA Tier II):

Combustible dust

Clean Water Act

This product does not contain any substances regulated as pollutants pursuant to the Clean Water Act (40 CFR 122.21 and 40 CFR 122.42)

CERCLA/EPCRA

This material, as supplied, does not contain any substances regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material

US State Regulations

U.S. State Right-to-Know Regulations

This product contains the following substances regulated under state Right-to-Know laws:

Chemical name	Massachusetts	New Jersey	Pennsylvania	Illinois	Rhode Island
Soybean oil			X		

California Proposition 65

This product does not contain any Proposition 65 chemicals

CANADA

Environmental Emergencies

This product contains no substances listed under Canada's Environmental Emergency regulations.

Canadian National Pollutant Release Inventory

This product contains no substances reportable under Canada's National Pollutant Release Inventory regulations.

International Inventories

Component	TSCA	DSL	EINECS/EL	ENCS	China	KECL	PICCS	AICS	NZIoC

	(United States)	**(Canada)**	**INCS (Europe)**	**(Japan)**	**(IECSC)**	**(Korea)**	**(Philippines)**	**(Australia)**	**(New Zealand)**
Iron 7439-89-6 (18-48)	X	X	X		X	X	X	X	X
Organic amendment (52-82)		X	X		X		X	X	X
Soybean oil 8001-22-7 (2)	X	X	X		X	X	X	X	X
Viscosity modifier (0-5)	X	X	X	X	X	X	X	X	X

Mexico

Mexico - Grade Slight risk, Grade 1

16. OTHER INFORMATION

NFPA	**Health Hazards** 1	**Flammability** 1	**Stability** 0	**Special Hazards** -
HMIS	**Health Hazards** 1	**Flammability** 1	**Physical hazard** 0	**Personal Protection** -

NFPA/HMIS Ratings Legend Severe = 4; Serious = 3; Moderate = 2; Slight = 1; Minimal = 0

References Refer to NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids* , for safe handling.

Revision date: 2016-02-18
Revision note Initial Release
Issuing Date: 2018-02-02

Disclaimer

PeroxyChem believes that the information and recommendations contained herein (including data and statements) are accurate as of the date hereof. NO WARRANTY OF FITNESS FOR ANY PARTICULAR PURPOSE, WARRANTY OF MERCHANTABILITY OR ANY OTHER WARRANTY, EXPRESSED OR IMPLIED, IS MADE CONCERNING THE INFORMATION PROVIDED HEREIN. The information provided herein relates only to the specified product designated and may not be applicable where such product is used in combination with any other materials or in any process. Further, since the conditions and methods of use are beyond the control of PeroxyChem, PeroxyChem expressly disclaims any and all liability as to any results obtained or arising from any use of the products or reliance on such information.

Prepared By:

PeroxyChem

End of Safety Data Sheet

Material Safety Data Sheet

1. Manufacturer Product Identification.
Product Identification: LactOil™ (bioremediation blend), non-edible.
Product code: 175950

Manufacturer: Archer Daniels Midland Company
4666 Faries Parkway
Decatur, IL 62526, USA
Telephone Number: 217 424-5200

2. Supplier Product Identification.
Product Name: LactOil™ soy microemulsion
Product Class: In-situ bioremediation product.
CAS NO: Proprietary blend.
Description: Brown to yellow liquid.
Product Code: SME-80

Supplier: JRW Bioremediation, LLC
14321 W. 96th Terrace
Lenexa, KS 66215
Telephone Number: 800-779-5545

3. Hazard Identification.

<u>Effects of over exposure</u>: May cause slight irritation to the skin and eyes. Vapors or mist in excess of permissible concentrations such as generated from spraying or heating the product may cause irritation of the nose and throat, headache, nausea and drowsiness. Ingestion may cause abdominal discomfort, nausea and diarrhea.

HMIS/NFPA Rating: Health – 2, Reactivity – 0
OSHA Flammability Classification- Combustible III B

4. First Aid Measures.
Skin: Wash skin with plenty of soap and water. Get medical attention if skin irritation develops or persists.

Eyes: Immediately flush eyes with plenty of water for at least 15 minutes. Hold eyelids apart while flushing to rinse entire surface of eye and lids with water. Get medical attention.

Inhalation: If symptoms are experienced, remove source of contamination or move victim to fresh air. If the affected person is not breathing, apply artificial respiration. If breathing is difficult, give oxygen.

Ingestion: If the material is swallowed, get immediate medical attention or advice.

Other: Soybean derived product. Avoid if sensitive to soy products.

5. Fire Fighting.
Extinguishing Media: Dry chemical, foam, carbon dioxide or water fog.

Special Hazards: None

Decomposition: None known

Protective Equipment: Wear full protective clothing and positive pressure breathing apparatus.

6. Accidental Release Measures.

Personal Protection: Wear protective equipment during cleanup.

Environmental Precautions: Prevent material from entering waterways.

Spillage: Contain spill if possible, contain with adsorbent materials such as clay or soil and shovel. Remove to approve landfill according to federal, state or local regulations. Avoid skin and eye contact. Surfaces may become slippery after spillage.

7. Handling and Storage.

Handling: Handle product to prevent contamination from any source.

Storage: Store product to prevent contamination from any source. Keep containers closed. Avoid freezing or excessive during storage.

8. Exposure Controls/Personal Protection.

Engineering Controls: General ventilation is recommended. Use local exhaust ventilation.

Personal Protection: Respiratory protection may be required if material is used in poorly ventilated areas or if material is sprayed or heated. Follow OSHA respiratory regulations found in 29 CFR 1910.134. Use an NIOSH approved respirator when necessary. Chemical goggles should be worn to prevent eye contact with spills, splashes or vapors. Chemical resistant gloves can be worn to prevent prolonged or repeated skin contact. Eye wash should be available. Take a shower after work if general contact occurs. Remove oil soaked clothes and launder before reuse.

9. Physical and Chemical Properties.
Boiling Point: N/A
Flash Point: N/A
Density: 0.986
pH: 6.5
Color: Yellow to brown
Odor: Bland

10. Stability and Reactivity.
Stability: Stable under normal temperatures and pressures.

Conditions to avoid: Hydrolysis may occur in the presence of strong acids or bases.

Materials to avoid: May react with strong oxidizing agents.

11. Toxicological Information

N/A

12. Ecological Information.

N/A

13. Disposal Considerations.

Does not contain hazardous ingredients. This product, as supplied, when discarded or disposed of, will not be a hazardous waste according to U.S. federal regulations. Care should be taken to ensure that the material or its containers are disposed of in an approved facility in accordance with current federal and local regulations.

14. Transport Information.

U.S. DOT   Product Ships as Non-Regulated.
International Maritime Organization (IMO)/International Maritime Dangerous Goods Code (IMDG): Not regulated by IMO or IMDG.
International Air Transport Association (IATA): Not regulated by IATA.

15. Regulatory Information.

United States
TSCA (Toxic Substance Control Act)
TSCA Status: All components are listed on the TSCA inventory.

16. Other Information.

The information in this data sheet does not constitute any contractual warrant as to product properties and is based on the current state of knowledge. For all chemical emergencies, call Chem Trek at 01 703 527-3887.